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GISRUK

GISRUK 2007

Proceedings of the Geographical Information Science Research UK Conference

National Centre for Geocomputation
National University of Ireland Maynooth
11th-13th April 2007

Edited by Adam C. Winstanley

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GISRUK 2007

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Cover illustrations show some of the projects involved with members of the National Centre for Geocomputation, NUI Maynooth.

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Foreword

On behalf of the organising committee I would like to extend my warmest welcome to all speakers and attendees at the 2007 *Geographical Information Science Research UK* conference (GISRUK) being hosted by the National Centre for Geocomputation, NUI Maynooth. The NCG was founded in 2004, the result of a grant from Science Foundation Ireland recognising the importance of GIScience and GITechnology in modern science and engineering. Great thanks are also due to Science Foundation Ireland for awarding a generous grant to support a keynote speaker and enabling us to offer 30 bursaries to assist student participation at GISRUK.

In 2007, the Geographical Information Science Research (GISRUK) conference again brings together theoreticians and practitioners, users and academics from the numerous related disciplines involved in the processing and analysis of spatial data. This is the fifteenth conference in the series and the first one to take place outside the UK.

The initial call for papers for GISRUK 2007 was issued in December 2006. Contributions were sought from researchers worldwide on all aspects of Geographical Information Science. The conference organisers received 116 papers from 99 different universities, colleges and institutions in 17 countries. Each paper was subject to a review by at least three members of the program committee. 76 were accepted for oral presentation and publication as full papers in the proceedings. A further 9 were recommended by the programme committee for poster presentation.

I wish to thank the members of the programme committee without whose comments and prompt reviews a conference of this type could not be successful. I am also grateful to the members of the local organising committee, the Maynooth Conference and Accommodation Centre and the support staff of National Centre for Geocomputation, NUI Maynooth and St. Patrick’s College, Maynooth.

GISRUK has prospered over the years due to the generosity of many sponsors who every year support the conference and the many associated prizes, competitions, workshops and social events. This year is no exception and, in addition to the usual UK sponsors, several Irish-based organisations have helped to make this a special event. We wish to thank them all again for their generosity. I would also like to thank our invited speakers: Professor Michael Worboys, Professor Mike Goodchild, Professor Nicholas Chrisman and Dr. Alesandro Annoni.

So welcome GISRUK delegates to Ireland and to Maynooth. We hope the conference is beneficial and you leave after having a useful and enjoyable conference.

Adam Winstanley
Chair GISRUK 2007

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All papers were reviewed by members of both national and local committees.

For further information about this and future GISRUK conferences see:

`ncg.nuim.ie/gisruk` (GISRUK 2007 site)
`www.geo.ed.ac.uk/gisruk/gisruk.html` (national GISRUK site)

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POSTERS

Science Foundation Ireland Keynote Address

The Disappearing GIS

Mike Worboys
University of Maine, USA

Abstract

In 1988, Mark Weiser, a chief technologist at Xerox's Palo Alto Research Center, introduced the term ubiquitous computing, and heralded "the age of calm technology, when technology recedes into the background of our lives." This vision is now fast becoming a reality. Computing will soon be embedded everywhere in the fabric of our lives: in our bodies, phones, homes, and the environments in which we live. This talk will explore some of the issues that this technological revolution raises for geographic information science.

Invited paper

REPRESENTATION AND COMPUTATION OF GEOGRAPHIC DYNAMICS

Michael F. Goodchild
University of California, Santa Barbara, USA

Abstract

If the geographic domain is defined as the surface and near-surface of the Earth, then geographic dynamics describes all time-dependent aspects of that domain, including the results of processes that transform and modify it. This is a vast field, encompassing both social and physical phenomena. GIScience traditionally focuses on the scientific issues that lie behind GIS. In the context of geographic dynamics, it seems appropriate that GIScience focus similarly on the generic: the tools, data models, software, and other resources that facilitate analysis and modeling of dynamic phenomena. Fields and objects provide a useful framework for further discussion, since processes can be identified as field-based, object-based, or based on both conceptualizations. I review the current state of the art, and identify some significant gaps as the basis for a research agenda.

Charting a course for network research: GEOIDE's research directions

Nicholas R. Chrisman
Scientific Director, Réseau GEOIDE Network; Professor Université Laval, Québec CANADA

BACKGROUND

Established in 1998, GEOIDE (GEOmatics for Informed DEcisions) is a research network group assembling 130 researchers at 31 universities across Canada, in a range of fields including termed "geomatics" in Canada (including surveying, geodesy, photogrammetry, remote sensing, geography, planning, and geographic information science). This network is funded through the Networks of Centres of Excellence (NCE) [1] programme, a permanent programme of the Government of Canada. After a rigorous review process in 2004 that mobilized talents from across the network, our second NCE funding cycle (2005-2012) was assured. At about the same time, Nicholas Chrisman became Scientific Director.

Figure 1: The GEOIDE logo depicts a three-dimensional Earth with cities and mountains rather vertically exaggerated, and a human form leaping off into Space. Perhaps a bit busy for its function, it provides a bilingual unity that other NCE networks rarely provide.

In its current phase of funding, GEOIDE supports 19 major projects covering a range of disciplines (See Table 1 below). These are four-year projects designed to finish in March 2009. In addition, the Strategic Investment Initiative (SII) supports shorter term projects, often tied to specific deliverables for industrial or government partners. The total budget for GEOIDE amounts to approximately 3.5 million$ (CAD) per year.

The mix of disciplines involved in GIScience or geomatics has fallen out differently from place to place, country to country. The role of institutions has varied, with strong state support in some places, and more industry role in others. Overall, this multi-disciplinary convergence presents an interesting case study in the history and sociology of science and technology. The naming of the field itself demonstrates this diversity of approaches, as well as signaling the complexity in building true international coherence. The long-established disciplines of cartography, surveying, geography, and geodesy have merged in various ways in different countries. For example, cartography as an academic subject is mostly practiced inside geography departments in North America, but this is not the case in most of Europe. Surveying as an academic subject has declined in North America despite the dramatic technological advances in the field. In most countries there have been mergers, but which have merged with the others is not guaranteed. The more recent fields of photogrammetry, remote sensing, geographic information systems have been merged in some places with some of the older

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[1] GEOIDE acknowledges the continued support of funding from the Networks of Centres of Excellence as well as its seven Partners.

disciplines under the title of geocomputation or geographic information science. In Canada, the term "geomatics" took root twenty years ago as a covering term for the whole collection of undertakings to collect, analyze and distribute geographic information.

RESEARCH PROGRAMME

The core of the GEOIDE Strategic Plan is to promote the development of geomatics research in a way that delivers benefits to Canadians. Unlike "curiosity-driven" research councils, NCE favors an interaction between "receptors" and the research community. Through this two-way flow, the traditional linear model of a linear pipeline of "technology transfer" is abandoned. Projects have been selected for their robust interdisciplinary communication and for their collaborations with a user sector in industry, government, or the non-profit sector. Table 1 lists the 19 projects at the core of Phase III.

Table 1: GEOIDE Phase III Projects

No	Title
01	Hyperspectral reflectance spectroscopy for rapid characterization of oil sands
05	SIST-Chronic diseases and primary care
06	GIST II- Intelligent Sensor Data / Knowlege Fusion for Geotechnical and Policy Decision Support
08	Multi-Scale Multi-Agent Geo-Simulation to support decision making in multi-actor dynamic spatial simulations MUSCAMAGS
11	Integrated Expertise Towards the Development of an Ice Jam Related Flood Warning System (FRAZIL)
12	Integrated geomatics for the Coastal Zone: Fusion of Terrestrial, Airborne and Marine Data (FUDOTERAM)
13	Géomatisation for archaeological digs: From data collection to analysis in context
14	Integrated modelling of juvenile Atlantic Salmon movement and physical habitat in fluvial and estuarine environments
15	Development of a 3D predictive modeling platform for exploration, assessment and efficient management of mineral, petroleum and groundwater resources
17	Promoting sustainable communities through participatory spatial decision support
20	Collaborative for Interactive Research with Communities Using Information Technologies for Sustainability
27	Mapping the ocean surface with geodetic and oceanographic tools
31	Next-generation algorithms for navigation, geodesy and earth sciences under modernized Global Navigation Satellite Systems (GNSS)
32	A National System for Water Vapour Estimation Using GPS and its Applications
34	Geomatics Enhancement With Dual Use of GPS II/III and Galileo
35	Monitoring Changes to Urban Environmental using Wireless Sensing Networks
36	Space gravimetry contributions to Earth monitoring
37	The Development of M2G- A Mobile Multi-sensor Geomatics system for Inventory and Analysis of Highway and Road Network Features
38	Coastal Security and Risk Management using GIS and Spatial Analysis

A number of these projects have explicit linkages to international partners. The NCE funding, like most research council support around the world, is targeted towards Canadian institutions. Often the research agenda aligns with other projects and funding sources in partner countries. Recently, GEOIDE has explored more of these avenues and specific project-to-project links have been forged with Ireland, Netherlands, Australia and others.

Specific exchange prospects

GEOIDE continues to host an annual Summer School, a Students' Network, an annual scientific conference (ASC), workshops and significant knowledge exchange activities. Every year, over 200 delegates from around the world attend our ASC. These activities are ongoing and have kept the Network on its toes. GEOIDE also supports mentor exchanges and student travel. Up to ten foreign graduate students attend the annual Summer School without registration or lodging cost.

Recently, GEOIDE has renewed its links with partner networks in other countries. In 2006, GEOIDE hosted a meeting in Banff, Alberta with twelve leaders from similar organizations around the world, including NCG Ireland. This network of networks will provide the basis for enhanced collaboration on exchanges and shared projects. The role of the GEOIDE Network in the coming years is to ensure that Canada is actively engaged in the geomatics research that will support a sustainable world in social, economic and environmental terms.

TOWARDS THE NEXT PHASE

A major focus during 2006 was to develop a new strategy. The Network worked with specific user communities, groups of government, industry, and associations to determine the most pressing needs by region across the country. This process culminated in a workshop held in conjunction with a Board meeting. The new approach will decide the broad directions of research, including the potential partners interested in working with the research community right from the start. The intent is to combine a more top-down selection of network directions with the ability for researchers to develop innovative solutions that pass through the refinement of peer-review from the bottom-up. The new strategic plan also includes innovative ways to ensure self-sustainability at the end of the NCE funding in 2012. In preparation for Phase IV (2009-2012), specific themes have emerged through a process of strategic planning. The three themes are purposely broad at this stage, to try to avoid too much duplication.

Mobility: centers on tracking and predicting the motion of people and objects. User representatives will include transportation sector, logistics enterprises, and security services. Researchers working on tracking technology, space-time models and simulations, and dispatching analysis at various scales will form the teams working on this theme.

Environmental change: centers on modeling changes in the earth system, fast or slow. User representatives will include natural hazard response agencies, geomatics industry representatives, and environmental policy makers. Researchers working on instruments, remote sensing applications, and sustainability policy dimensions will join this grouping.

Distributed sensors: centers on advanced technology to measure the environment and delivery innovative information products to users. User representatives will include instrument manufacturers, geomatics service providers, and resource managers from government and private sector. Researchers working on sensors, distributed network interactions, and integrative software will form teams on this theme.

GEOIDE has issued a call for participation to build the teams that will respond to these three axes. There will be a two-phase process of letters of interest followed by proposals. All decisions will be made by early spring 2008 so that the new projects can begin in April 2008. The first year of funding will be in a pilot format, followed by full funding for three years.

For all future projects, GEOIDE intends to seek international collaboration at every level for students and researchers to networks such as NCG Ireland, SIGMA-Cassini France, and CRCSI-Australia, plus regional groupings such as AGILE.

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http://www.geoide.ulaval.ca

INVITED PRESENTATION

Building a Spatial Data Infrastructure for Europe: the many research questions for which we need answers.

Max Craglia and Alessandro Annoni
European Commission DG Joint Research Centre, Ispra, Italy

The adoption of the INSPIRE Directive provides the legal framework for building a Spatial Data Infrastructure (SDI) for Europe. Putting this framework into practice across 27 countries, 23 languages and multiple professional and national/regional cultures is not trivial and will require a great deal of effort over a long period of time. Whilst many of the most serious challenges are organizational, financial, and related to the availability of relevant skills, the focus of this presentation is on the research challenges that need to be overcome to build an operational SDI now, as well as developing the next generation of SDIs. In the short to medium term, the research priorities center on: (i) the interoperability of services and infrastructures, (ii) methods for integrating data from heterogeneous and dynamic sources, including in-situ sensor networks, (iii) assessments of data and service quality for different users and applications, and (iv) measurement of social and economic impacts of SDIs at different institutional and organizational levels. In the longer term, the focus of research needs to shift the current data-centric view of SDIs, aimed primarily at a small technical elite, towards a new generation of SDIs which are service-centred and aimed at multiple users, including the non-experts. For this to happen, synergies with distributed (geo)processing Grid infrastructures, and e-science is needed, which in turn requires a major multi-disciplinary effort to ensure that different communities of researchers and practitioners talk to each other and work together. Yet another research challenge?

Towards a post-colonial GIS

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1. Introduction

Participatory Geographical Information systems (PGIS) are being used with Indigenous communities worldwide who are engaging with mapping technologies developed essentially in the developed world. However Indigenous people have their own understanding and cultures that include ways of knowing and understanding the world around them. This paper is an initial attempt to review different ways of spatial thinking and to make preliminary suggestions as to how modern visualization methods may be used to portray these representations.

2. Indigenous mapping and Participatory GIS

Indigenous and traditional people have an innate understanding of the environment in which they live and move but with limited resources to protect their use of these lands. Governments, conservation organisations, other NGOs and companies involved in the extraction of natural resource often have recourse to sophisticated Geographical Information Systems and other technological tools with which they manage and govern these same lands. These GIS tools are influential in negotiations and are used to demarcate boundaries. Participatory mapping is increasingly being used with Indigenous peoples to enable the political empowerment of local people, to establish land use claims and rights; and for environmental protection (Chaplin & Threlkeld, 2001; Laituri, 2002). However communication between Indigenous and others is often unbalanced in favour of those with the more sophisticated technologies and the recognised ways of analysing and visualising knowledge.

There is a growing field of research into developing integrated approaches to participatory development (Rambaldi et al, 2006[1]). A variety of methodologies are used within Participatory GIS (PGIS) stemming from a fusion of Participatory Learning in Action (PLA) with Geographical Information Technologies and Systems. PGIS is being used as a powerful tool to give Indigenous and traditional people a voice and has been identified as a positive means for the recognition of cultural heritage. At a basic level local people are encouraged to produce ground maps (sketches in the dirt) that maybe transferred at to computer-based systems. Rambaldi et al, 2006[2], are instrumental in introducing 3D participatory mapping, or physical construction of 3D models, that enabled people to visualise their environment more effectively. In other areas sophisticated multimedia GIS have been established to incorporate digital video, photographs audio and text that documents indigenous knowledge (Corbett and Keller, 2006). Where possible, representatives from the local people are trained in the use of GIS so that they have control over and maintain ownership of their knowledge.

3. Indigenous Spatial Thinking

Research within the PGIS arena is trying to integrate people's knowledge with western mapping. However, although Western-led PGIS practices have been demonstrated as being extremely beneficial, the spatial representations used are normally from the Euro-American perspective, in which there is a heritage of mapping techniques and methodologies based on colonial ideologies of land ownership.

The evidence for different types of spatial knowledge can be identified in literature from a variety of sources Writings on biocultural diversity (citations in Cocks, 2006) identify places of cultural identity that contribute to a people's sense of place. From anthropology, examples can be identified of alternative Indigenous or cultural ways of spatial knowing such as aboriginal dreamtimes and shamanic visions of place and movement. McCall[1], 2007, classifies indigenous spatial knowledge into three categories: Indigenous / local (spatial) technical knowledge, 'counter maps', or different viewpoints of local spatial knowledge, and sacred spatial knowledge or 'cosmovisions'.

Indigenous peoples often have a more fluid way of demarcating and sharing land and understanding space. Fox, 2002, describes the changes in spatial thinking made by Thai people when they had to construct boundaries to the Kingdom of Siam from fluid ideas of communal and shared land. Contrary to striving for greater precision in mapping, Indigenous maps may be more appropriate if they allow imprecision to characterise the mapping and to reflect vagueness.

It is still believed that the spatial paradigms used by indigenous groups are not fully understood or being incorporated into what are essentially Euro-American centric ways of thinking (Johnson et al, 2006). Renee Sieber, 2000, called for a change in the social construction of GIS by stating "changing the intrinsic nature of GIS and impact the individuals who make decisions about the design, development, and modelling of the technology."

Golledge (1981:21) alerts us to "the risk of becoming dogmatic by trying to force all worlds into one very limited format, and in doing so we ignore, belittle, or forget the others." It can be argued that methodologies and visualisations as used in GIS rarely include alternative, more individual, ways of thinking spatially. They are grounded primarily on the developed world's cultural heritage of spatial literacy. As there are many languages and ways of knowing the world should there not be other ways of analysing or at least visualizing reality?

4. Towards a Post-colonial GIS

There are already a few attempts to extend the repertoire of analysis and visualisation techniques to incorporate other ways of spatial knowing. Turnbull, 1998, calls for outside (Western) mapmakers to 'strive toward a post-colonial, post-modern cartography'. Johnson et al, 2006, use the example of a different epistemiology embedded in Hawaiian culture that is represented through dance performance. Bodily directions represent and communicate information about space. However Western map makers have difficulty recognising these cartographic literacies based on song, performance or story telling. They are down-graded and subsumed by the colonial cartographies that are embedded in GIS and which, without care, may be propagated through the PGIS mechanism. "The vast majority of PGIS systems cannot authentically reflect and represent the 'mental maps' of people that are situated in non-Cartesian, non-positivist, ambiguous, fuzzy, and non-discrete spatial ontologies." (McCall[2], 2007)

Within this current thread of research and development to incorporate other ways of seeing, there are avenues that may be pursued to link cultural methods of portraying spatial knowledge with modern technology. Ways need to be developed to bridge the gap, to empower people in their own spatial languages and to help to educate GI scientists and other users to adopt new ways of thinking so as to see with other mind sets. Users of technologies already have to make mental leaps to fully 'read' maps, so it should be possible to learn new mapping systems. Further, technologies such as multimedia and virtual reality systems are now becoming more sophisticated but instead of the constant strive to recreate reality in objective forms, it is also possible to recreate other realities and other ways of seeing (Moore, 1999). Perhaps a new step is for GI scientists to allow themselves a more subjective engagement with space instead of the harsh objectivity of much geographical analysis. For instance, theoretical constructs from phenomenological discourses that concentrate on understanding the world rather than trying to explain it may be applied to understand firstly ones own and then other forms of spatial knowledge. A re-evaluation of cognitive mapping and its inclusion within geographical information science (Mark et al, 1999) within new visualisation and computational methodologies may prove productive. Indeed, the question asked by Mark et al (1999:764), "What would a place-based, rather than coordinate-based GIS look like?" may be a starting point for theorising on an alternative GIS.

Several developmental threads within visualization can be imagined to support cultural concepts of space and place. The first uses more abstract modelling within virtual reality environments to understand what is important to other cultural mappings. The second would recreate some of the performances that represent spatial concepts, through multimedia or through abstract modelling. The final suggestion is the use of virtual reality systems with participatory GI activities (Lammeren & Hoogerwerf, 2003) to provide cross-cultural exchange of cognition and spatial understanding.

This paper will critically review the constructions of indigenous knowledge through Western cartography and the participatory mapping process. It will attempt to suggest means as to how the methodologies may be improved through acknowledgement and incorporation of other knowledge systems. It will review and discuss other forms of spatial knowing and visualization. The author sets out to ask questions of the audience about how they can engage with spatial knowledge in perhaps less objective but still meaningful ways. Finally it will try to identify the way forward to train Western mapmakers in other ways of spatial thinking and by using appropriate technology and methodology to start to develop a post-colonial GIS.

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Educational Planning in Palestine: the role of PPGIS

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1. Introduction

Public participation geographic information systems (PPGIS) pertain to the potential of using information and communication technology (ICT) to enhance public participation in spatial decision making. This paper presents the viability for customizing PPGIS to enhance public participation in school planning processes. The range of participants in the traditional participation methods is often diminished due to geographical and temporal constraints (Kingston, 2002), this is especially true in the case of the Palestine with great restrictions on physical movement.

The Internet has partly changed the perception that GIS is an ‘elite technology’ (Pickles, 1995) and for some time now it has been possible to access GIS functionality over the Internet (Craig et al, 2002, Kingston et al., 2000). Not surprisingly, the Internet makes a well suited medium to facilitate broad-based participation in planning and decision making even in developing countries where Internet diffusion is growing rapidly, giving a wide range of people the opportunity to access and participate in the planning process (Hall and Leahy, 2005). Furthermore the diffusion of Open Source Software (OSS) technology including geospatial web services can be highly customized and easily adapted to various applications, using Open Geospatial Consortium (OGC) standards.

2. Problem definition

Educational planning in Palestine is described as a challenging experience because of the daily Palestinian – Israeli conflict. The critical problem facing the Ministry of Education and Higher Education (MEHE) is how to provide quality education in situations of emergency and crisis (Mahshi, 2001). For many years education services have been deeply affected by frequent closure, mobility restrictions and damage to school buildings by the conflict. Further, the construction of a wall which began in June 2002 cuts through a number of cities and villages and has created several movement barriers and separated teachers and students from their schools (PMEHE, 2005). Given the geo-political situation, governmental institutions including the MEHE have recently realised the importance of working with local communities and the pressing need for innovative means designed to communicate with districts, schools and other stakeholders (Said and Badawi, 2004). The Internet has become the preferred medium of information exchange for Palestinians due to movement restrictions among other aspects (ESCWA, 2005). Over recent years there has been renewed interest among local communities to participate in decision-making processes as they become increasingly interested in educational and cultural activities as a result of the emergency needs during political crises (DSP, 2002).

Many educational planning problems such as physical accessibility to schools, redistricting schools, school performance and equity are geography-based. School Mapping (SM) techniques that integrate GIS and local communities have been effectively implemented in the school planning process (Govinda, 1999). The research is focused on the potential of web-based GIS in a geographical location faced with many political problems. While many aspects of PPGIS deployment could be investigated this research is focusing specifically on:

- How can the public be involved in school planning?
- What is the role of PPGIS in educational planning in Palestine?
- What tools are needed to assist the public in participation?
- How should the tools be designed and implemented?

The proposal here is to renew the traditional SM techniques as a 'bottom up' approach for school planning in the information age by developing Educational Planning Public Participation GIS (EPPGIS) tool for a more interactive communication platform.

3. Research Design:

3.1 Soft Systems Methodology approach

The potential participants using the EPPGIS come from a multiple of geographic locations and will be using the system at different times representing the interests of multiple cultures and a wide range of perspectives. All of these conditions point to the characteristics of this problem: semi-structured, spatial and unbounded organisations which necessitate multiple perspectives on the social, technical and organisational framework of developing an EPPGIS in a Palestinian context. Figure 1 represents the Web Information System Development Methodology (WISDM) used by Vidgen et al. (2002) which is adapted for this research.

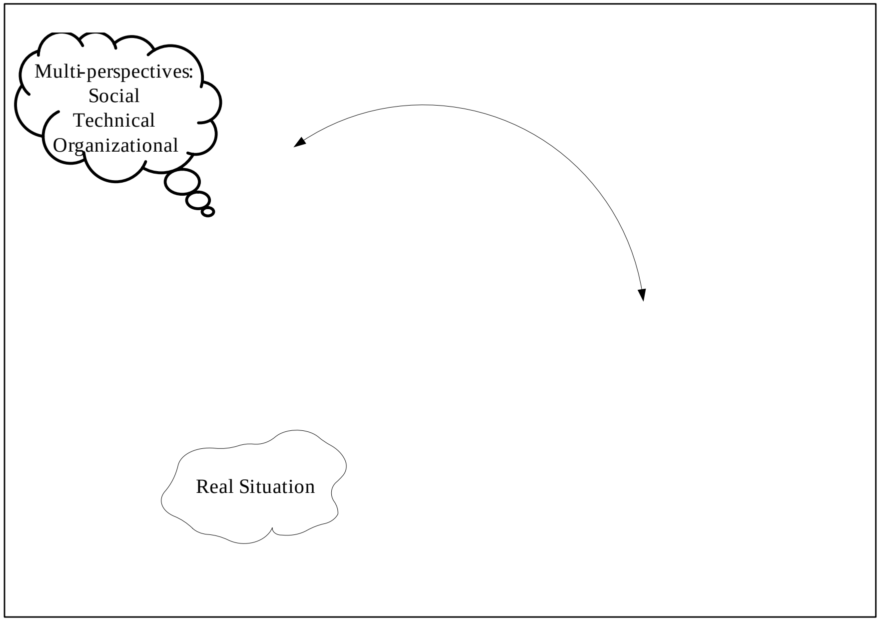


Figure 1: WISDM for EPPGIS (adapted from Vidgen et al. 2002)

The organisational analysis is based on human activity with a seven-stage Soft System Methodology (SSM) developed by Checkland (1999) aimed to arrive at a debate concerned with defining changes that are 'systematically desirable' and 'culturally feasible'. The technical design is concerned with how to integrate the stakeholders' needs and requirements and also with the direct participation of end-users in the information system development including the design of the human-computer interface (HCI). This was achieved by undertaking a series of in-depth stakeholder interviews and focus groups with residents in towns in Palestine during the summer of 2006. This was an extremely complex task considering the Lebanese conflict at the time. The focus here has been on asking potential users of the EPPGIS what they wanted to get out of the participation in school planning process. This was complemented by undertaking a series of interviews with Government officials and academics in Palestine and Jordan who had technical knowledge of web-based participation and GIS.

The findings from the interviews and focus groups suggested that utilising ICT for school planning required moving towards a more participative based process. The MEHE has already recommended the setting up of the required organisational procedures such as improving the technological infrastructure for EPPGIS, raising awareness and training program for stakeholders, and most importantly the legal framework. Since Al-Aqsa Intifada all meetings and workshops among Palestinian regions were conducted by video conference. One interviewee noted that ICT based participation has a good chance of succeeding in Palestine. He added that a high-technology tool is not strange in these environments as long as there is a group of people who can understand and use it. He also cited:

> *" even if we are at the lowest level of participation that does not mean that we should move up the ladder gradually step by step. It is not too early to develop this tool and it is the right thing to do. What is required for its success is to put it in 'an incubator' make, an 'artificial environment' in the meantime. This environment would be temporary for developing ' hotbeds for the future… "*

Source: interviewee

3.2 System Functionality

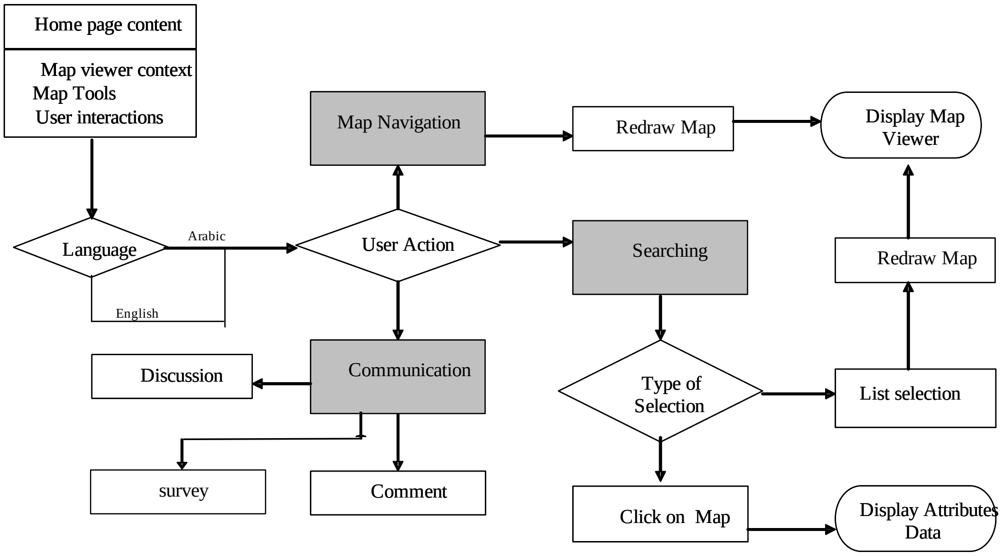
The results from the interviews and focus groups have helped to shape the design on the EPPGIS from many perspectives. Expected end users of this system fall into three categories: the official planners and the related professionals, stakeholders and general publics. Based on the analysis of their requirements, some features are identified as essential for an online participatory decision-making supporting system.

- Providing users with relative educational information (spatial and non spatial data) and instructions to help them understanding the spatial planning process;
- Providing the tools that handle a subset of map navigation (overlay, pan, zoom, measure).
- Enabling users for spatial and attribute queries by selecting features based on location or attribute values.
- Offering interactive ways for stakeholders to communicate with each other (such as online comment, voting and geo-referenced discussion groups); and
- Providing equal opportunity for the public to participate in educational policy making over the Internet.

In designing a web mapping system, critical considerations taken into account included the purpose and functionality of the system, the content and the target user groups. It has also been important to be mindful of the potential users' skills and their needs for an accessible site that has a simple and easy interface to navigate. EPPGIS will enable users to look at the schools within their spatial context by providing basic map layers including among others school locations, barriers to schools, road network and some school photos. Several key terms and concepts are also defined that will greatly aid users in understanding how the EPPGIS system works.

Once the users get general information about the schools in their areas and view spatial data by navigating maps, end users may specify the subject to participate in with three options: to text comments, to fill online survey and on line discussion forum Figure 2. Users also can view previous users' comments, results of the survey and the discussion forum.

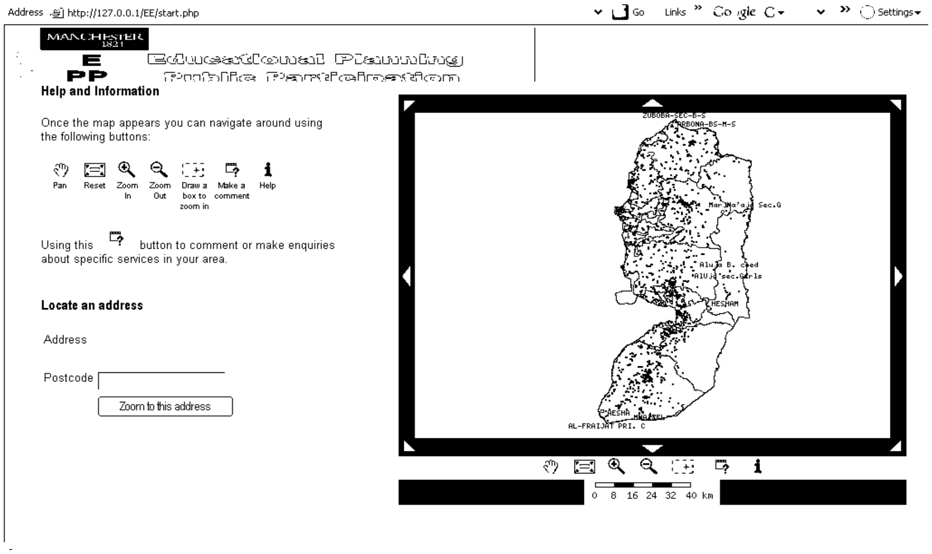
Figure 2: Process flow of the EPPGIS



EPPGIS will create a channel for the official planners to collect diverse viewpoints about how to improve the equity, quality and acceptability of schools. It is anticipated that planners would initiate online survey or discussions on a particular topic at specific time. For example, problems like location and allocation of the educational resources, where to locate a new school, school safety, the requirements and needs of school facilities. After that, by joining in and leading an efficient and fair online discussion, decision makers and planners can determine the needs of each school which help in setting the proposed plans. Residents can also initiate and generate their own discussions when issues of importance to them arise.

3.3. System Design

In designing a typical web-based mapping application a thin client three-tier architecture is followed (Peng and Tsou, 2003) . The EPPGIS is now being developed as a pilot application figure 3. The tool will have a multi-lingual interface in Arabic and English with architecture based on OSS using OGC compliant WMS technology, mySQL for the database and PHP scripting language for the discussion forum. The next steps in the research are to improve the user interface based on feedback from stakeholders and through pilot testing to check its functionality and user friendliness. This provides a rich set of data with which to test the robustness of the system design and the future potential for EPPGIS in Palestine. While the technical development and implementation issues are not to be underestimated it is the usability and acceptance by the public and the decision making community which is most important.



Help and Information

Once the map appears you can navigate around using the following buttons:

Using this button to comment or make enquiries about specific services in your area.

Locate an address

Figure 2: EPPGIS Interface

4. Conclusions

This paper presentation will focus on the system design and pilot testing which has been developed in conjunction with the stakeholders and focus group discussions. Over the coming months pilot testing will offer results to help improve this EPPGIS in Palestine. It is hoped that this will help to feed in to other participatory processes outside of the educational planning process in areas such as physical planning and redevelopment. There are many who have a preference for face to face interaction and the belief that these new technologies are not effective in empowering the general public and that they are targeted at skilled and educated people. The unique situation in Palestine means that the effectiveness of EPPGIS for providing information, communicating with, and discussing educational policy issues with stakeholders is promising for the near future with the Internet providing the potential to create a communication 'bridge' among Palestinian people.

5. Acknowledgements

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Biography

Khitam Shraim is a 2nd year PhD student funded by the Ford Foundation. She has an undergraduate degree in Computer Science, a masters degree in Finance and was previously a civil servant in the Palestinian Education Authority. Her supervisor, Richard Kingston, is a lecturer in urban planning and GIS who has broad research expertise in PPGIS.

Examining the potential of Internet-based Geographical Information Systems for promoting public participation in wind farm planning in the UK

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1. Introduction

Public attitudes to the development of wind power schemes have been examined extensively in previous research (for example Bishop and Proctor 1994; Devine-Wright 2005). Landscape and visual impacts have emerged as the most far-reaching effects of onshore wind farm developments and the effects of most concern to the public (Hull 1995; Pasqualetti, et al. 2002; DTI 2006). Landscape effects refer to change in perception and character of the landscape whereas visual effects are concerned with the potential visual impact from individual receptors and viewpoints, such as houses, parks, and roads for example (LI-IEMA, 2002).

A Visual Impact Assessment (VIA) therefore, is usually the most comprehensive and important part of a wider Environmental Impact Assessment (EIA), which is normally required to be submitted to local planning authorities in the UK by wind farm developers as part of the planning application for commercial wind farms. The focus of our research is to examine the use of traditional and emerging GIS-based visual impact techniques and their role in the advanced stages of planning, i.e. when a specific proposal has been submitted for approval. Information relating to visual impact for specific wind farm plans derived from these techniques becomes of vital importance in determining the success of an application, particularly in terms of public acceptance. Our aim is want to evaluate emerging three-dimensional (3D) GIS –based landscape visualisation (LV) technologies alongside traditional map and photo-based methods to determine if such tools can be employed to enhance information dissemination and public participation in the wind farm planning process. The following section provides a brief overview of these techniques and draws attention to the strengths and limitations associated with each, examples of which will be shown at the conference. In section 3, we then go on to describe the results of a survey we produced to determine which techniques are currently being used by environmental consultancies and agencies concerned with wind farm planning in the UK context.

2. Techniques used in Visual Impact Assessment

2.1 Traditional VIA Techniques

The three main tools traditionally used in wind farm VIA are ZTV (Zones of Theoretical Visibility) maps (Fig. 1), showing the locations from which a wind farm is visible, photomontages (Fig. 2), which are created by superimposing wind turbines onto a photograph, and wireframe diagrams (fig. 3) which are black and white diagrams containing no landscape detail or texture other than lines, or ‘wires’, depicting the terrain in grid structure with the only additional detail being accurately scaled drawings of the proposed wind turbines. ZVI maps provide only an abstract representation of visual impact, while photomontages and wireframe diagrams are only able to show ‘views’ from a limited number of locations. None of these techniques is unable to show the effects of the moving turbines, which has been shown to have an important influence on visual impact (Bishop, 2002).

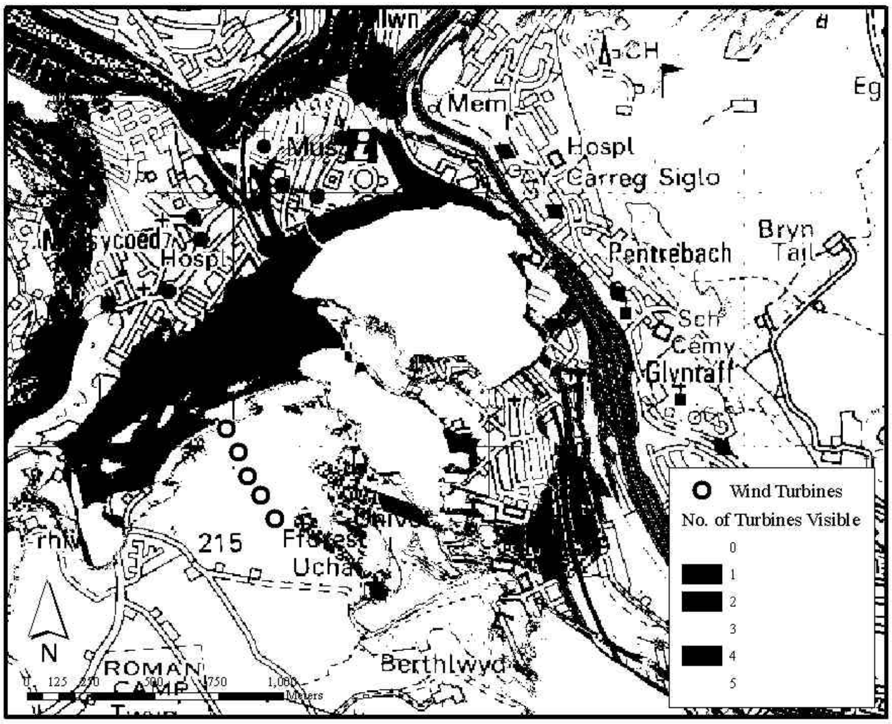

__Figure 1.__ ZTV Map for a theoretical 5-turbine wind farm development in South Wales.

__Figure 2.__ Photomontage of wind farm shown in Figure 1.

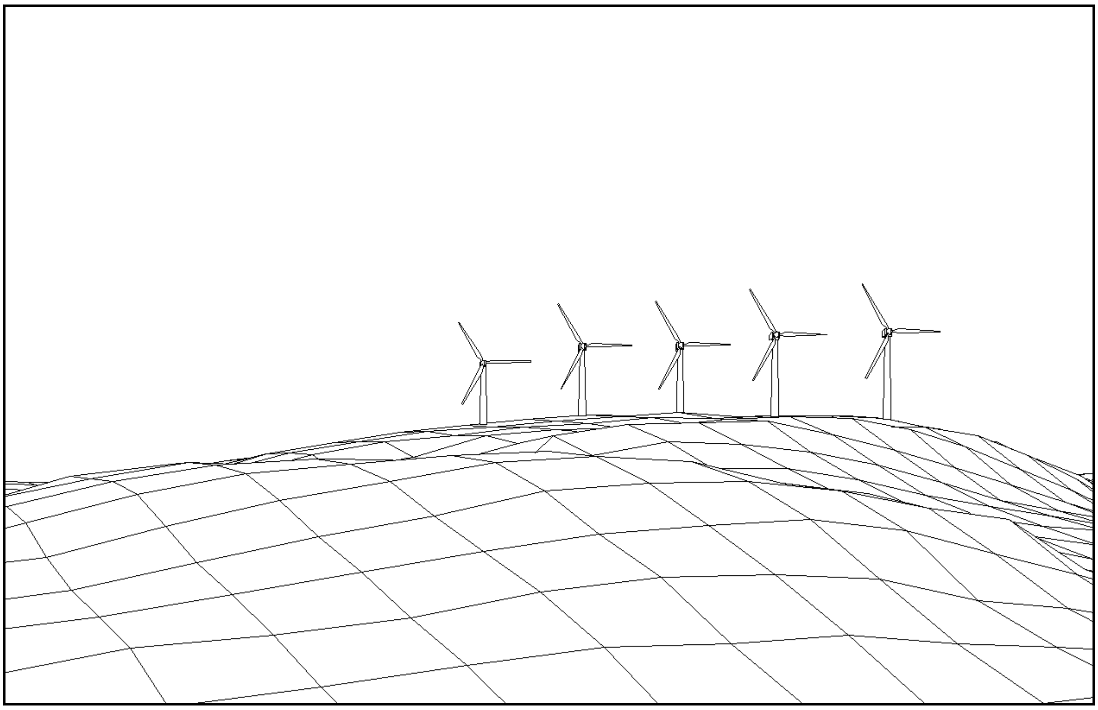

Figure 3. *Wireframe diagram of wind farm shown in Figure 1.*

2.2 Three-Dimensional Landscape Visualisation

Advances in computing and the growing quantity and quality of environmental information and spatial data has led to significant developments in GIS-based 3D landscape visualisations (LV) (MacFarlane, et al. 2005), which are increasingly being used in new areas of environmental, design and planning research (Bishop, 2000). In the context of the assessing the potential visual impact of wind farms, LV immediately offer a number of advantages over traditional VIA techniques. 'Views' towards a proposed development can be easily created from any location within the model, and the movement of the turbines can be shown. Most visualisation software allows real-time navigation within a LV and also has the capability of creating animated 'fly-throughs' or 'walk-throughs' where the user is taken through the 3D landscape along a predefined route. Output can also be provided in the form of more conventional static imagery. The availability of such outputs in digital form provides enormous opportunity for dissemination via the Internet, potentially widening public involvement in planning (Bishop and Lange, 2005).

However, despite the promise of the widespread use of LV in this context there has been less research on the current use of such techniques by professional consultants and wind farm developers for VIA and public consultation. An early study by Coles and Taylor (1993) suggested that the take-up of such techniques was low, but there is an urgent need to update their findings to take into account new developments in software and data. In the next section we draw on a questionnaire survey to gauge the current state of play with regard to the implementation of such tools in wind farm planning, and especially their use in public consultation scenarios.

In addition to the limitations associated with VIA outputs derived from traditional techniques, there has been much criticism directed towards current methods of public participation in the planning process. The benefits of effective public participation in planning decision-making are well documented (Petts & Leach, 2000). Access to planning information derived from VIA has been largely restricted to public exhibitions and meetings organised by developers as a way of informing the public and engaging them in the planning process. Factors such as the temporal and geographical constraints of such meetings and the often confrontational atmosphere which can prevail are known to discourage participation in planning (Kingston et al, 2003). Information dissemination and public participation via the Internet has been suggested many as a means of overcoming some of these limitations (Kingston, 2003).

3. Survey Results

In October 2005, a postal questionnaire was sent to 151 environmental consultants, landscape architects, freelance consultants, planners, academics and other professionals that had been identified as being involved in VIA work. The aims of the survey were to gather information relating to the use of the VIA techniques in wind farm planning and to gauge the extent to which VIA information derived from such techniques is contributing to existing public participatory processes.

A full analysis of the results will be presented at the conference, but the main conclusions drawn from the survey are summarised as follows:

- Traditional VIA techniques still dominate, with 90% of respondents using ZVI maps and photomontages respectively and wireframes also used widely (79%), whilst over half (63%) of respondents have incorporated LVs into the VIA.

- Organisations deliver visualisations using a range of CAD, GIS and VR software types both in animated ‘fly-through’ form and as still images, with CAD software marginally more popular than GIS software.

- Photomontages are clearly the favoured means of displaying visual impact information to the public (96% of respondents) with ZVI maps (63%) and wireframes (58%) used to a slightly lesser extent than in the VIA stage. It appears that LVs are also used less in the public consultation although 38% of respondents employing the use of LVs at this stage in the planning process nevertheless represents a significant proportion considering the lack of use of such techniques in the past.

- Still images of 3D landscape visualisations are the most popular format (89%) closely followed by animations, usually in the form of a pre-defined ‘fly-though’ or ‘walk-through’. Only one respondent indicated that they use interactive LVs in the consultation stage, whereby the user (e.g. a member of the public) is able to freely control navigation within a 3D environment.

- Only 2 respondents (8%) indicated use of the Internet for distributing VIA information. In one case this was simply a case of posting PDF documents of photomontages on a website, the other respondent had experimented with VRML but found it of limited value for disseminating LVs covering large areas.

4. Conclusions

Based on a literature review and our survey findings relating to the use of IT-based approaches in wind farm planning in the UK context, the main themes that have emerged from this research are three-fold. Firstly, we suggest that the issue of visual impact in wind farm planning is a contemporary and highly contentious one, and perhaps the single most important factor in determining the success of a planning application. This has been reinforced by some high profile decisions on recent wind farm proposals such as that of Whinash wind farm in Cumbria (BBC News, 2006). Secondly, our review suggests that there are limitations associated with traditional techniques used to assess visual impact and that there are clearly shortcomings associated with the manner in which outputs from visual assessment techniques are incorporated into the planning process, particularly in the context of the dissemination of such information to the public and their use in public consultation scenarios. Thirdly, whilst there has been some recent work concentrating on public responses to different landscape visualisation tools (e.g. Dockery et al, 2006), there remains a lack of research focussing on evaluating the potential of interactive online visualisation tools for enhancing public participation in the planning process (Strobl, 2006), despite their undoubted potential. There is a clear need for empirical work to assess this potential, with particular emphasis needed on assessing public responses to the usability of such tools to determine if they are a viable means of promoting participation, as well as recording reactions to the output imagery/information produced using such techniques.

5. Further Work

During the next phase of this PhD project we intend to evaluate the use of Internet-based LV and other techniques (ZVI maps, photomontages) for overcoming some of the previously highlighted limitations inherent in existing methods of information dissemination and public participation in wind farm planning in the UK, using a web-based experiment based on an existing wind farm proposal near the town of Gilfach Goch, South Wales. An outline of the experiment, some preliminary findings, and a detailed review of the VIA techniques and public participation issues will be presented at the conference.

Though focussed on wind farm planning in this instance, the findings of our work will likely be applicable to all manner of projects which are perceived to have potentially negative visual and landscape impacts. If such tools are shown to be successful in engaging the public in the landscape planning process, they could form the basis of a future Public Participation Geographical Information System (PPGIS) on which a participatory framework can be built which fully incorporates public feedback into the decision making process.

Biography

Rob Berry is a 3rd year PhD student at the GIS Research Centre, University of Glamorgan. Rob graduated from the University of Glamorgan with an MSc in Geographical Information Systems in October 2004.

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Developing and Applying a User-friendly Web-based GIS for Participative Environmental Assessment

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Key words: Geographic Information Systems; Strategic Environmental Assessment; Public Participation; Methods.

1. Introduction

The strong spatial and temporal dimensions of development plans necessitate certain requirements in relation to the analytical tools applied to support Strategic Environmental Assessment (SEA) processes. The nature of plans and, subsequently, spatial data requires presenting them in graphic format. Similarly, temporal variation can often be represented in visual form by spatially illustrating changes over-time. Furthermore, it is estimated that up to 85% of all data have a spatial component and, therefore, can be mapped using Geographic Information Systems (GIS) (Chan and Easa, 2000). In this context, the graphic display and analytical potential of GIS can significantly contribute to SEA of development plans by facilitating and enhancing the various stages of the process.

The SEA Directive (CEC, 2001) and the related Directive 2003/35/EC (CEC, 2003) make mandatory provisions for public participation in the assessment of potential effects of certain plans and programmes on the environment. SEA processes and the integration of environmental concerns into planning can be positively influenced by public participation (Risse *et al*. 2003; Al-Kodmany, 2002). It is considered that involving the affected public and interest groups enhances the level of legitimacy, transparency, and confidence in the decision-making process (Risse et al. 2003; Von Seht, 1999). Methods such as submission of written comments, public hearings, workshops, interviews, etc. as well as more modern forms of consultation such as internet-based fora are possible forms of participation (CEC, 2003). Selection of appropriate public participation techniques is necessary to ensure that citizens are given enough time and scope to participate in an effective manner while avoiding undesirable time delays in the decision-making process (Von Seht, 1999).

GIS packages tend to require skilled knowledge of the system to operate them, as applications normally have a technology focus rather than usability (Jordan, 1998; Sieber, 1998). However, recent developments in GIS are leading to more user-friendly software interfaces. Usability barriers are being reduced and a number of case studies indicate that GIS can be successfully used as a tool in participatory processes to facilitate spatial comprehension, enhance transparency and stimulate debate (Al-Kodmany, 2002; Bojórquez-Tapia *et al.*, 2001; Wood, 2005). In light of this, a GIS-based website has been developed for public participation in SEA.

2. Methodology

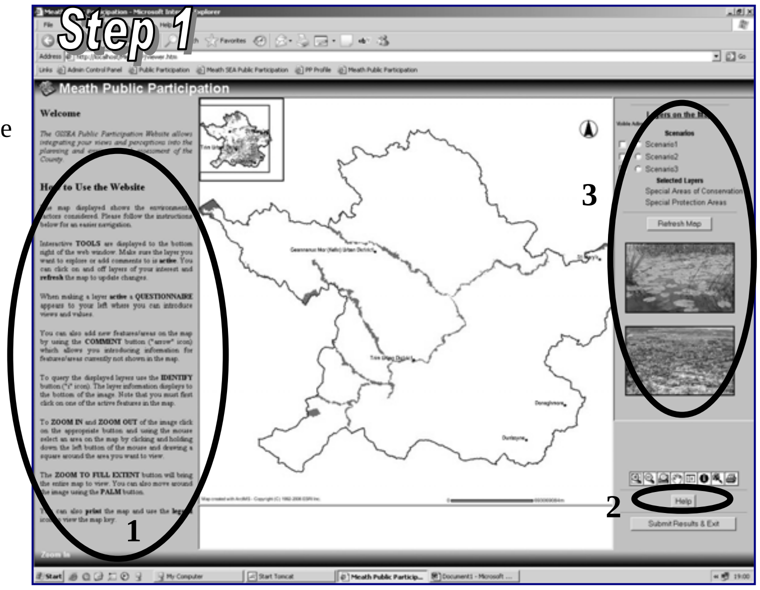
The research seeks to test the applicability and effectiveness of GIS in SEA. To address this objective, a GIS methodology has been developed and is currently being applied to SEA case studies of Development Plans in Ireland. These case studies will allow for the assessment of its usefulness from an environmental planning perspective.

As part of the GIS for SEA methodology (GISEA hereafter), a participatory web-based GIS tool has been developed. The aim is to both promote and expand the use of GIS to enhance public participation and promote the incorporation of spatially specific information in SEA. The availability of a web-based participatory tool can facilitate public consultation processes by providing an alternative way of informing the public and allowing them to remotely submit views and comments.

Consideration was given to open source versus commercial web GIS packages. The ArcGIS family of products was chosen as the platform for developing the GISEA method. It is considered that it provides the versatility and the tools needed to achieve the research objectives. The ArcIMS interface (i.e. the server GIS used for developing the public participation website) was edited to develop a user-friendly and easy to understand system that would not require specific GIS skills and could be manipulated with basic web-browser knowledge. Therefore, the viewframe and tools available in ArcIMS were adapted to the requirements of the research: including an enhanced browser, improved user interaction, incorporation of a database and display of tools and questionnaires specific to case studies. This was achieved by programming and editing the scripts on the ArcIMS files in several computer languages, including: php, java, html, sql and visual basics. The website has been designed to follow a number of steps guiding the user through the consultation process (Figure 1).

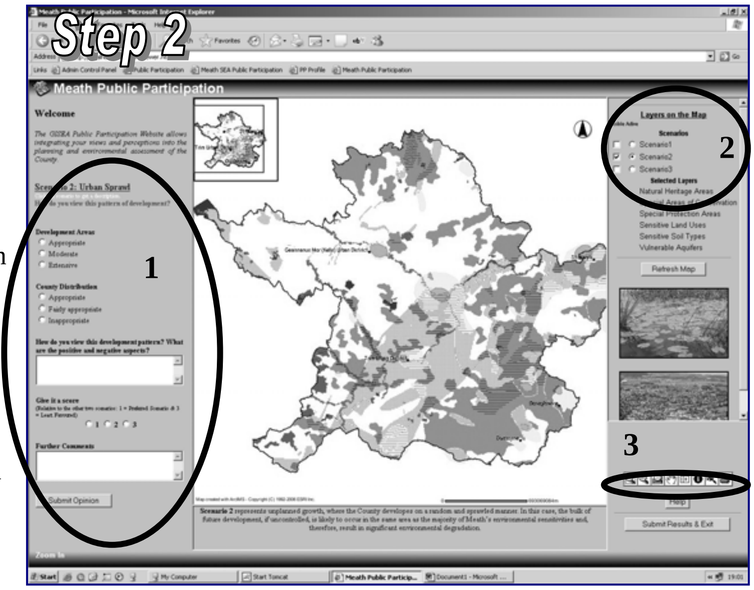
Initially this frame displays information on how to use the website (1).

The user can always come back to it using the help (2) button.



The environmental criteria chosen are displayed on the map and listed on the table of contents (3) which also includes the proposed scenarios. Pictures (3) give an indication of these scenarios.

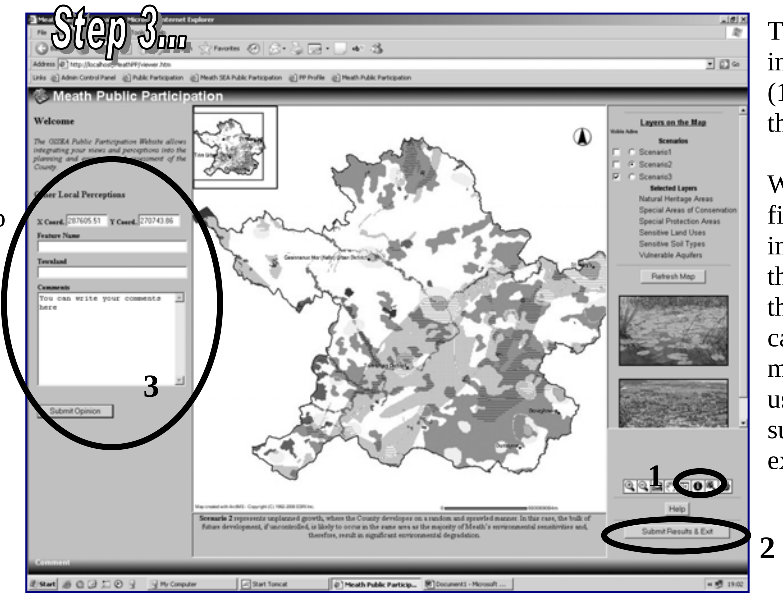
A questionnaire (1) is displayed for each scenario where the user can submitt personal views and opinions. The questionnaire is semi structured providing free space for personal comments.



The different scenarios can be turned on and off from the table of contents (2).

The tools (3) allow the user to move around the map (zoom and palm), identify the geographic data displayed and print the map.

The user can also submit information (3) in relation to a particular feature or area on the map (coordinates are automatically recorded when clicking on the map).



The add information button (1) is located in the toolbar.

When the user has finished interacting with the website (note that step 2 and 3 can be repeated as many times as the user desires), the submit (2) button exits the site.

Figure 1. Details of the GISEA ArcIMS webpage.

3. Results

Pilot studies on the understandability and user-friendliness of the GISEA public participation tool revealed that the majority of users (58%) found the website easy to use and navigate. The graphics were perceived as a good way of presenting the information. However, a number of users (30%) indicated that the absence of a more readily available legend (i.e. an alternative to having to select the legend menu) was a major drawback when understanding the map.

The website has been launched as part of the SEA of two County Development Plans in Ireland. The site is not intended to replace any public participation methods but to complement existing practices and techniques, ensuring that stakeholders have access to information and are provided with a mechanism to have a say outside conventional participatory processes. It is anticipated that this tool will contribute to a more transparent and better informed decision-making process. The objective is to gather spatially specific information and consequently integrate the weighted public participation results into the environmental assessment through GIS. This will provide an overall view (both scientifical and social) on the environmental significance/vulnerability of the different areas and the preferred scenario/alternative for development.

4. Analysis

GIS is recognised as a very useful tool for assisting decision-making. Case studies anticipate that GIS has the potential for improving the information available to the public and the spatial analysis of combined quantitative and qualitative data. However, it is still considered as an expensive solution that requires a high level of spatial understanding and technological skill to use (Kingston, *per. com.*, 2006). While open source GIS could solve the associated costs, proprietary software is most commonly used in the planning context to which the research applies, thus enhancing its usability. Concerns also derive from the apparent division between computer-skilled and ‘traditional’ citizens (Furlong, 2005; Scott and Oelofse, 2005) and varying degrees of access to technology. This is anticipated to affect the use of and the responses derived from the tool. Moreover, Kingston *et al*. (1999) suggest that the levels of participation are directly related to the geographical scale; the greater participation occurring at the larger or more localised scale.

This paper will discuss the key aspects of a user-friendly tool to complement traditional public participation methods and will evaluate its applicability, by addressing transparency, accessibility, understandability, accountability and usability issues. It will simultaneously provide an overview on the limitations, barriers and opportunities encountered when applying the internet-based GISEA public participation tool during the preparation of County Development Plans in Ireland.

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Modifying the 2001 Census Output Area Classification (OAC) for applications in Higher Education.

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1. Introduction

There are a variety of commercial Geodemographic classifications which can be adapted to inform spatial decision making in Higher Education. However none have been specifically designed for this purpose. Although contemporary Geodemographic classifications originated in the public sector through studies of deprivation in the 1970's (See Webber, 1975, Webber, 1977), the application of these techniques though the 1980s and 1990s remained predominantly within the private sector for market segmentation across a range of industries. Only recently have commercial vendors augmented these classifications with public sector data, however this has occurred superficially at the level of "pen portraits" to provide additional descriptive material of clusters (Longley and Goodchild, 2007). Although these classifications may be promoted as tailored solutions for the public sector, they do not address a number of key concerns including whether it is appropriate for a general purpose classification describing private sector consumption of goods and services to be applicable for public goods that are consumed collectively. Furthermore, for public sector use of geodemographic classifications, robustness in terms of social equality is acutely important as the misspecification of areas could have far reaching negative impacts. For example, in an advertising campaign targeting educational funding opportunities, residents of in an incorrectly prioritised area may lose real life chances by not receiving appropriate information, despite being stakeholders in the educational and taxation systems. Because of these issues greater transparency of classification procedures is required by public sector end users, including a greater level of methodological detail than has hitherto been provided by commercial vendors. The requirement for an open methodology is not easily achievable by commercial companies as the release of detailed information on how classifications are constructed is perceived as undermining competitive advantage. To date, details on classification methodology have only been made available at rather general levels, including detail of which clustering algorithms have been used (Harris et al, 2005) or the sources and broad mix of input data (Experian, 2006). It is in this context that this paper explores how a bespoke geodemographic classification can be created by combining public domain and sector-specific data, using explicitly specified techniques and tools required in classification. It then presents a pilot which could be refined and deployed though a centralised service to Higher Education (HE).

2. Variability of K-Means Clustering

Numerous clustering algorithms are available to create groupings from large multidimensional datasets and a thorough review can be found in Everitt (1980). These methods all aim to create homogenous groups from a multidimensional data matrix. Before running a cluster analysis data must be standardised to reduce the effect of outliers and measure the data on the same scale, in order to ensure that all variables have the same weighting. Romesburg (1984) discusses how standardisation prior to clustering prevents the units used for attribute measurement from affecting the similarities between objects, and therefore allowing more equal contribution by each of the variables. There are many ways in which the data could be standardised and these are evaluated by Vickers (2005), who found that a range standardisation method (Wallace et al, 1996) performs most effectively at reducing outlier effects in Output Area (OA) level classification. The Output Area Classification (OAC) classification is built using a *k-means* algorithm which partitions a multidimensional data matrix into *k* clusters or groups based on local a optimisation criteria. For a full evaluation of why this algorithm is most suited to clustering applications at an Output Area geography see Vickers (2005). After the first iteration of the model where initial cluster centroids (seeds) are randomly placed in the data matrix and all data points are temporarily assigned to their nearest seed, the *k-means* algorithm attempts to find a local optimum through an objective function that reallocates data points iteratively from their initial assignments. Each data point is considered for reallocation to other clusters, and after each test the model objective function is recalculated. If the outcome is larger, i.e. a less homogenous cluster, no further reallocation of data points takes place. Where reassignment of data points does occur, the cluster centroid values for the gaining and losing clusters are recalculated. The maximum number of iterations for this optimisation process can be specified by the user. However, with current computational power it is possible to leave the models running until the iteration process converges, i.e. further reassignments of data points does not improve the sum of squares statistic. Everitt (1974:26) astutely observes that “there is no way of knowing whether or not the maximum of the criterion has been reached”. This is because in a single *k-means* model there are multiple local optima, since the random placement of the initial cluster seed centroid means that there are multiple possible locally optimised models. This can be illustrated when two separate models are run to convergence where $k = 9$ on a two variable dataset extracted from the OAC input data (see Figure 1 and Figure 2).

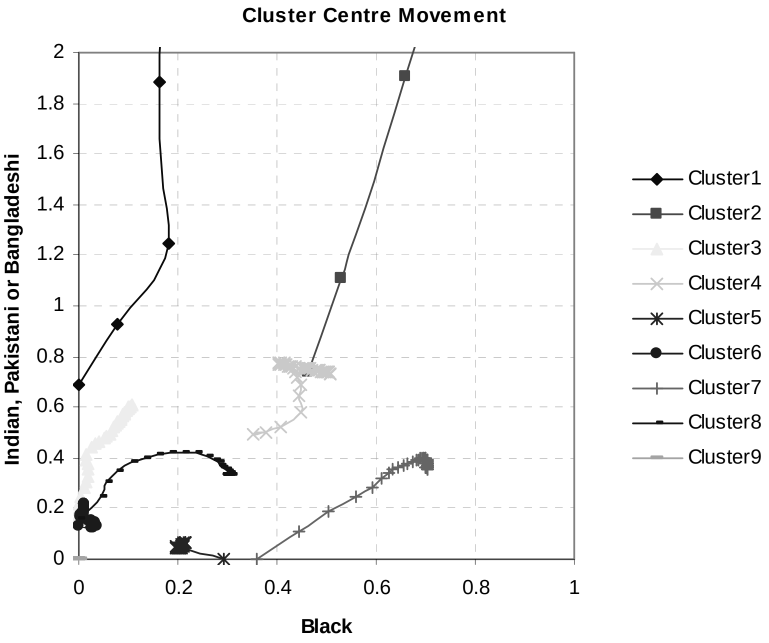

Figure 1: Cluster mean paths

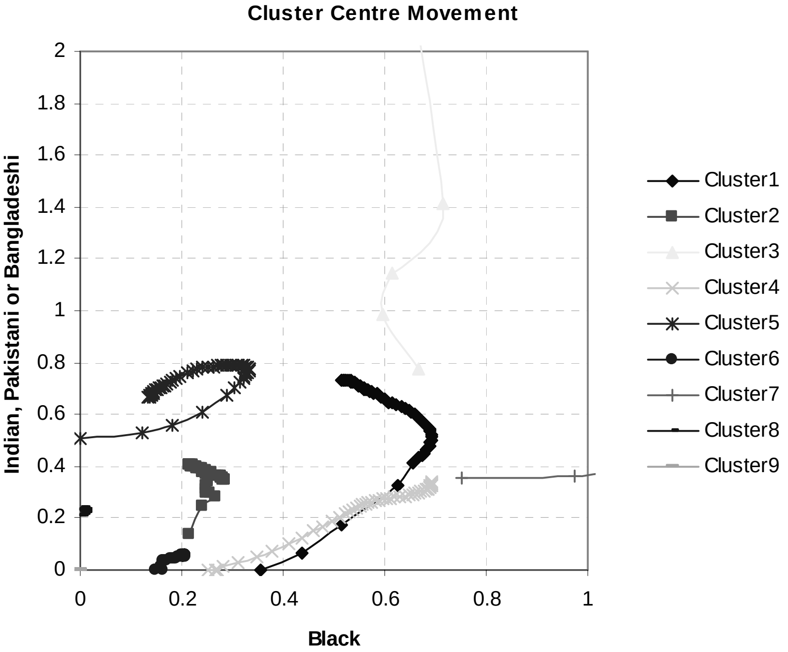

Figure 2: Cluster mean paths

Ignoring the arbitrarily assigned cluster names, these graphs show how the path of the cluster centroid can converge upon entirely different locations, depending upon the random initial seed location. Furthermore, as each iteration of the model reallocates data points to cluster centroids, "making the 'best' decision at each particular step does not necessarily lead to an optimal solution overall" (Harris *et al*, 2005:162). The most effective partitioning of the input data in a cluster model is globally optimised, although in reality this is not obtainable as there is no benchmark of global model performance for an individual data set. However, with sufficient computational power a globally optimised local model can be obtained by running *k-means* multiple times to convergence, comparing the results from each cluster analysis and saving the best performing classification. Figure 3 shows the results from a *k*=9 model which was run with a random seed allocation 150 times, and for each model an R-squared statistic was generated to estimate the quality of the model discrimination. This graph highlights the variance in overall model performance through selection of different initial seeds. Therefore, for an HE specific geodemographic classification it is essential that the model be run to convergence multiple times, with the explanatory power of each model compared.

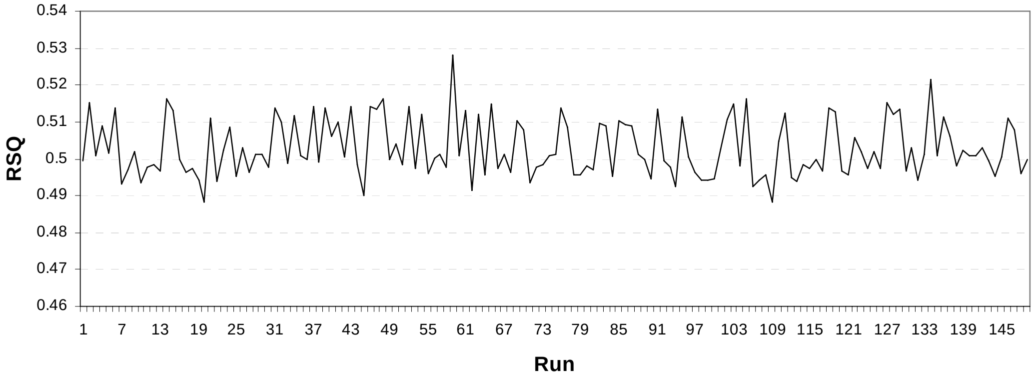

Figure 3: R-Squared Results from 9 cluster model

3. Creating an Educational OAC

An HE specific geodemographic classification could feasibly serve a number of different purposes including marketing, extending access, widening participation or subject specific targeting. When selecting input variables these purposes were considered with the aim of creating a classification useful for a variety of tasks demanded by HE decision makers. The data available for this study are from a subsection of the 2001 HESA database covering all students with English domicile studying within English institutions. This database contains of a variety of suitable variables for inclusion in the cluster analysis and the variables chosen are listed in Table 1.

Variable	**Numerator**	Denominator
Young participation rates	First year students aged 18-19.	Census 2001 18-19
Average distance from student's home to institution	N/A	N/A
Average A-Level Score of students	N/A	N/A
Proportion of students from low social class groups	Undergraduate degree students from the three lowest social classes (IIIM, IV, V)	All undergraduate degree students (Source: 2001 Census)
Proportion of students studying within degree course groupings	Those studying undergraduate degree courses within course groupings.	All undergraduate degree students (Source: 2001 Census)
Proportion of different ethnic minority Groupings compared to total HE population	Those undergraduate students from ethnicity minority groupings.	All undergraduate degree students (Source: 2001 Census)
Proportion of students previously educated in Independent Schools in Year	Those undergraduate students who previously attended independent schools.	All undergraduate degree students (Source: 2001 Census)

Table1: HE input variables for the cluster analysis

To investigate the most appropriate value of *k* in line with the observations from Figure 3, 10,000 separate cluster analysis were run from *k*=55 to *k*=65. The median, minimum and maximum R-Squared results are presented for each *k* value in Figure 4.

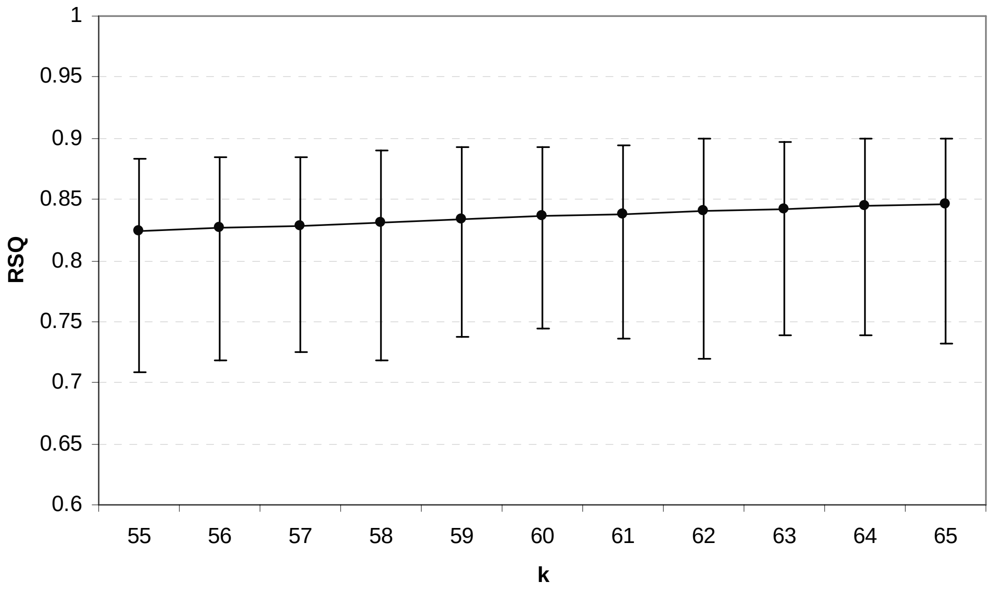

Figure 4: R-Squared Results from 10,000 Cluster Analysis

Each of these assignments of *k* appears to perform well at discriminating within the input data matrix and, as demonstrated in the earlier exploratory analysis, the minimum and maximum bars further illustrate the need to optimise each *k* allocation. Once the population distribution within each of these models were examined it was decided that *k*=64 was the most appropriate model as this had reduced outlier clusters. The Educational OAC Type level classification was therefore defined as comprising of 64 clusters, however, to create a more intelligible classification for end users a second hierarchy in classification was created which aggregates the finest level into larger groups. A second type of clustering algorithm was used to aggregate the 64 clusters (types) into the larger aggregation of groups. The Ward (1963) method assesses the loss of variance that would be associated by merging clusters together when those which are amalgamated minimise the "increase in information loss" (Everitt, 1993: 65). The result of which was an 8 group classification. Figure 5 demonstrates the variability in propensity to study particular subjects within one of these groups. Using an index score the average propensity is represented by the thin line at 100. Where Group D shows higher than average participation for a particular course, these scores rise above the line, and where participation is less than average these scores fall below the line. It is common practice in the geodemographic industry to consider an index score which is less than 80 and greater than 120 to be significant and these are represented by the two thicker lines. Therefore we could say that areas categorised as Group D shows an increased propensity to supply Veterinary Science and Language students.

This paper has demonstrated how a standard geodemographic classification can be adapted to serve a public sector market and an optimisation technique for the *k-means* algorithm has shown how great caution is required when building or interpreting classifications built using this method.

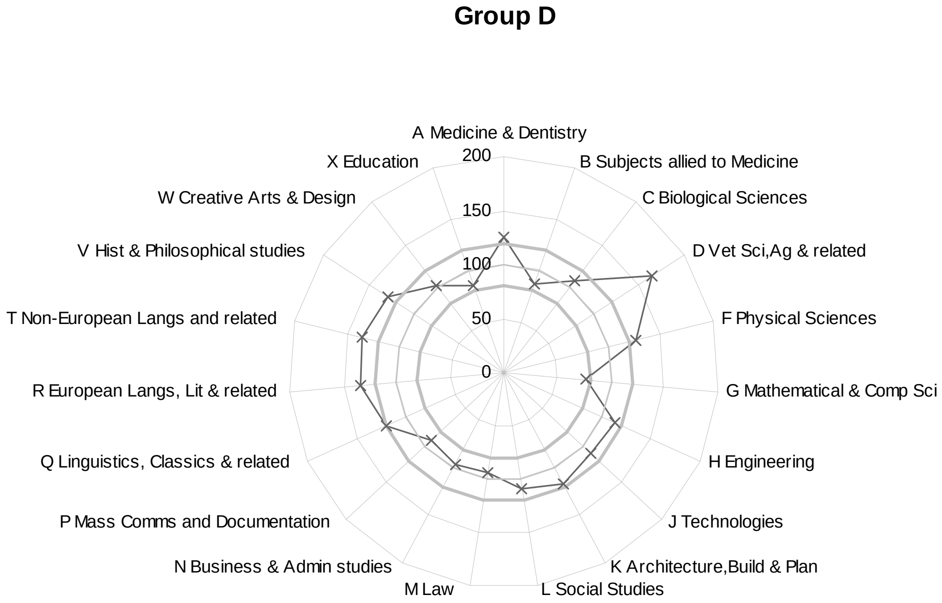

Figure 5: Group D – Course Propensity

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Avalanche education with mLearning

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1. Introduction and motivation

In Switzerland an average of 22 people per year die in avalanches whilst taking part in recreational activities outside of ski pistes. Many of these accidents could probably be prevented if skiers did not travel on slopes where obvious warning factors were present (McCammon and Hägeli, 2004). In estimating the risk involved in skiing a particular slope a range of factors must be considered including terrain, snowpack and weather factors – the so-called avalanche triangle. To ease the decision making process for recreationalists a number of simple decision making tools have been developed for use both in planning trips and while in the terrain (e.g. Munter, 2003). In conjunction with such tools, avalanche education is delivered through a wide variety of medium (for example books, classroom courses, lectures and courses in the field). Recently, increasing interest in new media has led to the development of new strategies for delivering avalanche education. For example, in 2006 the Swiss Federal Institute for Snow Avalanches published an interactive eLearning CD for those wishing to learn more about how to identify and avoid avalanche slopes (Harvey, 2006).

However, a significant difficulty in learning about avalanches remains in the translation of theoretical knowledge to its useful practical application. So-called "mobile Learning" (mLearning) is suggested by Okamoto et al. (2001) as being a possible means of bridging this gap between theory and practice, through the delivery of learning materials to a user who is in a realistic learning environment on a Personal Digital Assistant (PDA). Sharp et al. (2003) argue that mLearning offers the possibility to support informal, situated, context dependent and cooperative learning. In turn, a key element of context is location, and through the use of GPS materials specific to a learner's location can be delivered (Kondratova, 2004).

Here we describe the development of a location-based system for avalanche education, mAvalanche, whose aim is to teach methods relevant to the estimation of avalanche risk in avalanche terrain.

2. mAvalanche

In order that learners can carry out the exercises in mAvalanche in a safe but realistic environment, the materials have been implemented for a variety of routes within a ski area. A number of “learning routes” have been developed, each containing “learning posts”. Learners travel to the learning posts, where factors relevant to avalanches are introduced and illustrated through text, pictures and film and a series of exercises to reinforce and test learning are delivered. The exercises use the learner’s actual position to retrieve values from spatial datasets, so that for example, an estimation of slope can be compared with that stored on the PDA for a location. In principle, such exercises where the learner has an opportunity to self-test, should lead to a significantly improved understanding of the underlying concepts (Pavard and Dugdale, 2002). Since a key aim of mLearning is to further both self and collaborative learning, the materials are designed to be used either in small groups or alone without the need for an accompanying instructor.

3. Design requirements

In order to develop mLearning materials in general, and mAvalanche in particular a number of design requirements must be considered. These include the following:

- An application framework allowing the development of interactive content is required
- The application framework should be capable of loading learning content stored in a given (and standard) format
- The format used for storing learning content should embrace current didactic best practice in e-learning
- It should be possible to include multiple types of content: e.g. text, images, film and interactive animations
- Interactive elements should be developed to allow access to relevant location-based information (e.g. coordinates, context-specific mapping, current position)

4. Implementation

A prototype version of mAvalanche has been implemented in the Windows Mobile Operating System. The application itself is programmed using the Compact .Net Framework in C#. Through the use of OpenNetCF and ActiveX components multimedia components can be easily embedded.

Learning content was developed within the open source XML framework eLML, which is already used in a variety of eLearning products (Fisler and Bleisch, 2006). eLML is based on the didactic concepts encapsulated in E-CLASS (Gerson, 2000):

- Entry: The introduction to a lesson or unit (where a lesson may contain one or more units)
- Clarify, Look, Act: The content of a unit must contain one or more of the three elements of theory, examples and activities.
- Self-assessment: Exercises and group work should allow the learner to measure their progress at the end of a unit or lesson

- Summary: Every lesson should end with a short summary.

By using the E-CLASS schema two separate and important aims are achieved. Firstly, the developer of content is directed towards a didactically proven (and relatively standard) structure for the provision of learning materials. Secondly, by using eLML, the representation of the learning materials is cleanly separated from the content. Currently, mAvalanche supports all of the main tags in eLML.

The development of mAvalanche is an interactive process where both the usability of the application and the quality of the content must be constantly reevaluated. For example, one early result from testing suggested that users wanted to quickly undertake exercises relevant to their environment and had little patience to read large amounts of text. This resulted in a significant redevelopment of the content to place exercises at the centre of the learning materials.

5. Case Study

During the winter of 2006/7 mAvalanche will be tested in the Parsenn ski area with a variety of users for a specific learning route (slope) which is illustrated here.

Figure 1: The lesson begins by illustrating basic concepts related to slope in words and pictures. To ease understanding of concepts, films and interactive animations are used wherever possible. Figure 1 shows an example learning object, where a short film illustrates how ski tourers can estimate slope angle using ski poles. Such material is much more easily understood through such an animation than a diagram, with the added advantage that the user can immediately practice the method in the field.

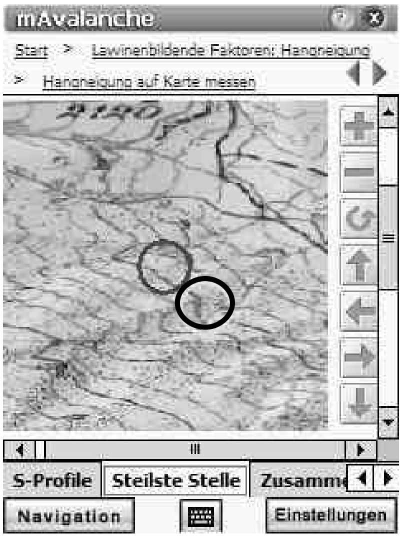

Figure 2: The main interactive learning objects in this lesson allow the user to estimate or measure slope at any point in their route and compare their values with those derived from a DEM for their actual position. At any time, the user can view their current position on a map and thus navigate to the next learning post. In the learning object on shown, the user is asked to estimate the steepest point on a route, before their answer is compared with that calculated on the basis of their actual route through the terrain.

5.1. Evaluation

An important, and oft-neglected, element of the development of new modalities in learning concerns evaluation. In the case of mLearning, we have hypothesised that the use of context-dependent materials in a realistic environment should improve learning success. However, without significant resources and a well-designed evaluation such hypothesises are in practice very difficult to evaluate. In a first stage of testing in the winter of 2006/7 we will evaluate a simpler question – “Is mLearning a practical means to deliver materials related to avalanche education?” Users will test the system in the field, and afterwards be asked to complete a questionnaire covering a number of aspects including their previous experience, the quality of the learning content and the usability of the mAvalanche system. At the time of writing we are carrying out beta testing of the system in the field, prior to user tests. We expect to report on our experiences of these user tests at GISRUK.

6. Summary

We have reported on a system in which context-specific avalanche education materials are delivered through an LBS. A key aim of this work is to deliver avalanche education in a realistic environment, in order that the learner can practice the skills they are developing in a realistic but safe environment. A further, and important aim in mLearning is to link the activity which learners find fun directly with learning in the hope that this will lead to greater success in achieving learning objectives.

By integrating eLML in the application, the diadactic concepts encapsulated in E-CLASS, which are designed with distance and independent learning in mind, have been included in mAvalanche. The use of this schema means that authors can quickly and easily develop further lessons for delivery as mLearning applications.

We are currently carrying out an initial evaluation of the system which includes elements of usability and learning success. However, further work will be required to fully test the hypothesis that context-dependent materials in a realistic environment improve learning success.

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Biography

Christoph Suter is currently working on his Masters thesis, results from which are reported in this paper. He is also an enthusiastic snow boarder.

Towards a Framework for Supporting GIS Competencies in Local Government

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1. Background

Information and communications technology (ICT) has become essential to the operations of organisations and communities worldwide, with huge sums of money, resources and user expectations invested in their implementation (ODPM, 2002). Yet many ICT projects fail to achieve their objectives, which may in part be attributed to a failure to understand how individuals and organisations learn to use and adapt to ICT (British Computer Society, 2005; Cabinet Office, 2000). This paper is based on research undertaken in 2006 that explores the implementation of one particular form of ICT, Geographical Information Systems (GIS), in a particular type of organisation, namely local government, where GIS usage continues to expand rapidly. The technology is considered fundamental to the achievement of local e-government, facilitating ‘joined-up’ services and access to information. GIS are complex, offering numerous opportunities for future development as well as considerable scope for things to go wrong, and thus present a particularly acute learning issue. Key constraints to unlocking the full benefits of GIS in organisations include organisational structure and remit, lack of awareness of potential applications, the skills base, and management support (Birks et al., 2003; Grimshaw, 2001; IGGI, 2002).

The study started from the position that staff are the most important factor in the successful organisational implementation of GIS, and in order to make the best use of GIS, local authorities and their GIS users needed to move into a position that allowed them to ‘act-with’ the technology (Zuboff, 1988), developing levels of learning which promote understanding of the principles and capabilities rather than simply knowing the operations required to carry out a specific task (Quinn et al., 1998). It aimed to explore the means by which local authorities and their staff can develop the ‘human factors’ for success, summarised as ‘ability’, ‘effort’ and ‘support’ (Birks et al., 2003) which promote the knowledge and skills necessary to make best use of GIS technologies. It thus addresses issues related to both individual and organisational learning and development (Sfard, 1998; Elkjaer, 2004). In order to do this three ‘communities’ were identified, namely suppliers of GI systems and training to local government customers, GIS managers in local authorities and GIS users in local government. Overall the research examined three questions:

- What GIS training and development is currently provided?
- How is training and development delivered to GIS personnel in local government? Plus a secondary question: Are there any discernible differences in organisations holding the award of Investors in People?
- What do users require of GIS training and development?

This paper addresses these questions and outlines how they have facilitated the specification of a framework of learning and training options to support the development of GIS skills across all levels of staff in local government.

2. Methodology

To investigate these questions, a multi-stage, multi-method approach was adopted comprising primary data sources (material collected using survey and case study methods) and secondary data sources (a review of services provided by GIS training suppliers). The three linked stages were:

- A review of education and training providers
- An e-survey of local authorities
- A series of case studies

The findings of this multi-stage approach informed the proposal of a framework for enhancing GIS skills within local authorities in the UK.

This paper focuses on the e-survey undertaken in summer 2006, which aimed to establish the range of GIS training and development delivery methods, attitudes to, and experiences of, training in the local government sector. In order to do this, a questionnaire survey was conducted across county, district, unitary and metropolitan authorities in England, Wales and Scotland. It also sought to establish whether there were any discernible differences in Investors in People organisations.

The survey targeted GIS managers, strategic managers, and ‘power users’ (users involved in geographical data management and GIS development, and advanced frequent users) in these authorities. The response rate of 52% (253 questionnaires), above average for a self-completion questionnaire (Flowerdew and Martin, 1997), indicates that this is a highly topical issue, and, while the purposive nature of the sample means that the results cannot be considered representative, the response rate, mix of types and geographical spread of responding authorities provide results broadly indicative of local government throughout Great Britain.

3. Results and Analysis

The survey revealed that GIS use is widespread, and its adoption as a corporate information tool is steadily increasing. GIS managers and ‘power users’ are generally a committed, motivated and knowledgeable group. However, the situation is inconsistent, both between and within local authorities, in terms of level of GIS application, senior management commitment, staffing levels, and training.

Specifically in relation to training:

- **Training and communication gaps:** a quarter of respondents worked in authorities where it was difficult for staff to get the training needed.
- **Skills gaps:** there is an indication of skills gaps, both amongst general users and GIS managers and ‘power users’.
- **Emphasis on tasks or competencies?:** the training and development emphasis appears to be on ensuring staff know what they need to do in specific circumstances, rather than on whether they have the understanding and ability to carry out these and other future tasks.
- **Mix of methods**: there is clear support for a combination of training methods to suit the topic, staff and requirements.
- **Preferred modes of delivery: s**mall group or individual hands-on training by professional trainers, product or software vendors, especially when customised to the organisation’s specific requirements, and on-the-job training from colleagues were preferred.
- **E-training**: although not widely used at present, there is a growing interest for the future.
- **Trainers:** much training is delivered by colleagues who are not trained trainers; whilst not a bad thing per se, there may be inconsistencies in delivery as well as gaps in knowledge.
- **Flexible programme timing:** some respondents prefer to learn incrementally, whilst some are keen to learn at any time indicating a need for flexible delivery of training
- **Obstacles**: unsuitable location, timing and topic are the most common reasons for declining the offer of training.
- **Wide user base/different training needs:** a widening user base for GIS, and its incorporation into the range of ICT tools available to local government staff, is accompanied by different training needs.
- **GIS or information management?:** there is debate about whether GIS training should be offered separately or as part of wider information and data management and ICT awareness and training programmes. These aspects are needed alongside GIS skills, but are unlikely on their own to generate spatial analysis, interpretation and presentation skills.
- **Knowledge- and experience-sharing:** there is no consistent approach to sharing GIS knowledge and experience - word of mouth is relied on to large extent.
- **Training budgets:** training budgets are generally small and training courses, especially those delivered by vendors, professional trainers, or leading to qualifications, are expensive, limiting availability to local government staff.
- **Investors in People:** there were no conclusive differences between the main sample and local authorities holding Investors in People status.

The survey results contributed to the specification of a set of criteria and conceptual model which allowed an innovative framework of training and learning options to be formulated, capable of customization to individual user needs and requirements.

4. Conclusion

This survey supported the view that the development of GIS knowledge and skills through the delivery of training opportunities in local government is by no means straightforward, and is surrounded by issues of many types, social, economic, political, technological and organisational in addition to educational. Further, there is unlikely to be a 'one size fits all' solution. This was explored in more detail by focussing on how selected case study local authorities seek to help their staff learn (not described here).

The findings of the multi-stage research process led to the proposal of a framework for enhancing GIS skills within local authorities in the UK which will be outlined in the paper. This proposes a series of 'pathways' of learning options which may be followed by staff with varying levels of GIS knowledge, skills and requirements in order to build the understanding necessary to make good use of GIS technologies now and into the future.

5. Acknowledgements

This research formed part of an MSc in GIS and Management undertaken at Manchester Metropolitan University (UNIGIS).

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Biography

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Using GIS data in a m:n-AC^k cellular automaton to perform an avalanche simulation

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KEYWORDS: Cellular automata, m:n-AC^k, GIS, simulation, avalanche.

1. Introduction

The purpose of this paper is to represent, in a virtual reality environment, the simulation of avalanche phenomena. We use GIS data to define the different elements that take part in the calculations. All these data can be modified and maintained in a common GIS. To use these data in the simulation engine a m:n-AC^k cellular automata is used. m:n-AC^k is a generalization of the classical cellular automaton allowing the use of different layers in a single cellular automata.

The paper first describes briefly the m:n-ACk cellular automaton structure, next we describe the GIS data used to define the avalanche model, and finally some results are presented.

2. Cellular automata

Cellular automata are discrete dynamical systems whose behaviour is completely specified in terms of a local relation (Emmeche C., 1998). Cells represent automaton space; time advances in discrete steps following “the rules”, the laws of “automaton universe”, usually expressed in a small look-up table. At each step every cell computes its new state in function of its closer neighbours. Thus, system's laws are local and uniform. Next figure shows one-dimensional cellular automaton initial state and successive two states after rules application.

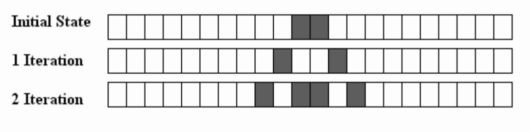

Figure 1: One-dimension cellular automata.

3. Multi:N-Dimensional Cellular Automata (M:N-AC)

A multi:n-dimensional cellular automaton (m:n-AC) is a generalization of a cellular automata defined as follows (Fonseca et al. 2005):

Definition 1: m:n-AC^k

A multi n dimensional cellular automaton is a cellular automaton generalization composed by m layers with n dimensions each one.

The representation is:

$m{:}n- AC^k$

Where

m: is the automaton number of layers.

n: is the different layers dimension.

k: is the number of main layers (1 by default). A layer in a m:n-ACk is a main layer if a transition function Λ is defined in order to modify its state. A m:n-AC automaton only presents one main layer, while m:n-ACk automaton presents k main layers.

Since multiple layers belong to a single automaton, its state is defined as follows.

Definition 2: $E_m[x_1,..,x_n]$, layer m state in $x_1,..,x_n$ position

E_m is a function describing cell state in position $x_1,..,x_n$ of layer m.

E_m function allows state representation for each cell in the different layers of the automata, but this is not the global state of the automata. This state is represented by the *EG* function.

Definition 3: $EG[x_1,..,x_n]$, automata status in $x_1,..,x_n$ position.

EG returns automata global state in position georeferenced by coordinates $x_1,..,x_n$.

The global state of cellular automata depends on EG function in all automata positions.

Combination functions Ψ is represented by equation:

$$\Psi(E_1[x_1..x_n],\overset{m-2)}{\cdot\cdot},E_m[x_1..x_n]) = EG[x_1..x_n] \tag{1}$$

In a common cellular automaton, evolution function allows global automata state change through cells value modification.

In a m:n-AC^k vectorial layers use makes necessary to generalize the neighbourhood and later define a new function that determines something similar to cell size (nucleus function).

Definition 4: Evolution Function Λm

Function defined for the layer m to modify its state through the state of others layers using combination function Ψ, and vicinity and nucleus functions.

Intuitively evolution function allows the representation of the modifications in this layer (modifications in nucleus area of a point $x_1.x_n$), using the state of other layers with combination function Ψ, and the vicinity area.

For more information about the vicinity and nucleus area and the vicinity and nucleus function, (Fonseca et al. 2005) can be reviewed.

4. Avalanche overview

An avalanche is a massive slide of snow, ice, rock or debris down a mountainside. Can be provoked by an earth tremor, extreme precipitation or man-made disturbances (such as a mountain skier). The impact of the falling material and the winds produced by the flow can cause extensive damage to anything in its path. In the next picture the avalanche fatalities in IKAR countries is shown (the IKAR countries considered are Germany, Norway, Slovakia, France, U.S.A., Austria, Switzerland, Italy and Canada). In the case of a snow avalanche, the new snow that accumulates on top of another heavy layer of snow can begin to slide down the mountainside. The risk of an avalanche can be reduced by building a snow shed — a barrier made of rocks, soil and other materials — or by triggering a controlled avalanche at a time when no one is on the mountain.

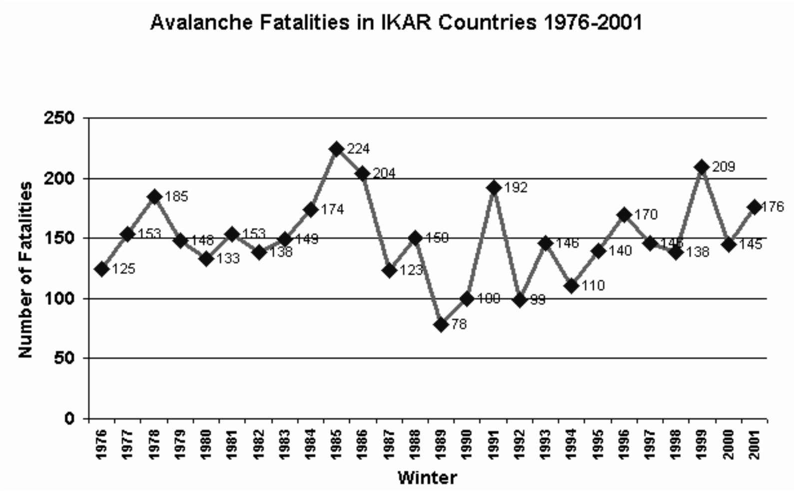

Figure 2: Avalanche fatalities in IKAR Countries (Avalanche 2007)

Minimal requirements for the occurrence of an avalanche are snow and an inclined surface, usually a mountainside. Most avalanches occur on slopes between 30 and 45°. Two basic main types of avalanches are recognized according to snow cover conditions at the point of origin.

1. A loose-snow avalanche originates at a point and propagates downhill by successively dislodging increasing numbers of poorly cohering snow grains, typically gaining width as movement continues down slope. This type of avalanche commonly involves only those snow layers near the surface. The mechanism is analogous to dry sand.
2. The second type, the slab avalanche, occurs when a distinct cohesive snow layer breaks away as a unit and slides because it is poorly anchored to the snow or ground below. A clearly defined gliding surface as well as a lubricating layer may be identifiable at the base of the slab, but the meteorological conditions, which create these layers, are complex.

In this model the slab avalanche is the only kind of avalanche considered.

5. Avalanche Model: $6+N:2\text{-}AC^{4+N}$ on Z^2.

$N \in [0,5]$, represents the maximum number of obstacles typologies that can be added to the model. Since all the parameters of the simulation are represented in these layers, is easy to perform different simulations representing different alternatives or situations. The problem to perform a simulation is reduced to find the layers that represent the area we want to simulate. No modifications in the simulation engine must be performed.

These data is stored following the IDRISI32 file format. To perform the avalanche simulation the data can be obtained from the ICC (Catalonia cartographic institute, http://www.icc.cat/portal/), from the Creaf (Center for Ecological Research and Forestry Applications, http://www.creaf.uab.es/mcsc/mms/index.htm) and from the Meteocat (http://www.meteocat.com/marcs/marc_muntanya.html). In the next table, the different layers used in the automata, and the source, are shown.

Name	Type	Description	Qtt	Source	Modifiable
Height	Raster	Layer representing the height of the environment.	1	ICC	No
Thickness of the snow	Raster	Represents the thickness of the "slab snow"	1	Meteocat	Yes
Floor features	Raster	Represents the kind of surface (rocks, sand, snow, ice,..). Each surface has his own specific rough parameter.	1	Meteocat Creaf	No
Snow that causes the slab features	Raster	Density, compactness of the snow.	1	Meteocat	Yes
Obstacles	Raster	Represents the obstacles that have the environment (small rocks, big rocks, houses, trees,…)	N	Creaf	Yes
Crack	Vectorial	Line representing the breakdown of the ice.	1	Input data	Yes, at beginning.
State of the snow	Raster	Shows the state of the terrain, **empty** (without snow that causes the windslab), **static** (contains snow that is stable) and **dynamic** (contains snow that in the next iteration is moving)	1	Meteocat	Yes

Table 1: GIS data used in the simulation model

5.1 Vicinity, nucleus and evolution functions

The Moore neighbourhood is used over Z^2. The figure 3 shows the representation of the cells relations. The vicinity and nucleus functions allowing the definition of the evolution function are based in the discrete topology over Z^2. The vicinity functions represents, in Z, what is the cells that must be taken in consideration to perform a calculation for the cell defined by (x_1,x_1), while the nucleus function represents the cell that must be modified due to the calculus.

Vicinity function: $vn(x_1,x_1) = \{(x_{1-1},x_{2-1}), (x_{1-1},x_2), (x_{1-1},x_{2+1}), (x_1,x_{2-1}), (x_1,x_2), (x_1,x_{2+1}), (x_{1+1},x_{2-1}), (x_{1+1},x_2), (x_{1+1},x_{2+1})\}$

Nucleus function: $nc(x_1,x_1)= \{(x_1,x_1)\}$

The evolution function (Λ) is based in the analysis of the global state ($EG(x1,x1)$) for a selected cell, through the combination function that merges the data contained in each one of the different automata layers ($\psi(E_1[x_1,x_1],E_2[x_1,x_1],..,E_{4+N}[x_1,x_1])$). The figure 4 shows a state machine representing the evolution function. Is not a complete description of the evolution function, but represents the three main states in witch each cell can be.

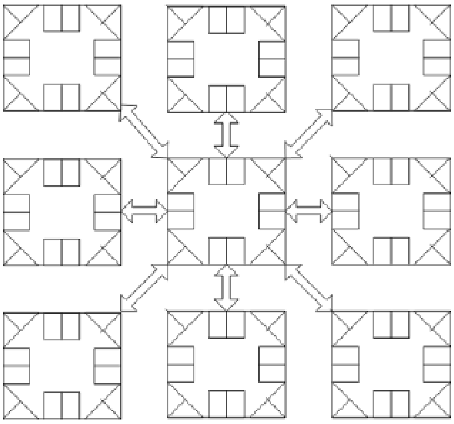

Figure 3: Moore neighbourhood

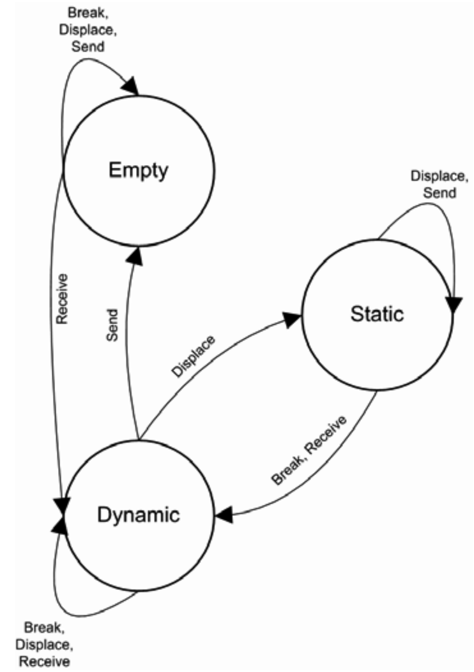

Figure 4: evolution function (Λ)

6. Results

The simulations of five different avalanche models have been conducted, obtaining data that can be compared with real avalanches data. In addition, a graphical tool, useful to understand the avalanche evolution has been developed. In the picture, a representation of an avalanche is shown:

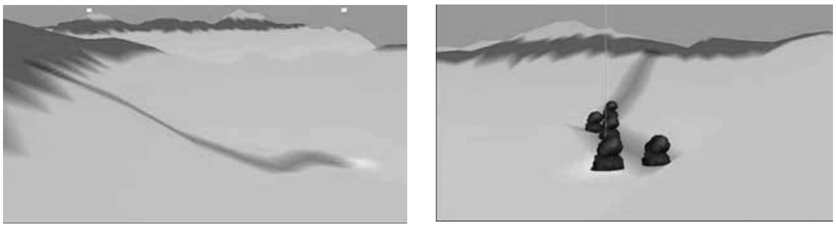

Figure 4: avalanche representation

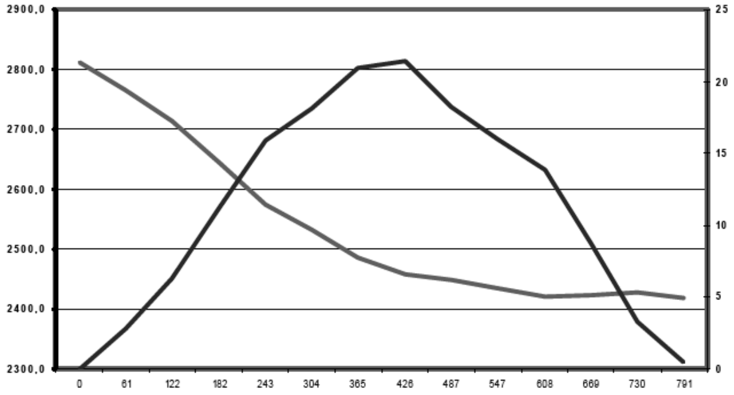

Figure 5: avalanche speed and height

In the figure 5 is shown a representation of the evolution of the snow speed in meters per second (blue line) and the height in meters (red line) for a simulation experiment.

7. Concluding remarks

An application to represent in virtual reality format the avalanche phenomena using GIS data thought the m:n-CAk cellular automaton is presented.

The comparison of the output data with studied phenomena for the speed variable shows promising results. Comparing the simulation output with (Leaf 1977; Mear 1976) we obtain similar results. In four different models, the maximum speed is about 21m/s (small or medium avalanche). In a test for a big avalanche, the maximum speed in the model is about 67m/s (little over the typical value for a big dimensions avalanche) (Leaf 1977; Mear 1976).

The structure in layers of all the elements that can interact with the evolution function of the avalanche, simplify the calculus of the evolution functions, allowing an easier implementation of the model, and a clear specification.
Since the layers represents all the model variables and are obtained from GIS data, the construction of a new simulation model is based on the definition of these layers, work that can be performed in a GIS, simplifying the modelling task.

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Avalanche 2007, http://www.avalanche.org/~uac/graf_world_ava.html (accessed 26/12/2006)

Biography

PAU FONSECA obtained his degree in computer engineer on 1999 from the Technical University of Catalonia. Now is full time professor of this university, teaching in statistics and simulation area. Also he works in the LCFIB (Barcelona informatics school computing laboratory) developing Simulation projects since 1998, and is member of LogiSim group dedicated to the research and simulation tools development.

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A GIS tool for the digitisation and visualisation of footpath hazards

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1. Introduction

GIS has gained rapid currency in recent years with outdoor leisure users, who can use packages such as Anquet Maps (www.anquet.co.uk) or Memory Map (www.memory-map.co.uk) to aid planning and visualisation of hiking or cycling routes. Such is the affordability and user-friendliness of today's leisure GIS software that sophisticated tools such as 3D photorealistic fly-throughs, previously confined to expensive commercial GIS, are placed within the grasp of users armed with little more than a home PC and £80 to spare.

Yet for all that these packages empower users with hitherto inaccessible digital geographical data and processing techniques, thereby enabling them to 'get a feel' for a route from the comfort of home, there remains a paucity of information to describe a route's potential hazards. Hazard data, which might include information on uneven terrain, steep slopes or water hazards, would be of great value to recreational walkers, as well as to professionals charged with looking after others in the outdoors (e.g. mountain leaders and school teachers). That such data is not readily available in the current crop of outdoor leisure GIS is remiss, and forms the key deficit that this work seeks to redress.

The aim of this work is to develop a prototype system for storing and visualising footpath hazards within a GIS. The next section briefly identifies the types of hazards that might exist along footpaths, and proposes a method for their digitisation. Section 3 considers how best to visualise hazard data, and presents an algorithm designed to generate hazard density maps at a range of spatial scales. Section 4 concludes by suggesting that the visualisation techniques developed here could be equally well applied to a wide range of other problems.

2. Hazard identification and digitisation

A typical risk assessment for a section of footpath would identify a range of different hazards, which are defined as 'things that have the potential to cause harm'. Hazards can be split into three broad categories (after Long, 2005): 'landscape hazards', such as wet rock or boulder fields; 'timing hazards', such as bad weather or nightfall; and 'people hazards', which include navigational errors or poor decision making. Of these three categories, landscape hazards are the most amenable to storage in a GIS because they can be ascribed real world coordinates; timing and people hazards, by contrast, exhibit strong social and spatio-temporal variation, and so are less well suited to digitisation within a geographic database.

2.1 Footpath hazard examples

The following landscape hazards, illustrated in figure 1, were identified during a risk assessment of the footpath that traverses the Lairig Ghru, a mountain pass in the heart of the Cairngorms National Park, Scotland (see figure 4 below). These hazards were chosen for two reasons: either they increase the risk of a fall resulting in injury (climbing over boulders, for example); or they increase the severity of the consequences of a slip or stumble (compare the consequences of tripping on a flat path against those of tumbling off an exposed drop). It is important to acknowledge that the hazards featured in this project were identified *subjectively*, so that different users' hazard assessments may differ considerably. Furthermore, the ambient conditions during which risk assessment takes place may strongly influence results: consider how a thin layer of ice can render a benign (under summer conditions) footpath far more hazardous.

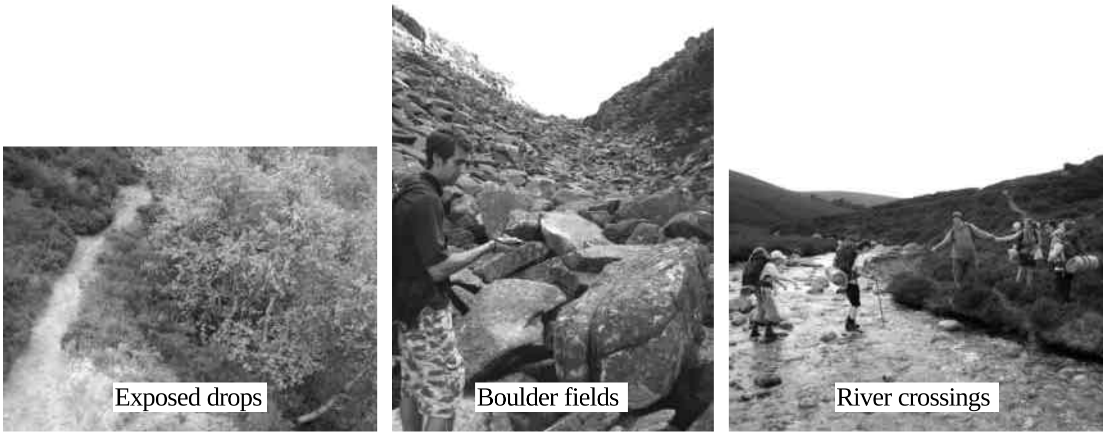

Figure 1. Examples of footpath hazards identified in the Cairngorms during fieldwork.

2.2 Footpath hazard digitisation

Having identified which hazards to record, a formal specification of how to digitally represent them is required. The proposed system, which uses only waypoints from handheld GPS devices, is intended to be as user-friendly as possible, with the ultimate aim that members of the public could contribute to a shared database of footpath hazards. The system comprises two different scenarios, which are presented below:

2.2.1 Short hazards

If the hazard (exposed drop, boulder field or stream crossing) is less than 15 m in length, it should be recorded by a single GPS waypoint, as per figure 2:

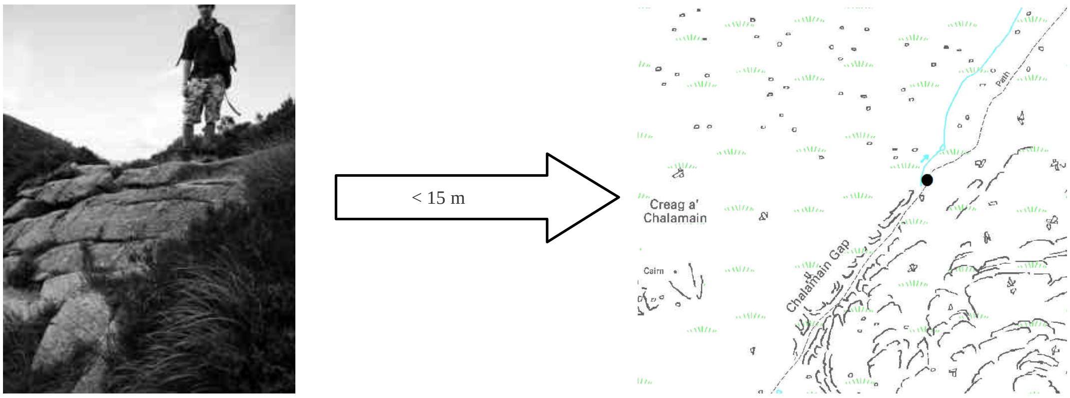

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Figure 2. Procedure for presenting hazards less than 15 m long.

2.2.1 Long hazards

If the hazard exceeds 15 m in length, then GPS waypoints should be recorded along the length of the hazard, taken at 15 m intervals, as per figure 3:

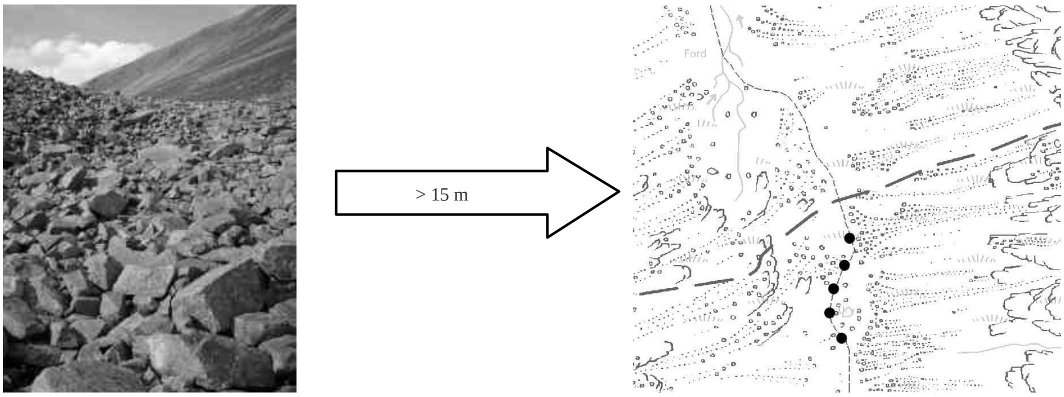

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Figure 3. Procedure for presenting hazards greater than 15 m long.

2.3 Data Collection

Although longer hazards would be more logically represented in a GIS using one-dimensional lines, most handheld GPS units do not allow the storage of line features with start and end nodes. It is much simpler to generate a point dataset comprised of GPS waypoints. This method of data acquisition was trialled in the Cairngorms National Park during a three day camping expedition in July 2006. The surveyed paths, which total 14 km in length, are indicated on figure 4. GPS waypoints were recorded using a Garmin eTrex Summit, and were subsequently converted to a text file of *x* and *y* coordinates using Garmin's MapSource software. The next section describes how the waypoints were visualised.

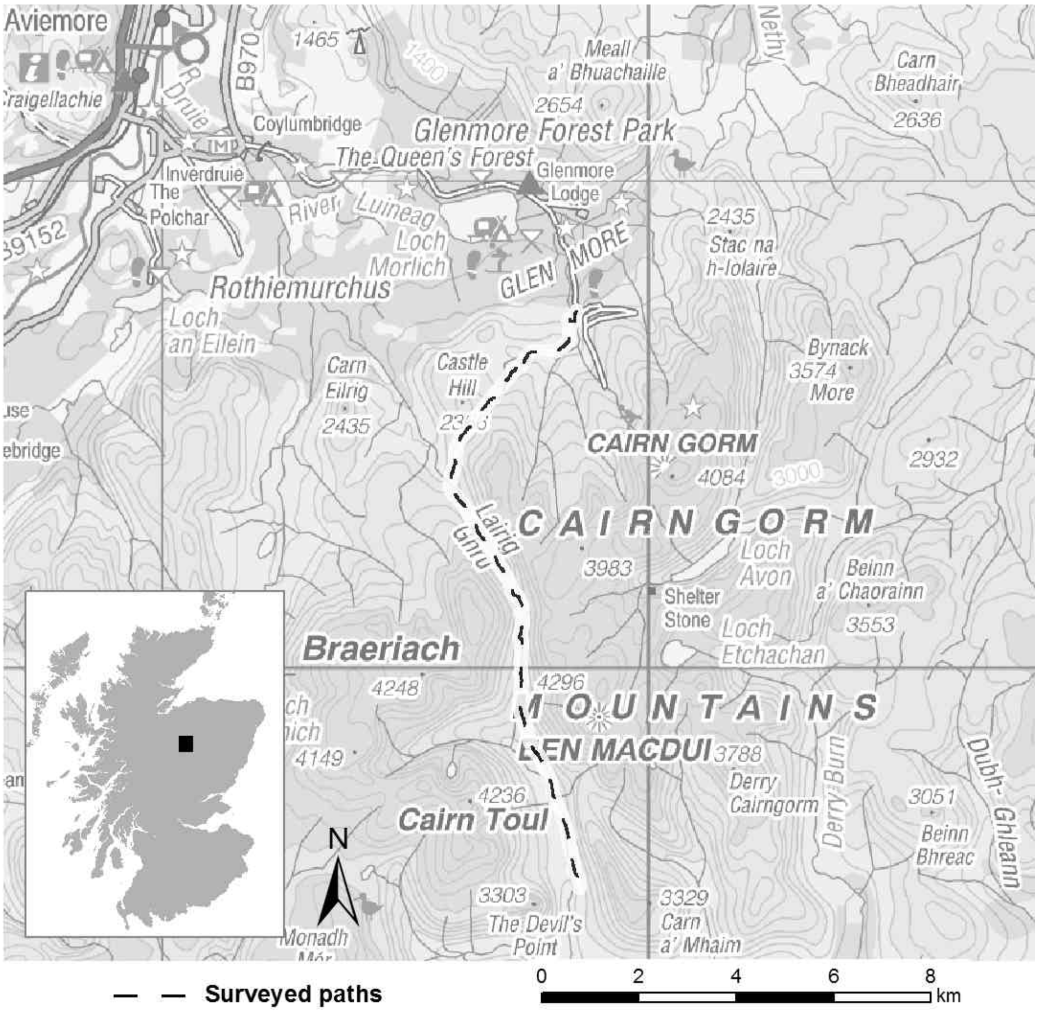

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Figure 4. Study area map, showing location of paths surveyed during fieldwork trial.

3. Data visualisation

Recall that the overall aim of this work is to devise a means by which footpath hazard data can be stored in a GIS in order to better inform walkers. This aim is premised upon developing an effective method of cartographic visualisation that would show, at a glance, the relative distribution of hazards in an area. The ability to visualise hazard data at a range of spatial scales would also be advantageous, since expedition planning requires knowledge of a route's overall hazard distribution (small cartographic scale – 1:100,000) as well as locations of individual hazards (large scale – 1:10,000).

A prototype application, which can produce hazard maps at a range of spatial scales, was developed in ArcGIS using Visual Basic for Applications and ArcObjects. The application employs kernel density estimation (KDE) to create a continuous field to represent the density of GPS hazard waypoints (Silverman, 1986). The search radius of ArcGIS 9.1's quadratic distance-weighted kernel function, known as the kernel bandwidth, can be adjusted. This adjustment is the key to tailoring hazard map content in response to changes in viewing scale: increasing kernel bandwidth leads to smoothly varying output rasters, which are better suited to small viewing scales; decreasing bandwidth produces more localised surface patterns, which are best viewed at a large scale (O'Sullivan and Unwin, 2003).

3.1 Map generation

The three stages of hazard map generation are shown below in figure 5. First, hazard waypoints are downloaded from the GPS unit and snapped to footpath vectors. Second, a kernel density surface is created from the GPS waypoints. Third, the original footpath vectors are intersected with the kernel density surface to create a line whose colour is proportional to the incidence of hazards at each location.

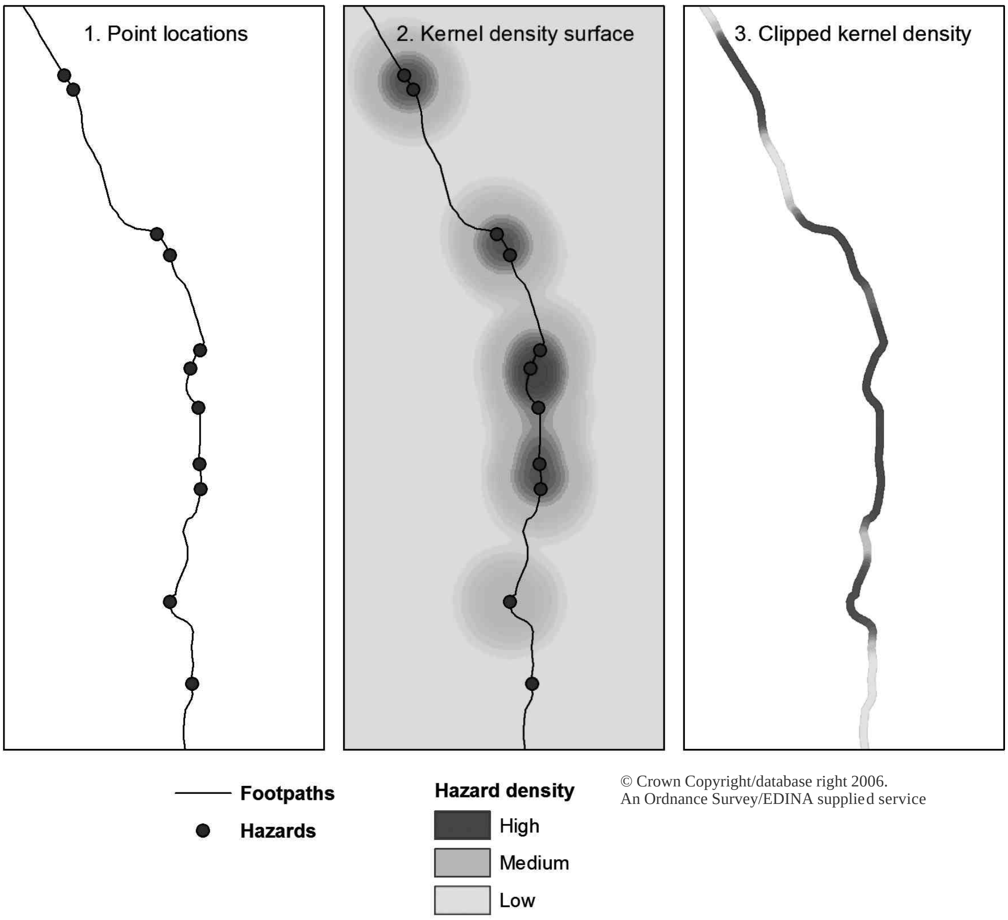

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Figure 5. Three stages of hazard map generation, automated by ArcObjects code.

3.2 Altering cartographic scale

By varying the kernel bandwidth (in inverse proportion to the denominator of the map scale, returned by ArcObject's *MapScale* property of the *IMap* interface) it is possible to produce a visualisation appropriate to the scale at which it is viewed. Changing maps' content on the fly to suit their scale, known as automated generalisation (McMaster and Shea, 1992), has long been pursued by geographers. Indeed, for many it is something of a Holy Grail (João, 1998). To be effective, changes between scales must be smooth and progressive, rather than the "quantum leap" steps that result when moving between different map types (Jones and Ware, 2005:859).

Figure 6 presents two maps at different scales (an extent box shows which portion of map 1 (left) is zoomed in on in map 2 (right)). Map 1, which shows the whole study area, uses a coarse kernel bandwidth (600 m). If the same bandwidth were used on map 2 then results would not show any localised detail. Instead, because the cartographic scale of map 2 is increased, a smaller bandwidth is used (50 m). This shows local variation much more effectively. Altering the kernel bandwidth in response to changes in cartographic scale allows users to drill down from small scale overview to large scale detail, without experiencing problems of pixelation (going from small to large scale) or map cluttering (from large scale to small scale). This is of great potential use to a leader, for example, who might initially examine a footpath from a small scale to get an overview of where hazardous sections are located, before zooming in to locate individual hazards more precisely.

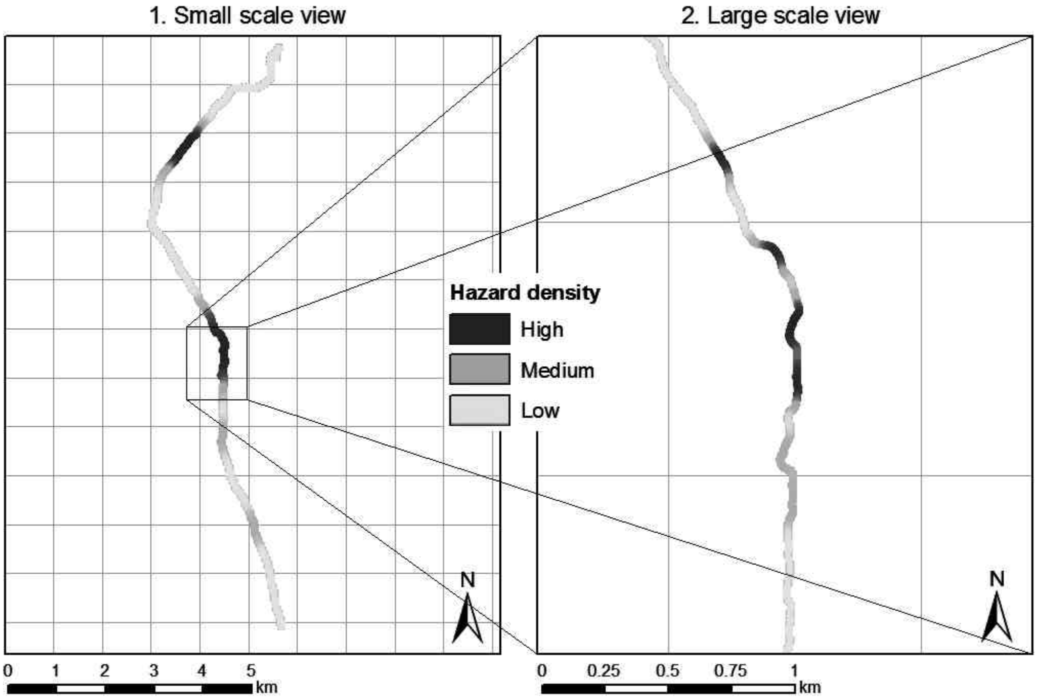

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Figure 6. Adjusting kernel bandwidth in response to changes in viewing scale

4. Conclusions

The work presented here offers a robust solution to visualising the number of footpath hazards along a hillwalking route, at a wide range of cartographic scales. The custom ArcGIS tool can in fact be applied to any scenario where the density of point data along a line feature needs to be viewed at different scales. Examples that spring to mind include visualising frequency of accidents along a road network, monitoring the number of wildlife sightings along a stretch of river, or assessing density of point source pollution along a coastline.

As the tool is designed to process simple text files of GPS waypoints, it is possible, in theory, for members of the public to contribute hazard data: any walker equipped with a GPS device could log the locations of prominent hazards, which could then be shared with other users. Over time, a comprehensive hazard database of a region's entire footpath network could be built up.

Future work will be focused towards developing more objective criteria for hazard reconnaissance in the field, and improving the system's ability to cope with temporal hazard data (e.g. increased risks of falling during icy conditions, or at night). A final research challenge concerns how to integrate the hazard density maps with Anquet Maps and Memory Map.

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Inertial Navigation Sensor and GPS integrated for Mobile mapping

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1. Introduction

Raised Pavement Markers (RPMs, Cats eyes), traffic signs and road markings have retro-reflective properties on the roads. Road paint and traffic signs depreciate periodically, whereas RPMs tend to fail without having a fading period. Malfunctioning RPMs are one of many factors that contribute to road traffic accidents (BERG, 2006). Unfortunately detection and mapping of broken or damaged RPMs is difficult on busy motorways. In collaboration with the National Road Authority of Ireland (NRA), research at the Institute of Technology Blanchardstown has resulted in the development of a mobile and portable mapping system that is capable of the identification of RPMs, traffic signs and road markings. Using stereo computer vision techniques, RPMs can be identified in images and their estimated national grid coordinates can be found. The inter-spatial distances between studs can be used to infer the number of defective or missing studs (MULVHILL, 2005).

Earlier versions of the Mobile Mapping System (MCLOUGHLIN, 2005) had adequately high precision with the identification of RPMs positions from vehicle-mounted cameras. This prototype estimated the vehicle/camera location and trajectory using a GPS sensor. Thus the portable mapping system had shortcomings due to the GPS's two main problems, signal obstruction and low refresh rates (KONOSHI, 2000).

An alternative solution was to incorporate strap-down Inertial Navigation Sensors (INS) to obtain the vehicles attitude and velocity at high refresh rate (DOROBANTU, 1999). INS obtains measurements for the rate of turn using a gyroscope and acceleration using an accelerometer. These measurements need to be integrated over time to obtain orientation changes and velocity measurements. The INS components produce small measurement errors that accumulate over time and cause drift errors. Therefore the sensor is accurate over short time intervals but needs to be combined with other devices to obtain stability over long measurement periods. The INS sensors can also be combined with a magnetometer that uses the magnetic north as a reference to stop orientation errors; this is known as an Inertial Measurement Unit (IMU). To limit the errors when calculating trajectories with the INS or an IMU, they can be combined with a GPS device through a complementary filter (RODGERS, 2003).

Techniques are described in the following paper to incorporate GPS with an IMU sensor. A complementary filter known as the Kalman Filter (KF) provides the possibility to integrate values from the two sources whilst minimizing errors to provide an accurate trajectory of the vehicle. The following GPS and IMU data is post-processed by an Extended KF (EKF). Preliminary tests have shown that the use of GPS aided INS approaches in the Mobile Mapping System can provide high bandwidths for the vehicles kinematics and facilitates the generation of three dimensional topographic maps of the road surface.

2. Data Acquisition System

The data acquisition system is located in a vehicle roof box consisting of two cameras, a Global Positioning System (GPS), an Inertial Measurement Unit (IMU) and an interfacing PC (Figure 1). Three-dimensional information of the roadways is obtained with two vehicle-mounted cameras (CMOS FireWire IEEE1394 PixeLink). The vehicle kinematics are obtained by a Garmin GPS and a XSENS IMU sensor. An interfacing PC synchronises the hardware and stores all the data from the devices. This interfacing PC is controlled across a wireless network with an in-car notebook PC. The acquisition software uses the Microsoft Foundation Classes (MFC) for event driven data capture.

Figure 1: Data acquisition system

The two main parts of the GPS/IMU system are:

- An acquisition system that synchronises all the devices and stores the data for post-processing.
- A navigation processing system that integrates the GPS and INS data to find the coordinates of the mobile mapping vehicle over a surveyed road.

3. Strapdown navigation mechanism

The IMU sensor consists of three orthogonal accelerometers, gyroscopes and magnetometers. It can provide computed attitude data along with calibrated sensor kinematics data. An internal sensor fusion algorithm using an Extended Kalman filter compensates for attitude drift by reference to the magnetic north (magnetometers). The table opposite gives a reference of the performance specifications of the IMU (XSENS, 2006). The data stream from the sensor contains the orientation in quaternion form.

The calibrated data contains the accelerations and rates of turn in the three orthogonal axes. The Kalman filter prototype was generated in MATLAB and it uses GPS distance and velocity to correct the drift errors of the INS.

Orientation performance
Dynamic Range: all angles in 3D
Angular Resolution: 0.05° RMS
Static Accuracy: <0.5°
Accuracy (heading): <1.0°
Dynamic Accuracy: 2° RMS
Update Rate: max 120 Hz

Calibrated data performance
Accelerometer
Full scale: ± 17m/s/s(1.7g)
Noise density (units √Hz) 0.001
Rate gyro
Full scale: 17 ± deg/s
Noise density (units √Hz) 0.1

Table 1: XSENS MTI SENSOR

3.1 Attitude and Navigation Equations

The Earth Centered Earth Fixed (ECEF) coordinates are used as a common reference frame between the GPS and IMU. GPS positions are transformed from its output format (WGS84) to the ECEF frame. To track a position the attitude and distance traveled must be known. The attitude must be projected from the ECEF to the navigation frame and is calculated from two rotations. The first rotation, $C_{body}^{navigation}$ (Equation 1), consists of the IMU sensor data in Quaternion form and the second rotation, $C_{ECEF}^{Navigaiton}$ (Equation 2), uses the current tangent plane coordinates. Combining these direction cosine equations gives C_{Body}^{ECEF} (Equation 3), the rotation matrix for the common frame (TITTERTON, 2004).

$$C_{body}^{navigation} = \begin{pmatrix} \left(a^2+b^2+c^2+d^2\right) & 2(bc-ad) & 2(bd+ac) \\ 2(bc+ad) & \left(a^2-b^2+c^2-d^2\right) & 2(cd+ab) \\ 2(bd-ac) & 2(cd+ab) & \left(a^2-b^2-c^2+d^2\right) \end{pmatrix} \quad (1)$$

where the Quaternion vector is $Q_b^n = \begin{bmatrix} a & b & c & d \end{bmatrix}^T => [q1 \quad q2 \quad q3 \quad q4]^T$

$$C_{ECEF}^{Navigaiton} = \begin{pmatrix} -\sin\phi\cos\lambda & -\sin\phi\sin\lambda & \cos\theta \\ -\sin\lambda & \cos\lambda & 0 \\ -\cos\phi\cos\lambda & -\cos\phi\cos\lambda & -\sin\phi \end{pmatrix}, \quad (2)$$

where ϕ is latitude and λ is longitude

$$C_{body}^{ECEF} = C_{navigation}^{ECEF} C_{body}^{navigation} \qquad (3)$$

The velocity dynamics (Equation 4) use the acceleration forces in the body/sensor frame from the accelerometer, f^i, and take subtracts the centripetal accelerations $\omega_{ie}^i \times V$ and gravitation forces. The Cosine matrix $\left(C_{body}^{ECEF}\right)^{-1}$ is used in the projection of the gravity vector to the body frame. The following velocity equation does not take into account Coriolis accelerations, as the effects of the earth's rotations are small over small distances and short times intervals.

$$\dot{v} = f^i - \omega_{ie}^i \times V + C_{ECEF}^{body}.g\ , \qquad (4)$$

Where,

V= Previous velocity vector

$\omega_{ie}^{i\ T}$ = Angular velocities in the gyroscopes

g = Gravity vector

$f^i =$ Accelerations in the accelerometers

C_{ECEF}^{body} = Cosine matrix, ECEF frame to body frame

The velocity dynamics are in the body frame after applying Equation 4.This velocity must be transformed to the ECEF navigation frame (Equation 5) and then integrated over time (Equation 6) to find the position vector R.

$$V^{ECEF} = C_{body}^{ECEF}.\dot{V}^{body} \qquad (5)$$

$$R(t) = \int_0^t V.dt + R(0) \qquad (6)$$

3.2 Kalman Filter

The EKF was used for the correction of the position and velocity dynamics of the INS sensor with GPS data. Further reading on Kalman filtering can be found in (WELCH, 2004). The general filter is used to generate the best-estimated state for a system when given a measurement vector and state vector that can justify Equation 7.

$$\begin{aligned} X(k+1) &= A(k)X(k) + w(k) \\ Y(k) &= CX(k) + v(k) \end{aligned} \qquad (7)$$

Where X is the state matrix, Y is the measurement matrix, A is state transfer matrix and C is observation matrix with noise v and w at time k.

The state vector (Equation 8) consists of the positions XYZ in the ECEF frame, velocity NED in ECEF frame, attitude in quaternions and gravity in the Z plane. As the navigation formulas are nonlinear, a linearized error form is desired for the Kalman filter algorithm. Using a Taylor series expansion we can make an approximation of the state transition matrix A (RODGERS, 2003).

$$\begin{aligned} X(k) &= \begin{bmatrix} P_X & P_Y & P_Z & V_N & V_E & V_D & Q_a & Q_b & Q_c & Q_d & g \end{bmatrix}^T \\ Y(k) &= \begin{bmatrix} P_X & P_Y & P_Z & V_N & V_E & V_D \end{bmatrix}^T \end{aligned} \qquad (8)$$

The EKF uses a five-step iteration process (Figure 2). The measurement update and correction is carried out only when the GPS has a correct and valid signal i.e. it has lock on 4 or more satellites.

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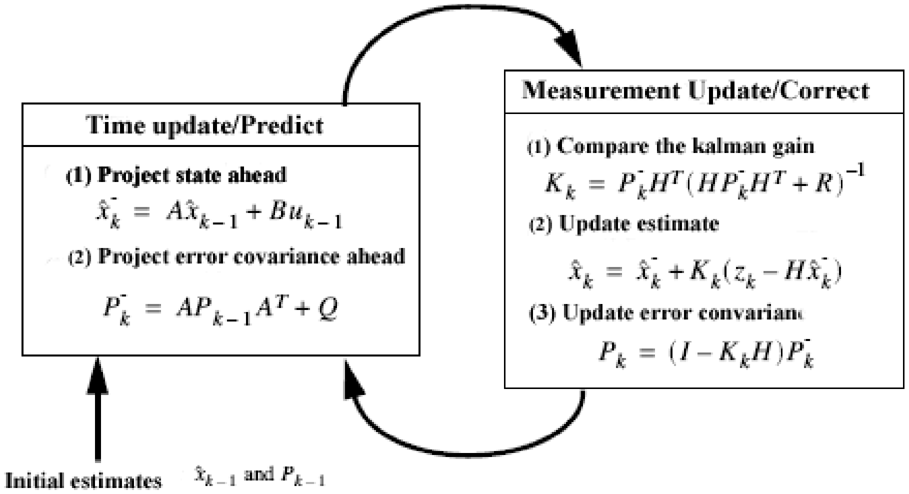

Figure 2: KF block diagram

4. Experimental Results and Conclusion

The experimental test run consisted of a two-kilometre road an urban environment that had numerous roadside trees, surrounding high walls and a roundabout. The GPS lost its position lock regularly. The IMU sensor bandwidth was 100Hz and GPS rate was at 1Hz. The attitude or orientation (Figure 3) had very little noise as it had been directly calibrated from the sensors internal algorithm. The position data (Figure 4) is an observation of the INS positions being aided by the GPS. The GPS position and velocity were only used when it had lock onto four or more satellites. Figure 5 gives a graphical presentation of the results after GPS and IMU have been combined on the road section. Figure 6 shows the more detailed section of the road, where the IMU trajectory is corrected. This type of system can be used at normal road speeds and gives accurate measurements of the road surface to identify safety failures. An ongoing evaluation of the system is taking place on different routes and road conditions. Future work will see the combining of this navigation system with the in-house automated RPMs and road sign vision systems.

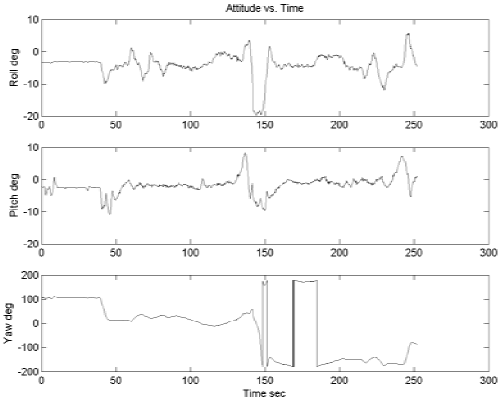

Figure 3: Attitude of the test run

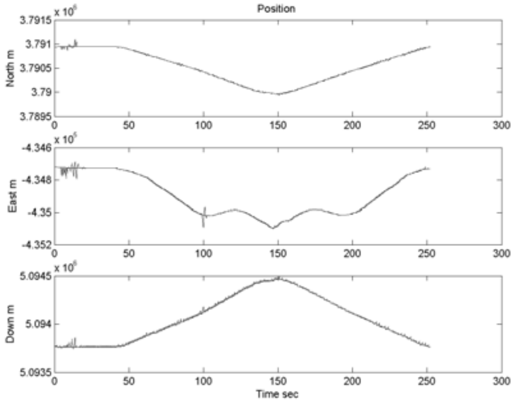

Figure 4: Position filtering

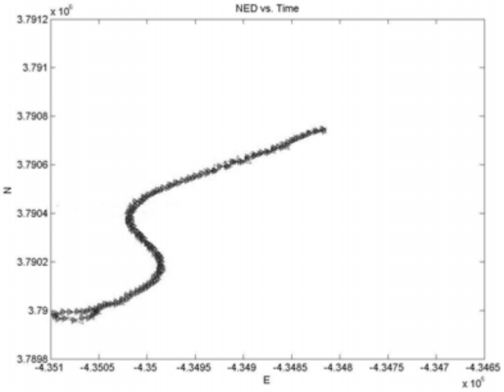

Figure 5: GPS/IMU trajectory path on the test run

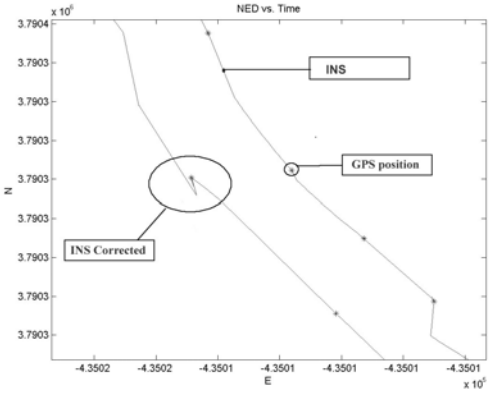

Figure 6: Detailed view of the test run

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Biography

The principle author completed his undergraduate at NUI Maynooth in Computer Science and Software Engineering. His undergraduate research was in the area of spatial mapping of celestial bodies for VTIE (Virtual Telescopes in Education). He is currently doing a research Master in Engineering at ITB in the integration of Inertial Navigation System with a Computer Vision System.

A Model for the Representation of Evolving Road Features

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1 Introduction

The [1]Ordnance Survey MasterMap Integrated Transport Network (ITN) layer provides a topologically structured representation of the UK's driveable roads. This representation is continually updated, and as such can be regarded as composed of evolving road features. Road features in ITN data are composed of links and nodes, and changes to these components represent a change in the Road feature. These changes, however, are not adequately represented in the data, meaning that only the current state of the road network is recorded, and that past versions are inaccessible. It would be a significant benefit to a system utilising ITN data to be able to store and retrieve past versions of the road network, for example in accident analysis, or to project future or alternative representations to facilitate traffic management. To enable the development of such a system, a mechanism for the versioning of spatial objects is necessary, along with an understanding of methods of spatial data modelling that include a time dimension, known as spatiotemporal data modelling. Methods of object versioning have been developed most notably in Computer Aided Design (CAD), where compound design objects are constructed from versioned component objects. This translates well to ITN data where compound Road feature objects are constructed from component link and node objects, meaning that

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[1] This project is supported by EPSRC and Ordnance Survey

techniques for versioning design objects should be applicable to Road feature objects.

This research aims to develop and implement a system that can represent evolving road features through the techniques of spatiotemporal data modelling and object versioning. So far these areas have been investigated and applied to devise the Static Feature Histories model, and future work will implement the data model and develop an efficient query model using JDBC strongly typed interfaces to allow the manipulation of versioned road features.

(This research is sponsored by Ordnance Survey, and as such is constrained to use ITN data and Oracle Spatial).

2 Previous approaches to versioning and evolving features

2.1 Object versioning mechanisms

The most common versioning model is that of the representation of a component as a generic object, with all revisions of this object being its derivations. The generic object also stores references to all its versions, and references to specific versions are then resolved at run-time by a process called Dynamic Reference Resolution (DRR). If the most recent version is copied or modified to create a new version, then a linear Version Derivation Graph results (VDG). If any other version is modified, a branched VDG results. Miles et al. (2000) present a versioning approach called Describe, which employs this model. VDGs can also be used for composite objects, but this can be problematical. Instead an ordered list can be employed to record the histories of composite object versions [Goonetillake (2004)].

2.2 Previous implementations

There have been several previous attempts to represent evolving features. Spatiotemporal GIS implemented for ArcInfo [Candy (1995); Raza et al. (1996)] record historical data, and systems to represent changes to historical boundaries [Ott and Swiaczny (1998); Winnige (2000); Gregory (2002)] have been developed using an underlying relational data model. The Tripod system [Griffiths et al. (2001)] is built on an object-oriented (OO) data model, represents spatial data using abstract data types (ADTs), and implements object behaviour in C++. However, Tripod's underlying database system was bespoke, meaning that it would be problematical to apply it to another system, and its development did not continue. Nevertheless, the OO model has been shown to be much more successful in representing complex objects that represent more real world entities, and spatial objects fall into this category.

3 Structure and limitations of ITN data

The basic unit of the Road feature is the Roadlink. Roadlinks are comprised of a polyline geometry with a Roadnode object at each end. A Road feature is an aggregate of Roadlink objects. The Road feature does not contain the road's geometry, only a reference to its constituent Roadlink objects. Roadlinks, Roadnodes, and Roads all have the attribute 'change history', which is a collection data type. Each element of this collection has a date and description, which is either 'new' or 'modified'. No other information on the changes are recorded.

Although the ITN data contains spatial objects, it remains essentially relational in nature, meaning that aggregation of Roadlinks is represented by relational joins, and Roadnode objects relating to Roadlink objects are similarly referenced in another join table. The version information provided means that the frequency of change can be seen, but previous versions of features cannot be retrieved from the data.

4 Methodolgy

4.1 The benefits of the object-relational model

Oracle Spatial provides important benefits when devising a spatiotemporal model. Firstly, Oracle Spatial is object-relational (O-R), and as such supports Abstract Data Types (ADTs). Spatial ADTs can have spatial and aspatial data associated with them, and as such allow geographic features, in this case roads, to be abstracted independently [Rigaux et al. (2002), Voisard and David (2002)]. ADTs also offer the ability to extend spatial objects in the form of User Defined Types (UDTs) to include version information and time-dependent attributes, which are important in the representation of evolving features. Further, Oracle's data types include collections, meaning that attribute histories can be recorded by combining a time element with a data value or object. The O-R model also means that aggregation and other associations can be modelled using pointers (REFs) instead of the more costly (in performance terms) relational joins.

4.2 The Static Feature Histories model

Although most versioning models employ generic types and dynamic referencing, this is not ideal for ITN data. The generic types mean that there are levels of indirection in the model, introducing additional complexity when it comes to specifying a feature. If we examine the accepted benefits of dynamic referencing in the CAD environment, and view them as they apply to ITN data, then these benefits are questionable. The two main benefits are the elimination of version percolation, and the facility to freely combine components to create new configurations [Goonetillake (2004)]. Version percollation applies when many configurations exist that contain particular components, meaning that a change to the components has a cascading effect on updates in the configuration version hierarchy. In a system where updates are relatively infrequent and the number of configurations is restricted, as is the case for ITN data, then this is not an issue. Further, the restriction on configurations means that we do not need the facility to freely combine components. Therefore, a model based on generic types has no particular advantages and one major disadvantage - layers of indirection.

For this reason, we have devised the Static Feature Histories model. This model distinguishes between the invariant attributes of the objects, their version attributes, and their spatial attributes. Invariant attributes are contained in the generic object [Ahmed and Navathe (1991)], while specific version information is stored in a version descriptor [Chou and Kim (1988)]. A road version is thus comprised of static references to a generic object, a version descriptor, and to its component link versions. Figure 1 shows the structure of the static references for road, link, and node objects. Previous versions of a feature are recorded in a histories object, which contains the version information for all versions of the feature (number of versions, next version number, default version) and a history attribute, which is a collection of version descriptors.

The benefits of the model are:

- no indirection in resolving specific versions
- efficient retrieval of a spatial feature for a given time or time interval
- invariant attributes are not copied when a new version is derived

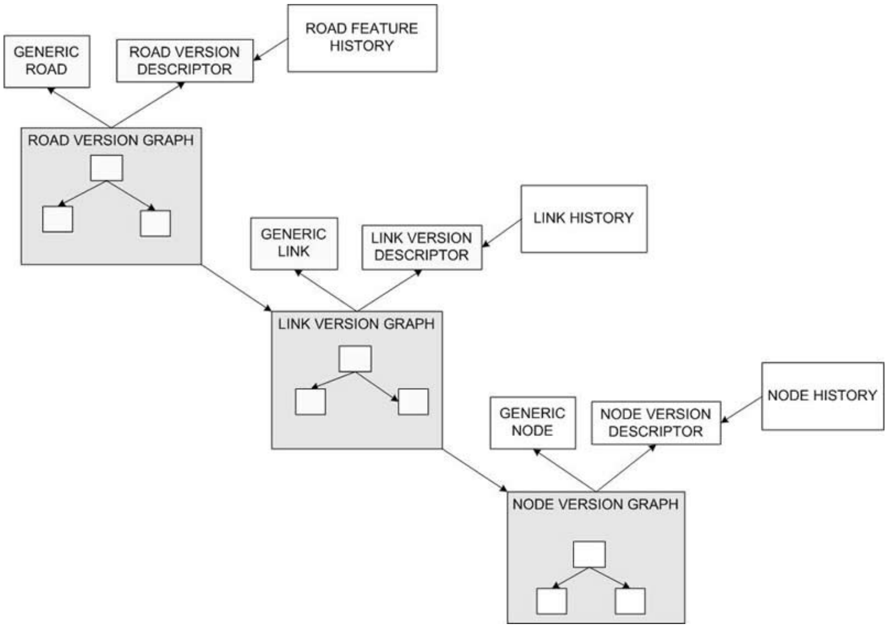

Figure 1: Static feature histories

One disadvantage is that the model relies on storing all versions exhaustively. However, storage hardware is now capacious and inexpensive, the degree of versioning required is relatively low, and ITN data is lightweight (in storage terms), and therefore this is not considered to be a significant drawback.

5 Conclusions and future work

Feature evolution involves the asynchronous evolution of numerous spatial objects and their attributes, and therefore to effectively represent feature evolution we must version-enable both spatial objects, their attributes, and features, unifying all within a temporal context. Currently, ITN data cannot provide adequate representation of evolving road features, and Oracle Spatial provides an object-relational framework within which to design and implement a spatiotemporal data model to version-enable ITN data. Future work will implement the Static Feature Histories model and develop a query model to manipulate versioned road features.

Biography

The author is currently a second year PhD student at the University of Glamorgan, under the supervision of Dr Nathan Thomas, Dr Tom Carnduff, and Dr Mark Ware. PhD topic: The Management and Representation of Evolving Features in Geospatial Databases.

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Implementing ISO-compliant Feature Metadata

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1. Introduction

The role metadata have played in the management of geospatial datasets has been widely documented (Göbel and Lutze, 1998; Kim, 1999; Tsou, 2002; Limbach *et al.*, 2004). Often employed by institutions to organise, maintain and document their geographic resources internally, metadata can also provide a vehicle for exposing marketable data assets externally when contributed to geospatial exchange initiatives such as the UK's public sector metadata service *gigateway* and its academic equivalent *Go-Geo!* Regardless of application, geospatial metadata provide information which support decisions involving the resources they describe, whether for the data custodian, data user or potential procurer.

The evolution of geographic data storage and access strategies have meanwhile resulted in the introduction of solutions advancing beyond the traditional monolithic, single-user dataset paradigm to multi-user enterprise or corporate GIS solutions that support access and extraction of information at sub-dataset levels. These advances have more recently been mirrored by the development of feature-driven web visualisation techniques such as OGC-compliant Web Feature Services (WFS) in a fundamental departure from the pioneering raster image approaches.

Consequent to these developments, not only have multiple (and often simultaneous) routes of access to individual data resources been opened, but the ability to disseminate and exchange resource subsets has been enabled. Nevertheless, with no guarantee that dataset metadata (when extant) will either accompany these subsets, or indeed be adequate to accurately depict their key statistics, doubts can arise as to the appropriateness of the constituent features. It could therefore be argued that many affected applications would benefit from even a minimal indication of quality, embedded at the feature level.

2. ISO Standards and Feature Metadata

An integral part of any metadata approach should be the adoption of a well-defined convention. The ISO 19115:2005 Geographic Information – Metadata standard details a content schema for the documentation of geospatial data. While some provision has been made for the generation of metadata at varying degrees of resolution, its focus arguably lies with the depiction of data at the dataset, and to a lesser degree, dataset series level. Metadata at the sub-dataset level are presented within a metadata hierarchy (Figure 1); but suggested implementations only include definitions at these levels when exceptions occur. Further, as metadata conforming to ISO 19115 are held discrete from the resources they describe by convention, this treatment for metadata on its own is insufficient when considering some of the aforementioned issues.

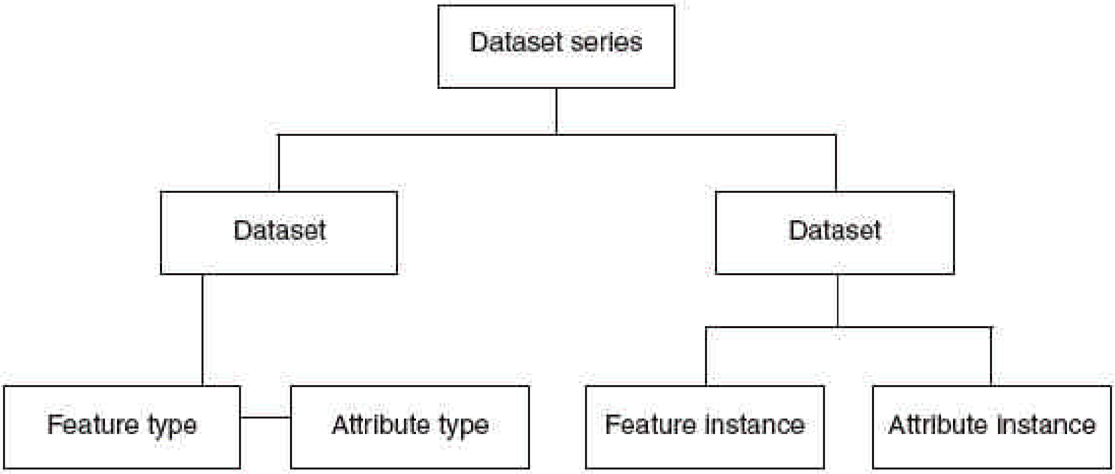

Figure 1. ISO 19115 Metadata Hierarchy

The ISO 19109:2005 Geographic Information – Rules for Application Schema standard meanwhile allows for the definition of conceptual data models which define the logical structure of an application’s data. Geographic feature types are classified based on a structure defined by the General Feature Model (GFM); feature type definitions (detailing feature attributes, operations and association roles) may be elaborated in feature catalogues.

Of particular interest is its specific treatment for feature attributes as well as the general ability to integrate within any ISO 10109 application schema other ISO standard schemas. Here, any feature attribute (GF_AttributeType) can have atomic metadata items associated with it by sub-classing entities beneath the GF_QualityAttributeType specialisation of the GF_MetadataAttributeType entity (Figure 2). Attribute types accordingly defined (specifically, to carry metadata information such as quality and currentness) obtain their value type definitions and value domains from the ISO 19115 MD_Metadata entity. It should be noted however that temporal attributes used as metadata items (described below) are arrived at in this manner, and not through the GF_TemporalAttributeType entity included in Figure 2, which is employed for conventional temporal attribute definition.

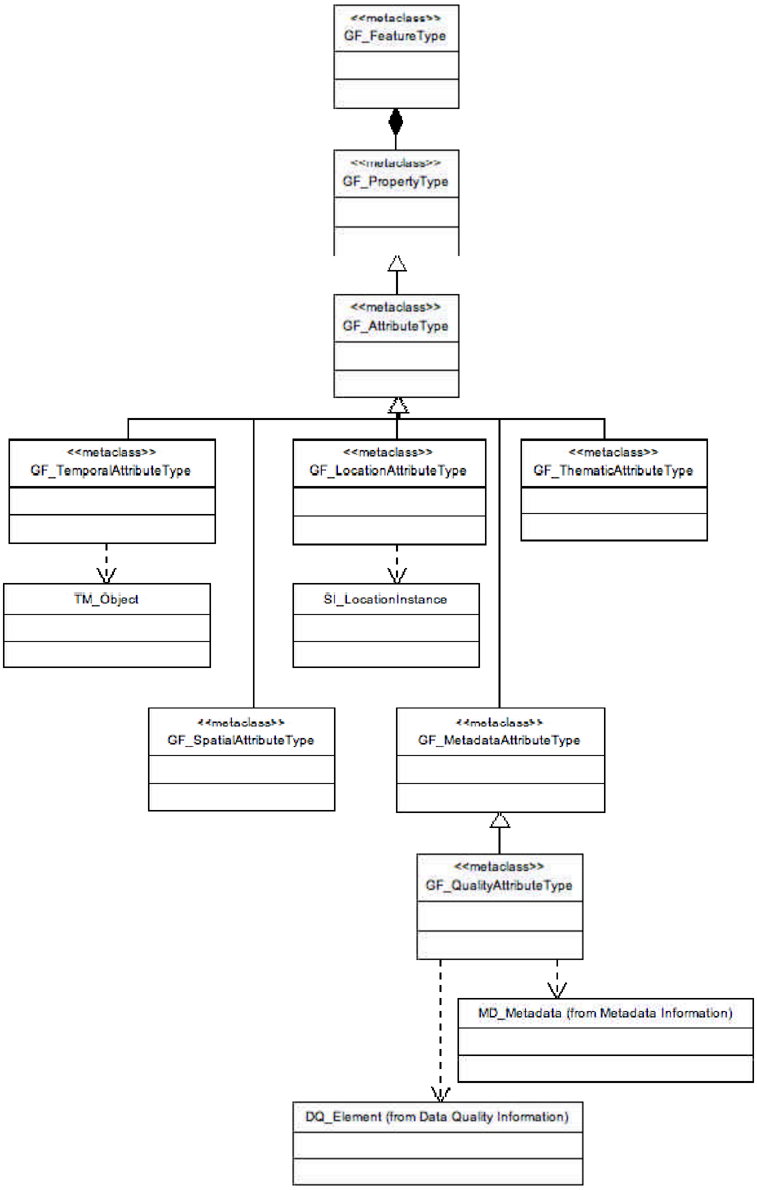

Figure 2. Attributes of feature types (adapted from ISO 19109)

3. Feature Metadata Implementation

To illustrate how this conceptual model translates into a practical ISO-compliant treatment for embedded feature-level metadata, an existing published standard was identified and transformed. Providing a sparse approach for feature depiction, the USDA Forest Service's feature metadata standard (summarised in Table 1) was therefore deemed appropriate.

Attribute	Data Type	Description
REV_DATE	Date	Date of feature creation or revision
DATA_SOURCE	Character (2)	Source of feature
ACCURACY	Number (6,2)	Feature accuracy measured in dataset units of measure

Table 1. Attributes of feature types used in the USDA Forest Service feature metadata standard[1]

3.1 REV_DATE

Denoting the date instance of feature creation or update, the ISO equivalent of REV_DATE may be arrived at through traversing the schema illustrated in Figure 3 (as are DATA_SOURCE and ACCURACY below). Two candidate entities are presented: DQ_DataQuality>LI_Lineage and MD_Identification>MD_DataIdentification. The latter is defined as containing information relevant for data identification and so may be dismissed; the former is chosen as it is formally defined as supporting information regarding the "events or source data used in constructing the data" (ISO 19115, clause B.2.4.2.1).

Due to the ambiguity of the REV_DATE definition (creation OR revision), a decision must be made between which specialised LI_Lineage entity to adopt: LI_Source depicts data creation information, LI_ProcessStep the data transformation and maintenance details. LI_ProcessStep is consequently selected due to probability of data being revised, as indicated by the source standard's attribute name. The entity's *dateTime* property is thus identified as the ISO equivalent, a field which may more appropriately be implemented using its short (more specific) name *stepDateTm.*

3.2 DATA_SOURCE

LI_ProcessStep entity is also used to define the DATA_SOURCE field; its *description* property (short name *stepDesc*) is chosen as it specifically provides for a narrative of the data creation process. And as this is constrained by a non-prescriptive free text domain, incorporation of existing dictionaries are permitted (such as that defined within the example USDA standard).

3.3 ACCURACY

Assessments of a data object's quality are documented in ISO 19115 via the subclasses of the DQ_Element entity. The positional accuracy field as defined in the USDA standard is consequently represented by the DQ_AbsoluteExternalPositionalAccuracy specialisation of DQ_DataQuality>DQ_Element.

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[1] http://www.fs.fed.us/gac/metadata/feature_level.html

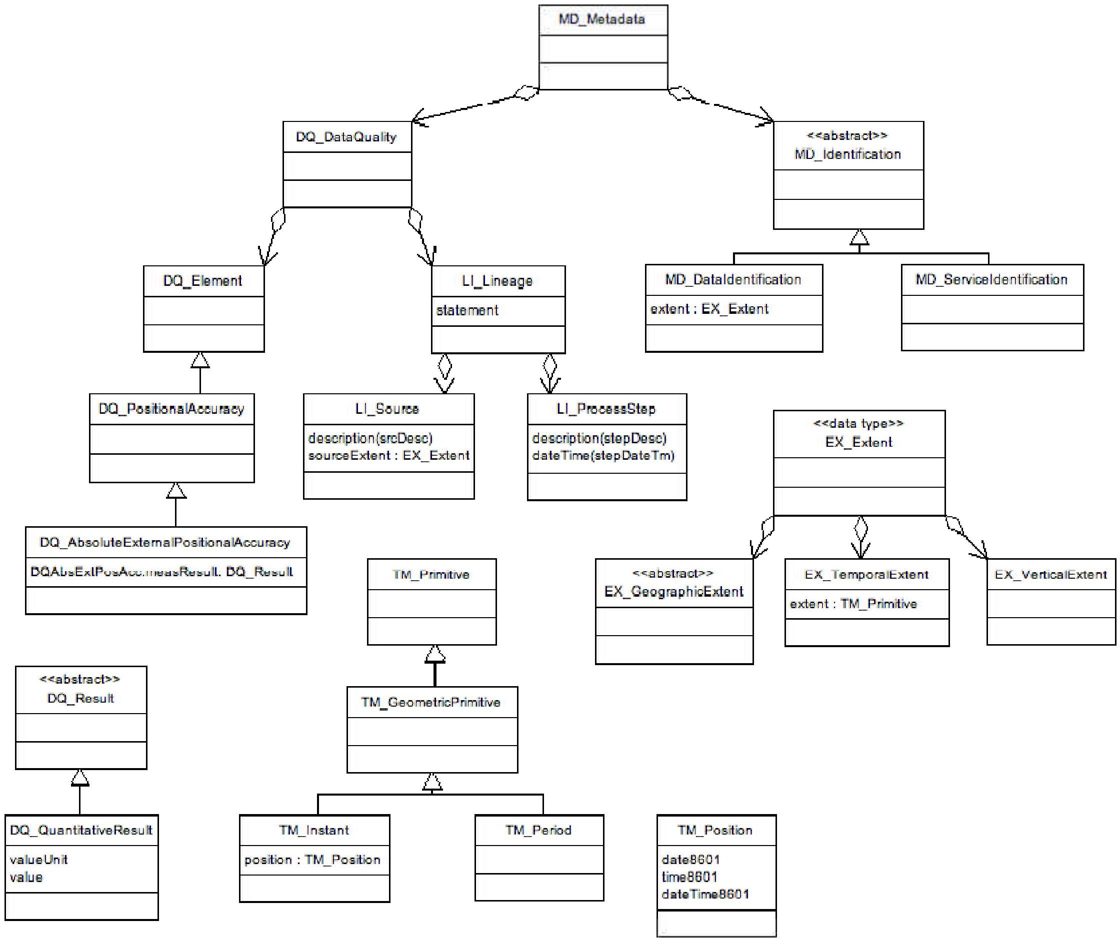

Figure 3. ISO 19115 metadata objects used in the definition of feature metadata

3.4 Character Encoding

While strict ISO compliance requires that the character encoding for each feature type be respected (and are consequently included herein), decisions as to whether this degree of adherence is desirable will depend upon the application. Disambiguation may be necessary where feature provenance is unclear (such as in some web applications) whereas a less stringent encoding may suffice for quality tracking at , for example, organisational level.

Attribute	Data Type	Character encoding
stepDateTm	DateTime	dateTime (ISO 8601)
stepDesc	Character String	Free text
DQAbsExtPosAcc	Number	Record (ISO 19103)

Table 2. ISO equivalents of USDA feature types

4. FLM Applications

The objective of the current paper was to illustrate an approach for implementing ISO-compliant feature metadata; while proposing no conclusions *per se*, it is contended that the prospective uses for metadata at the feature level are various. Current implementations further illustrate the merits of metadata at this resolution, as observed in the Ordnance Survey's Change Only Updates service. Other applications which have leveraged embedded metadata include those focussed on quality control and the representation of data 'fuzziness' (Kennedy, 2000), feature-time series analyses (Goodall *et al*, 2004) and (attribute) data mining (Merrett, 2002).

The following meanwhile outlines some preliminary musings on potential areas of investigation surrounding future implementations. Topics for consideration within each include the degree of schema detail, the encoding mechanism (whether embedded or associated), the method for querying and retrieval, proprietary versus open source implementations, among others.

4.1 Metadata generation

Whether yielding elements via type definitions, or allowing for more accurate assessments of data update events, feature level metadata can play a potential role in automated processes aimed at automatically documenting geospatial assets at higher degrees of resolution. While potential contribution may well prove modest, coupling feature metadata analysis with other metadata authoring processes will have a cumulative impact.

4.2 Asset management and visualisation

Real-time visualisation of data resources for activities such as quality control, workflow allocation and productivity surveillance is often tied to proprietary systems requiring specific clients and data formats. Coupling feature metadata with open source web service technologies provide the potential for overcoming restrictive approaches and enable local and remote connectivity.

4.3 Feature semantics

Unlocking the semantics inherent in features and their metadata may provide for a different approach in verifying data validity. Such an approach could involve associating feature types with an ontology encoded with rules, such as defining the geographic occurrence of certain objects, or the permitted surveying techniques for a given category of feature. Processed using computerised reasoning approaches, inconsistencies can thus be identified and addressed.

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Biography

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Approaches for providing user relevant metadata and data quality assessments

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1. Data discordance

Spatial data, especially natural resource inventories, vary for a variety of reasons that are not to do with differences in the feature being measured. Often these differences in data well known amongst geographers: the real world is infinitely complex and all representations (such as are contained in a map) involve the processes of abstraction, aggregation, simplification etc. In the creation of any spatial data there are series of choices about what to map and how to map it. These choices over representation will depend on:

- The commissioning context specifically legislation and policy (often related to who “paid” for it?);
- Observer variation such as the classic geography field trip (what do you see?);
- Institutional variation in classes and definitions (why do you see it?);
- Representational variation over map scale, minimum unit, (how do you record it?).

A second set of factors that contribute to data discord and variation originate in the demand for ‘better’ science. New technologies, improved techniques and changes in the understanding of the phenomenon offer greater insight into the process under investigation. Such changes in representation and understanding have a profound effect on the end data product and the meaning of the data in its widest sense. They change the data collection context in terms of data ontologies (specifications), data epistemologies (measurement) and data semantics (conceptualisations).

2. Metadata

Prior to its inclusion under the wider umbrella of information sciences, the GI community developed metadata standards for reporting data quality. Metadata for spatial data focussed on the need to document information about data for data quality assessments. The FGDC Content Standards for Digital Geospatial Metadata places an emphasis on using metadata elements in a discovery and query environment to provide “fitness for use” information to prospective users of digital geospatial data. In these standards metadata typically describes data quality in terms of the Positional Accuracy, Attribute Accuracy, Logical Consistency, Completeness, and Lineage. Consequently standards for data quality and metadata reporting have been based on these measures.

More recently the GIS community and spatial data standards have been included within the wider informatics and computing science community. There are a number of organisations concerned with the specification of metadata standards for describing the components and character of spatial data which are converging to differing degrees (e.g. OGC, Dublin Core and ISO). Despite the stated objectives of enabling users to understand data, typically these standards comprise a number of elements that principally specify how to document information relating to the cataloguing, finding and retrieval of data. Metadata standards are useful because they provide a common language, enabling parties to exchange data without misunderstandings. However their specification (content) is always a compromise and consequently they do not represent the depth of knowledge held within scientific community. They are:

- Focussed on aspects relating to data production and data mediation rather than the use of the data;
  Passive, rather than active descriptions relating to potential applications;
- Recording the easily measurable aspects of data rather than the most pertinent aspects of the data;
- Providing overall or global measures of data quality, not ones that relate to individual map objects;
- They are difficult for users to interpret in relation to a specific application

The data quality parameters reported in metadata do not communicate the producer’s wider knowledge of the data and relate to use, rather they reflect data production interests, reporting the easily measurable and showing that the data producer can follow a recipe (Comber et al., 2005).

We propose that the focus of metadata be towards the user. As an alternative definition to metadata being “data about data”, a user-focussed definition of metadata is:

> *Information that helps the user assess the usefulness of a dataset relative to their problem.*

Any measure of dataset quality can only be relative to its intended use. However it is impossible to predict every possible future use.

3. Recommendations for User-focussed Metadata

1. Socio-political context of data creation: actors and their influence

By examining the negotiation and discussion within the project documentation it is possible to identify the major actors and the nature of the influence they exert over the project. Comber et al. (2003) applied this approach to provide insights and to reveal fundamental differences between different land cover mappings in the UK in terms of the different socio-political context of the data creation.

2. Critiques of the data: academic papers

Academic papers could either be in the form of a critique of the data or describe their application to a specific problem. They would provide an independent opinion of the quality and fitness for use.

3. Data producers opinions: class separability

The opinions of the data producers on how separable classes are allow informed assessments of data quality to be made. Comber et al (2004a, 2004b) and Fritz and See (2005; See and Fritz, 2006) have applied such descriptions of class separability as weights for assessing data quality for assessing internal data inconsistency.

4. Expert opinions: relations to other datasets

Experts, familiar with the data, through experience of applying it in their analysis, can provide measures of how well the concepts or classes in one dataset relate to those of another. Comber et al. (2004a, 2004b) applied this approach to determine whether differences between different datasets were due to data inconsistencies (i.e. different specifications) or due to actual changes in the features being recorded. Expert opinions of how datasets relate have also been used to identify relative data inconsistencies for global land cover data (Fritz and See, 2005; See and Fritz, 2006) and for international soil classifications (Zhu et al., 2001).

5. Experiential metadata

Users could provide feedback about their experience of using the data. This could be from an application or disciplinary perspective in order to describe positive and negative experiences in using the data. Possible solutions are a metadata wiki and a system for use case logging where the data use was monitored via a web portal. User experience would provide independent opinions of data quality and fitness, would allow different user communities to be differentiated and provide a framework within which new potential data users could learn form the experience of others.

6. Free text descriptions from producers

The existing and emerging metadata standards include elements for free text slots – “Descriptions” in the Dublin Core and “Generic” and “Extra” in the NERC DataGrid specifications. Currently these are not extensively used. Wadsworth et al (2005, 2006, in submission) have concluded that free-form *descriptions* of classes longer than about 100 words provides sufficient information to be processed and used by someone unfamiliar with the epistemology, ontology and semantics of the data.

7. Tools for mining free text metadata slots

In order to identify suitable data, of a phenomenon that may not be familiar to the user, tools are needed to assist them make sensible and appropriate selections over their data choices. If free text slots are populated then novel approaches to metadata mining and analysis are needed. Wadsworth et al. (2005, 2006, submitted) and Comber et al. (submitted) have shown how simple text mining analyses can be used to generate measures of semantic and conceptual overlap between different datasets and different classes. The inclusion of free text descriptions of the data, coupled with text mining tools would allow users to identify consistencies and inconsistencies between the user and the data concepts.

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Biography

Lex Comber gained his PhD from the Macaulay Institute and the University of Aberdeen in 2001. Up to 2003 he worked as an RA on the EU REVIGIS project developing methods for integrating semantically discordant data. After a year in GIS consultancy with ADAS, Lex took up a lectureship at the University of Leicester where he now directs the MSc in GIS.

Relating Land Use to the Landscape Character: Toward an Ontological Inference Tool

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1. Introduction and Context

The latest buzzing notion in geographic information science draws from cognitive science, an offspring from psychology, philosophy, linguistics, computer science, neuroscience and anthropology dating back to the 1950s (Miller, 2003). The notion relates to the spatial characteristics of an environment which determine a human's conceptualisation of that environment. In that context it sounds reasonable to posit that the understanding of space is anchored in the experience of people's perception of space, and spatial cognition and behaviour. However, there is a gap between the widely deployed models of space and what research in cognitive science and related fields identified as being important for human interaction with and conceptualisation of space (Mark *et al.*, 1999). This gap still needs to be bridged in order to establish realistic representations of space that correspond with human conceptualisations allowing more efficient spatial information processing (Mennis *et al.*, 2000).

In the present work this bridge will be formed by relating human spatial perception of land use to the landscape characteristics in order to build an ontology that is capable of representing the acquired knowledge and to allow inference of land use information from Ordnance Survey's MasterMap topographic database. The relevant material is to be provided by a survey aiming to derive consistent cognitive information from human experience of geographical space.

2. Interviewing for Ontology Engineering

Knowledge can be modelled by an ontology, which explicitly states how relevant concepts and their constituting objects relate to each other and manifest themselves in their physical existency both in reality and that of their representing geography. After all, it is the physical environment that provides the most basic examples of geographical phenomena with which we all are familiar. As stated by Lowenthal (1961, pp. 241-242) "*geography observes and analyzes aspects of the milieu on the scale and in the categories that they are usually apprehended in everyday life*", and "*like geography, however, the wider universe of discourse centers on knowledge and ideas about man and milieu; anyone who inspects the world around him is in some measure a geographer*". Accordingly, the universe of geographical discourse is shared by billions of amateurs all over the globe, allowing us to take a much broader approach instead of founding the ontology on a single domain expert. Moreover, a study of ways non-experts conceptualise a given domain of reality might help efforts to maximise future usability of the ontology, let alone through its empirical testing (Smith and Mark, 2001).

3. A Spatial Knowledge Questionnaire to investigate the 'Map in the Head'

The 'map in the head' is a metaphorical description of how people process and recall spatial knowledge according to conglomerations of information drawn from different sources and modalities pulled together for a particular purpose (Mark *et al.*, 1999). Indeed, a picture is worth a thousand words (Pinker, 1997) enabling cognitive economy (Rosch, 1978), but as a visual object it may or may not convey univocal meaning (Peuquet, 1988). Nevertheless, knowledge can be captured and translated into a machine readable knowledge base if one can account for the ways in which people represent and combine geographical information, categorise common properties for the instances of a land use concept and its spatial structure, and reason to derive new knowledge. These ways can be described by the 'map in the head' metaphor, which, being inspected by the 'mind's eye', is functionally identical to a graphical map inspected by a 'physical eye' (Kuipers, 1982). This implies a direct relationship between the map's depicted reality and that of a map reader, as illustrated in figure 1 derived from Kolácný's (1969) communication model about cognitive aspects of cartography. Both the map and the person inspecting the map carry a representation of reality determined by a variety of factors, which will be mapped onto an ontology.

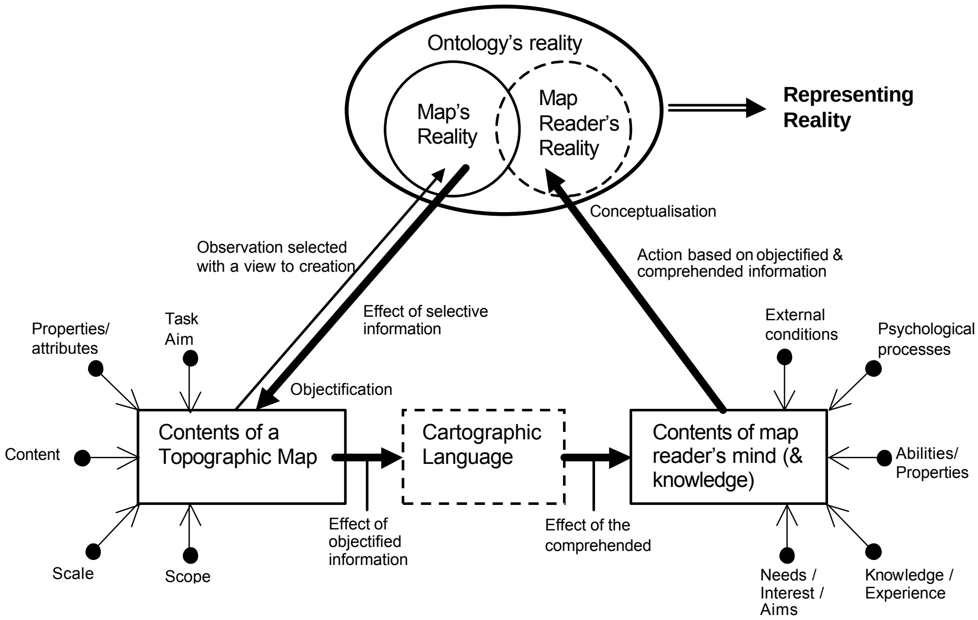

Figure 1. A unified representation that combines both detailed, spatial information from the map data as well as human-acceptable concepts that are intrinsically tied to their underlying geography, and thus to the data itself.

The purpose of this study is (a) to study a plain topographic map according to the processes that operate on it when it is being inspected by the map reader; (b) to study the nature of the input, or stimulus, perception and analytic processes and the nature of similarity judgement; (c) to study a person's conceptualisation according to the principles and structure of categorisation; and (d) to study the respondent's demographic characteristics as an influenceable factor in all of the above. For example, the study of a person's conceptualisation is based on people's inner knowledge representation and principles of categorisation (Rosch, 1978). Therefore, questions are structured according to a horizontal dimension, where separate categories describe a land use spatially, and to a vertical dimension, where those categories are further described in detail by a further set of questions. The information gathered from this process will look similar to the representation given in figure 2, starting with functional concepts that make up a specific land use category, which are then further described according to their purpose, role, affordance (i.e. words), physical property and spatial relations. Hence, the land use is represented and defined based on its underlying land cover, taking a top-down approach from the general to the specific.

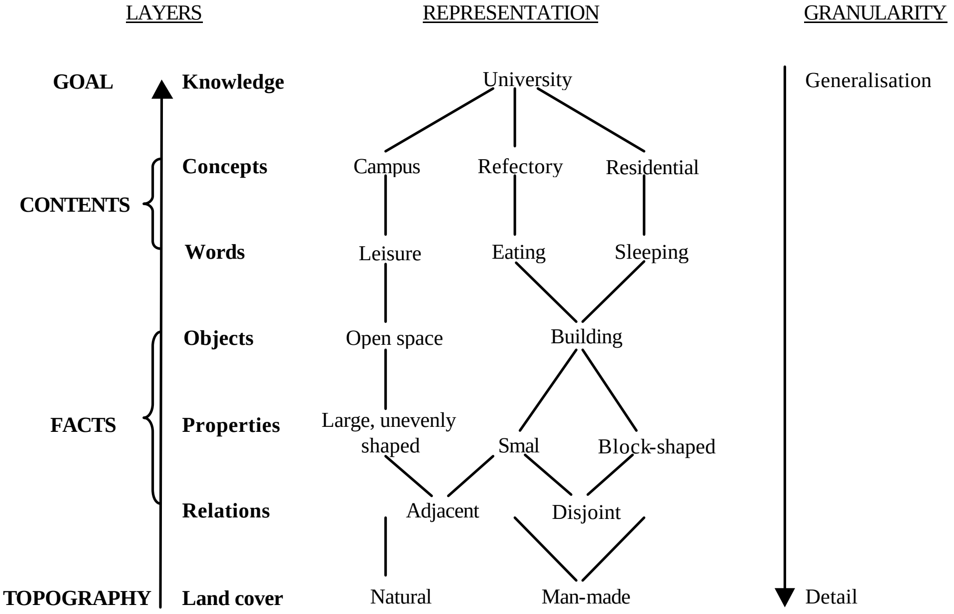

Figure 2. A top-down approach for capturing a person's inner conceptualisation

4. Preliminary Results

Some preliminary conclusions can be drawn from results of a small pilot study, based on PhD colleagues from the Department of Geomatic Engineering, UCL. The results suggest that people are capable of inferring land use information from a plain topographic map, despite not necessarily being very familiar with this type of data. The most accurate interpretations were achieved with respect to residential areas, such as terraced houses, and recreational areas, such as parks and sports grounds, which have quite distinct features. More difficult proved to be the interpretation of larger features and buildings, which could either be industrial or educational buildings, retail outlets, hospitals, or offices. Most respondents approached the interpretation task by looking for the road network, shapes and sizes of objects, whose similarity as well as their overall shape determined the perception of groups. The greatest difficulty in the interpretation was caused by misinterpreting objects based on the inability to correctly understand an object's meaning, while the fuzziness of where one land use starts and the other ends was not a major obstacle. None of the respondents recognised the depicted area's location in reality.

The conceptualisation of a land use category seems more difficult than expected. Nevertheless, results indicate that conceptualisations are similar across respondents despite small variations depending on what was felt is important in describing a particular land use at that moment in time. Further, conceptualisations resemble much of the real environment due to the factual information about a land use's spatial organisation. However, respondents did not differentiate much between a member category's purpose, role or affordance, showing that there is a very fine distinction among those concepts, which people are not always aware of. Results from the conceptualisation of industrial area and educational institution seem to fortify the observation of Smith and Mark (2001) that the number of instances given by respondents per title category appears to reflect some combination of the familiarity of the category itself and the richness and diversity of familiar category members.

A further approach to capturing people's mental representation of land uses was tested in the form of sketch maps. Despite existing analytical methods used with sketch maps (Okamoto *et al.*, 2005), the results are impossible to analyse, since the sketch maps do not relate to a specific known geographical location in the real world. Furthermore, Downs and Stea (1977) defy such a pursuit, as sketch maps vary greatly due to personal variations in age, experiences, and skills, and a one-to-one correspondence to the real world is apparently absurd due to people's limited storage capacity of information and its selective cognitive processes.

5. Conclusion

Land use information is readily available from various commercial sources. However, the methods with which such information is created are time consuming and still require considerable amount of human interaction. Ordnance Survey's strategy is to capture and maintain once, but to use many times. Hence, the aim is to infer additional information from existing data repositories in order to tailor future products according to customer needs. Such an inference, especially from a topographic database, is not easy. In this research the use of ontologies for such a purpose is investigated using human knowledge and their map interpretation abilities as a starting point. Whilst we are trying to embrace elusive measures such as human values, attitudes, beliefs, judgement, trust and understanding of a land use domain, the information captured is specific but objective in its contents, yet it is general across people's knowledge but subjective in its nature. One pitfall may indeed be the infiltration of human knowledge with erroneous beliefs (Smith, 2004).

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Spatial Concepts and OWL issues in a Topographic Ontology Framework

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1. Introduction

The aim of the GeoSemantics programme at Ordnance Survey is to develop the methods and tools needed to create a topographic ontology and support interoperability between Ordnance Survey's data, their topographic ontology, customers' ontologies and data. This paper focuses on how to consistently represent and model spatial entities and non-spatial concepts that are related to spatial entities in an ontology. This is a fundamental piece of research, as this spatial entities ontology module will be reused within the topographic ontology that is being built by Ordnance Survey (Dolbear at al., 2006a).

2. Background

Ordnance Survey, the national mapping agency for Great Britain, supplies complex data products that represent a topographic interpretation of the landscape and its significant structures and features. Our customers currently face significant costs in integrating these data with their own data and business processes and consequently these costs are a major barrier to the adoption and efficient exploitation of complex data sets, for example Ordnance Survey's MasterMap®. The Ordnance Survey topographic ontology will encode knowledge about topographic objects surveyed by Ordnance Survey, describe these objects and their relationships, and link this encoded information to a GI data base. One of the important steps in this process is developing a conceptual framework for how the spatial aspects of physical and non-physical topographic objects will be encoded. For more information on the technical aspects of our work, please consult Dolbear et al. (2006b).

An important point to note is that location is only one aspect in the description of a real world object (such as a building). Other important aspects include *what* the object is and *how* it relates both semantically and spatially to other objects. For this reason we regard a real world object not only as a geometric entity (such as a polygon) with attribution assigned to it but also a semantic object that has uses and functions that has spatial information assigned to it.

3. Analysis and Discussion

There are two main categories of topographic objects – those that are physical and those that are non physical. These will now be introduced.

3.1 Physical topographic objects and Space

Physical topographic objects such as a building, a mountain or a lake, have several qualities that are spatially relevant but not all these qualities are relevant for any given domain. A building has a volume of space it occupies in three dimensions, an area of its outside surfaces, a height and a depth, if it has under ground levels. A building also has a footprint on a two dimensional surface (such as an earth surface), as well as a roof footprint area which may be different from its ground level footprint.

Other physical objects such as a river or a mountain have a different set of spatially relevant qualities. A river has a volume of space it occupies in three dimensions, a surface area and a footprint in two dimensional space. Its channel has a cross sectional area, a width, and a depth. The river may have a depth that is different from the depth of its channel. A mountain also has a volume that the materials making up the mountain (soil, rocks, etc.) occupy in three dimensional space. It has a footprint projected downward on a two dimensional surface, its sides have an area and its peak has a height. Again, in a given domain ontology, not all of these different spatial qualities are relevant. On the ontological treatment and delimitation of landforms, the work of Mark and Sinha (2006) suggests that "landforms may form continua and the land form classes may be based on perceptual factors."

Which ones of these spatial qualities are relevant for which object depends on the domain ontology. An architecture or mining ontology would look at space in a very different way from how a topographic ontology needs to consider space. As the aim of this work is to create a topographic ontology, we have to identify a set of spatial qualities relevant for topographic objects.

All physical topographic objects have a footprint – a projection onto a two-dimensional space that is relatable to one or more polygons in a GI data set. We express this in two ways, using Rabbit (a kind of controlled English developed and used by the Ordnance Survey) and OWL, the Web Ontology Language (McGuinness, and van Harmelen, 2004):

Rabbit:	A physical topographic object has a footprint
OWL:	All PhysicalTopographicObject HasFootprint Some Footprint

Since we are interested in space from a topographic point of view this two dimensional space is the Earth's surface – or rather a model of the Earth's surface given as a map projection. All physical topographic objects also have a height relative to their surroundings although, in case of a plain and a river, this height may be zero. All physical topographic objects also have a height above sea level. Some physical topographic objects such as rivers or buildings may have a depth (a negative height) relative to the height of the surrounding land. In fact, a building with levels both above and below ground and an embanked river or canal will have both height and depth. Some physical topographic objects, such as buildings also have other spatial qualities that are relevant to them, such as the length of their frontage, or the area of their roof. These other spatial qualities may or may not be relevant in topography.

Physical Topographic Objects could be divided up into three main categories: Water bodies (lakes, rivers, etc.), Land objects (for lack of a better term, such as mountains, plains, etc.) and Structures (buildings, bridges, etc.). The footprints of water bodies, land objects and structures may overlap and may include pieces of water area, land area or both (tidal areas). In natural language we would say: a lake is on a mountain. The mountain is an object and has a footprint. A lake is an object and has a footprint. The two footprints overlap because the material the mountain is made of is still present under the lake and because the mountain is a topographic unit. This way, "the lake is located on a mountain" relationship could be represented with the RCC8:Non Tangential Proper Part (Randell et al., 1992) relationship.

3.2 Non-physical topographic objects and Space

Not all topographic objects are physical. Some are non-physical topographic objects which are also called FIAT objects (Smith and Varzi, 2000) such as administrative units (districts, counties, parishes, etc.), settlements (cities, towns, villages, etc.) and informal named extents (e.g., 'The Cotswolds', local neighbourhood names, etc.). All these have a physical spatial region associated with them. This physical spatial region has a footprint. It has been suggested that it would be much easier to say that a county has a footprint and use spatial operators on that footprint, as we did with the physical topographic objects. However, a county is an administrative unit, which is an abstract concept, not a physical concept. It is not a two or three dimensional object and hence cannot occupy space on a two-dimensional surface. It would be ontologically wrong to say that an abstract concept spatially contains or spatially overlaps with another abstract concept. Instead, the concept of a spatial region is used to allow the abstract concept to have a footprint (spatial extent). A spatial region would then be defined as a physical piece of space with definable boundaries and with no height.

We admit that this is computationally intensive (and probably inefficient) when we have to operate on thousands of instances, therefore we accept an alternative solution: using a different relationship to relate Non-physical topographic objects to their footprint. We see this later solution as a creative compromise (or syntactic sugar (Marsolo et al., 2003)) that allows us to retain the conceptual subtlety of the domain while also keeping in mind the computational limitations encountered while working with large data sets.

So instead of saying:
Rabbit: A non-physical topographic object has a spatial region that has a footprint.
OWL: All NonPhysicalTopographicObject HasSpatialRegion Some SpatialRegion.
All SpatialRegion HasFootprint Some Footprint

We would say:
Rabbit: A non-physical topographic object has a related footprint.
OWL: All NonPhysicalTopographicObject HasRelatedFootprint Some Footprint

3.3 Land Cover, Land Use and Space

Land cover types, such as forest, field, meadow, and sand, are (more or less specific) groupings of vegetation and/or materials that are associated with a piece of land. Land use types (pasture land, industrial areas, etc.) are abstract concepts that reflect how a piece of land is used, and are similar to land cover type in that we consider them as qualities that Physical topographic objects (land objects) have. We do not consider that land cover and land use types are Physical topographic objects directly. Rather, we consider them as qualities (Marsolo et al., 2003) that Physical topographic objects (land objects) or Spatial Regions have. This is useful because while land use may change rapidly (go from pasture to residential in less than a year) land objects (mountains, cliffs) are much more stable in time (barring land slides and earth quakes). Also, the nature of a mountain does not change whether it is covered with a forest or a meadow. It is only the cover associated with it that is changing.

Hence, we could say that:

Rabbit:	A Land object has a land cover type.
OWL:	All LandObject hasLandCoverType Some LandCoverType.

One might also consider that is also possible for a land cover object to have its own independent existence. For example a forest (for example, the Ampfield Forest) as a topographic unit may be considered a land cover object that would have its own footprint. In this case, land cover may be represented as both a quality and an object. There is no conflict the two; they are merely different representational forms. Since Land Objects, Spatial Regions and Land Cover Objects have footprints, their qualities also become associated with their footprint, and hence it will be possible to express RCC spatial relationships with other objects that also have a footprint.

We are aware that first, the edges of land cover types or other land objects often do not have clear boundaries and addressing fuzzy boundaries will be necessary. Researchers have argued that modern approaches to geographic information have not been admitting this lack of definition and hence have been suffering from its shortcomings (Fisher and Wood, 1998).We also think that this may not need to be done at an ontological level alone: it might be best addressed in the data. The degree of fuzziness that needs to be modelled is domain dependent, therefore if addressing fuzziness in an ontology is necessary at all, it might be best be done in a separate ontology module. It is clear that the relationships between land objects (mountain) and land cover types (forest) are not one-to-one. This issue will be best addressed by incorporating it into a spatial relations ontology module, which we are in the process of building.

4. Conclusions

We have highlighted the need to consider topographic objects not only from a spatial but also from a semantic aspect. The ways in which non-physical topographic objects, land use and land cover may be modelled in a topographic ontology were explored. The findings of this paper will be implemented in a spatial entities ontology and used within the topographic ontology that is being built by Ordnance Survey

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Using Structured English to Author a Topographic Hydrology Ontology.

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1 Introduction

Ordnance Survey, Great Britain's national mapping agency, is currently in the process of building a topographic ontology to express the content of its topographic database with the aim of enabling the semi-automation of data integration, product repurposing and quality control. We are devising a methodology that enables domain experts working with ontology engineers to construct ontologies that have both a conceptual, human readable form, and a computation form that is interpretable by machines (Mizen, et al, 2006). A key part of the methodology is that it enables the first stages of ontology authoring to be conducted using a restricted form of English which enables the domain expert to be in charge of the authoring process and other domain experts to understand and verify the content. The computational aspect, expressed using OWL (W3C, 2004), is treated as an assembler code version of the conceptual ontology.

This paper introduces Rabbit, the constrained form of English that we are developing and gives examples of its use in constructing a hydrology ontology and how it maps to OWL.

2 Related research

Ever since OWL was conceived there have been concerns that its form makes it inaccessible to those without a good understanding of logics (Horridge, 2006). It is difficult for domain experts to use OWL to author or validate ontologies. This in turn creates a serious impediment to the adoption of OWL and semantic web. There have been a number of attempts to resolve this issue through the creation of grammars for OWL that attempt to make it more understandable. Such grammars include the Manchester Syntax (Horridge, 2006) which attempts to replace the abstract symbology of description logic. Whilst this is significantly more readable than the pure mathematical representation, the average domain expert will still struggle to understand what it means.

Other approaches are to use constrained forms of English, examples being ACE (Fuchs et al, 2005) and Processable English (PENG) (Schwitter et al, 2002) both of which provide grammars based on constrained English to represent First Order Logic (FOL) and both have now Description Logic (DL) subsets (Kaljurand et al, 2006) and (Schwitter et al, 2006). These do provide significantly more readable representations. For example in PENG DL simple statements such as "France is a country." can be made in. As these grammars are representations of OWL they also allow more complex statements to be made. These more complex forms also begin to sound a bit unnatural but are still readable: “If X has Y as a topping then X has Y as an ingredient and X is a pizza and Y is a pizza topping and Y is a topping of X.”

Lastly, it is worth mentioning that all these approaches are limited to representing only what can be stated in DL (or FOL). They will also reflect any optimisations or modelling “tricks” that an ontology engineer might apply and which whilst necessary for either efficient reasoning or accurate modelling will obscure the ontology from a domain expert’s point of view.

3 Rabbit – motivation and design principles

Our research has been focused on developing a language that overcomes some of the limitations described above. We have named this language Rabbit, after Rabbit in Winnie the Pooh, who was really cleverer than Owl. We have involved domain experts from the outset in the core language design decisions. It is a language in its own right, rather than merely a syntactic veneer on OWL. This means that it contains constructs such as “typically” (meaning an unquantified but significant majority but not all) that are needed by the domain expert, even though they cannot be expressed in OWL. These constructs are included to ensure that domain knowledge is not lost, even if it cannot be fully exploited.

The fundamental principles underlying the design of Rabbit are:
- Maximal Expressibility;
- Be based on a formal grammar;
- To hide ontology engineering optimisations and modelling tricks;
- To be independent of any specific domain.

3.1 Principle 1: Expression

Rabbit focuses on keeping the sentences natural sounding and where possible short: for example using “A River flows into a Sea” rather than the OWL-like “All Rivers flow into some Seas”. To make it easier for the domain expert to produce, several defaults are assumed for example “or” is assumed to be an exclusive or, and all concepts are assumed to be disjoint, unless specified otherwise. As domain experts tend to think in terms of the closed world assumption, these defaults are more natural for them. The open world assumptions of OWL have to be explicitly closed down when such Rabbit sentences are converted to OWL. This leads to relatively simple expressions in Rabbit having complex expression in OWL. For example the Rabbit statement:

A river flows into a sea or a lake or a river or a reservoir.

would result in the following OWL:

River -> flowsInto some (Sea or Lake or River or Reservoir) and not (flowsInto some Sea and flowsInto some Lake) and not (flowsInto some Lake and flowsInto some River) and not (flowsInto some River and flowsInto some Reservoir) and not (flowsInto some Reservoir and flowsInto some Sea) and not

> (flowsInto some Sea and flowsInto some River) and not (flowsInto some Lake and flowsInto some Reservoir).

Use of some constructs such as “typically” can be represented in Rabbit but cannot be represented in OWL. They are included in Rabbit to ensure that the domain can be captured as accurately as possible and to ensure that a better quantification of information loss can be made.

3.2 Principle 2: Grammar

Concepts in Rabbit may comprise one or more words such as “River” or “River Stretch”. Homonyms are differentiated with the addition of a disambiguation term following the concept name in brackets: Pool (River). This is converted to OWL as Pool_River and an rdf:label of “Pool”.

Rabbit has a few predefined relationships such as “Is a kind of” to introduce super and sub-class relationship. Mostly authors will define their own relationships such as “flows into”. Relationships may be modified using phrases such as “only”, “typically”, “at least” and “does not”. For example, “a braided river stretch flows in at least 2 channels”.

3.3 Principle 3: Interaction between domain expert & knowledge engineer

An important aspect worthy of a little more discussion is the interaction between the domain expert, the knowledge engineer and the translation process in “compiling” Rabbit into OWL. Translating Rabbit to OWL will have three significant effects on the modelling process. First, it is likely to expose flaws in modelling which will need correction in Rabbit. Second, it gives the potential to include optimisations in the OWL version (for reasoner efficiency) which need not be reflected in the Rabbit representation lest they obscure the clarity of the ontology. Third, the knowledge engineer may wish to use “modelling tricks” (again to help the OWL form) which need not necessarily be explicitly represented in Rabbit. An example would be the representation of transitive properties. These are interesting, because if we took “has part” as an example, we could say that “a car has a part engine” and that “an engine has a part piston” and so on. Normally if we asked what were the parts of a car, then we would expect a list of the major components. However, if “has part” is defined in OWL as transitive, then a reasoner would return all parts. This is probably not what most people would expect. One solution (W3C, 2005l) is to define the “hasPart" property as transitive and then to define a subproperty “hasDirectPart” which is not transitive. This enables a choice to be made at query time as to whether all parts or just “direct parts” are selected. Rabbit has adopted this convention in that all transitive relationships in Rabbit translate to OWL by defining a property and subproperty pair.

3.4 Principle 4: Domain independence

Rabbit has been developed over the course of authoring an ontology in the domain of hydrology and has been further tested with the buildings and administrative geography domains. We believe that it now contains most of the necessary constructs to author ontologies in any domain, including expressions beyond OWL or OWL 1.1.

4 Conclusions and future work

Currently, we are finalising the grammar and translation and are also working closely with the University of Leeds on the development of a tool to assist a domain expert to input an ontology in Rabbit, following our ontology authoring method. An important aspect of this is the implementation of a tool subset that supports the ontology author in the construction of Rabbit sentences and their automatic conversion to OWL. In the near future we will be conducting human subject testing of the grammar to ensure that the statement constructs are interpreted with a significant degree of accuracy. Here we do not expect to be able to design a completely unambiguous grammar; whenever using a natural language-like construct, one has to accept some misinterpretation. However, we do expect such work to show significant improvement in interpretability by domain experts over existing alternatives and to enable us to identify problem areas for resolution.

In conclusion we have introduced the work we are performing to develop a language to enable domain experts to better author and interpret ontologies. We see the advantages of Rabbit over other methods and DL syntaxes as being:

- Greater clarity of expression due to the involvement of the domain expert both in the development of Rabbit, its authoring and use.
- The ability to hide certain modelling complexities and optimisations.
- The encouragement, through its grammar, to produce short sentences that are more easily interpretable.

We would also stress that another important aspect of Rabbit is that authoring should be supported by a tool as an integrated part of any ontology authoring methodology.

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Biography

Glen Hart is the Principal Research Scientist working within Ordnance Survey’s Research Labs. His research interests include spatial data modelling and integration geosemantics and vernacular geography.

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GIS data capture of glacier change in western Canada

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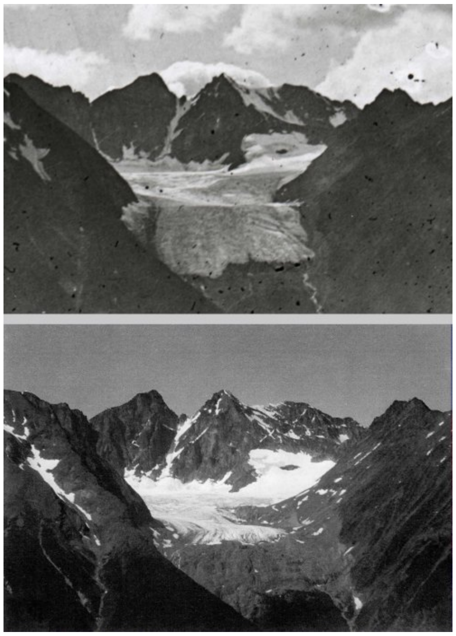
1. Introduction

Alpine glaciers worldwide have experienced accelerated rates of retreat in the new millennium, and continuous retreat in western Canada since at least 1980, largely as a result of higher summer temperatures, which have seen the greatest relative increase outside arctic latitudes in North America. Glaciers are important for many reasons: as 'canaries' of climate change, as reservoirs of freshwater, in providing meltwater for hydro-electric power, to augment late summer river flow, to moderate summer water temperatures in fish-bearing streams, and for their tourism values (Figure 1). The Western Canadian Cryospheric Network (WC2N) is a funded consortium of universities, government institutions and researchers which will map past and present glacier extents and investigate the links between climate and glaciers over 5 years (2006-2010).

Figure 1: the iconic Hudson Bay Glacier at Smithers, BC. 1912 (above) and 2003 (below)



The most recent inventories represented by federal and provincial GIS mapping layers from the 1980s are out of date and not fully reliable in both glacier extents and elevations, where the latter are stored either as mass points, interpolated grids or contour data. A variety of sources are being used in this study to update and monitor both extents and surface elevations, as well as to create historic data layers by incorporating past surfaces where available. Glacier extents have been derived by digitising historic topographic maps, scanning intermediate aerial photographs, importing vector data sets, and digital image processing of current and recent satellite imagery (1982-2006). This paper will focus on data capture methods, integrating historic and current sources, and the processing of digital elevation models in order to estimate and portray rates of change. These include issues of GIS data quality, scale and uncertainty, associated with data capture in remote and extreme mountain environments.

2. Methodology

2.1 Vector data sources

British Columbia is covered by approximately 1100 federal map sheets at 1:50,000 scale (approx. 30% contain glaciers) based on aerial photography ranging from 1948-1990. Many of these have been digitised into the National Topographic DataBase (NTDB), and where they have not, the glacier contours and extents have been digitised from scans by undergraduate students in-house, using GIS software. Later editions include updated glacier extents, but not updated elevation values. Additional federal map sources include early twentieth century maps by alpinist surveyors, using ‘photo-topographical’ methods triangulating from mountain peak vantage points. A second additional source includes specialised glacier maps produced during the International Hydrological Decade (IHD) 1965-75 (Table 1). The province of British Columbia (BC) has been topographically mapped in 7000 digital tiles from photography 1979-88 through the Terrain Resource Inventory Management (TRIM) program. This has been updated after 1996 via the TRIM II program, involving new glacier vectors (but not contours), as well as 1 metre resolution orthophotos. These form a solid base layer, although not perfect as they were generated from panchromatic aerial photography often saturated in areas of high reflection, and by photo-interpreters more experienced in forestry applications.

2.2 Satellite Image processing

Digital image processing of satellite data has become increasingly appropriate due to the combination of reduced map and vector production by mapping authorities, increasing rates of environmental change, the repetitive nature of image acquisition, the large area covered by image scenes, and the reduced cost and increased availability of image data. Early Landsat (MSS) data are of limited use due to lower resolution and temporal overlap with provincial mapping. Improved resolution from both Landsat and SPOT data have been augmented this century with the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) sensor launched onboard the Terra satellite in 2000, and supporting the Global Land Ice Measurement from Space (GLIMS) project to create an updated worldwide inventory of glaciers via a network of regional stewards and centres (UNBC is the regional steward with responsibility for the Western Canadian Cordillera). Image classification methods for feature extraction of glacier extents and surface morphology build on established techniques (Kaab 2002, Paul 2002, Sidjak and Wheate 1999). These meet challenges posed by debris covered ice and shadows, which may require image overlay and GIS queries incorporating DEM derivative layers

2.3 Digital Elevation Models.

Digital elevation models (DEMs) have been used to generate estimates of volume loss by subtracting current and recent DEMs from historic models. Early elevation models have been created either by digitising contour maps and interpolation to create raster grids, or by stereo photogrammetry (from archival aerial photography). A standard 25 metre gridded DEM is available for the whole province through the TRIM program (1980s), although elevation values are suspect in upper glacier elevations (accumulation areas) due to photographic saturation inhibiting the acquisition of mass points. In some cases, we are going back and recreating these DEMs from optimally processed photographs. Contemporary models include those produced from ASTER and SPOT satellite stereo imagery, and the Shuttle Radar Topographic Mapping - SRTM (Table 1). The latter provides a continuous 90 metre DEM for the western mountains, with some gaps on steeper slopes. Any ASTER scenes also provide a (15 metre) DEM as the sensor includes a backward looking mode band in addition to the nadir mode used for image data collection. This results in some data gaps on steep north facing slopes, but these tend to be non-crucial. The generation of multiple DEMs enables 3D visualisation techniques in addition to volume estimations.

Maps, GIS data or Images	**Dates**	**Polygons**	**DEM**
Historic alpine maps	1890-1950	x	x
Glacier maps- IHD	1965-75	x	x
National Topographic maps	1950-85	x	x
Stereo aerial photography	1948-96	x	x
BC provincial TRIM data	1986-88	x	x
BC provincial TRIM II data	1996-2006	x	
Landsat MSS	1972-82	x	
Landsat TM	1982-2006	x	
Landsat ETM+	1999-2003	x	
SPOT HRV	1986-2006	x	
ASTER	2000-06	x	x
SRTM	2000		x

Table 1: Data sources for glacier (extent) polygons and DEMs

3. Results and analysis

Our deliverables include a province wide assessment of glacier change for three time periods, and over 5 year intervals for seven selected areas of focus. Preliminary results indicate current average rates of retreat approaching 20 metres per year, but these are greater in the southern parts of the cordillera. Overall area loss in ice cover is in the order of 10% province-wide between 1988-2000. As one would expect, smaller glacier polygons have lost a higher percentage of their total area than larger icefields. Potential sources of error include misclassification of perennial and late snow as ice, and incomplete reliability of historic vectors (Hall et al, 2003). Subtraction of historic-current DEMs - indicate a loss of depth of ice between 50-100 metres immediately upslope from the snout in the dozen years between the late 1980s (TRIM data) and 2000 (SRTM). Initial comparison with postwar national topographic mapping indicates a similar volume loss between 1965 and 1988 (that is, over a longer period). We anticipate that in 2007 we will find increased rates of loss in volume and distance retreat since 2000 given the record average temperatures experienced in the new millennium. Apparent gains in the upper accumulation areas since the 1980s are suspect due to potential data errors from photo saturation and will be examined during further analysis using alternatively derived DEMs.

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Biographies

Dr. Wheate is an Associate Professor and GIS co-ordinator at UNBC. He has 20 years experience in geomatics information processing and received his Ph. D from St. Andrews in 1997. His research focuses on information extraction from remotely sensed image data and high mountain cartography.

Application of GIS and logistic regression to fossil pollen data in modelling present and past spatial distribution: A case study in the Colombian Savanna

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1. INTRODUCTION

Climate change at glacial-interglacial cycle time scales have had an impact on the vegetation in many parts of the world. Vegetation change is reflected by changes in abundance, geographic extent and floral composition of plant populations, from which pollen grains are naturally preserved in lakes and peat bogs. By drilling at sites of interest, sediment cores are obtained which show the temporal variations in the pollen assemblages. Palynologists present these data in pollen diagrams and interpret the downcore changes in pollen spectra in terms of past vegetation change and inferred environmental conditions.

So far little research has been carried out, in which palynological data is analysed by software specially designed for spatial data analysis, like Geographical Information Systems (GIS), although the arguments for its implementation are divers: palynological datasets in general are large and complex to interpret; the data consists of changes which have occurred over an area (2-dimensional surface) and over time (a third dimension-variable); and frequently data from different locations must be compared to make an interpretation of a complete area rather than of one single site only.

The implementation of GIS in palynological research appears to be in an explorative stage as the examples are scarce, e.g.: displaying plant-distributions (e.g. Giesecke and Bennett, 2004), habitat suitability analysis (e.g. Lyford *et al.*, 2003) and the reconstruction of past vegetation with historical maps (e.g. Veski *et al.*, 2005). Due to the complexity and the spatial heterogeneity of the variables influencing the spatial distribution of vegetation, palynological analysis thus far seems to be limited by non-spatial methods, hence trying to find structures in a multidimensional data set with one-dimensional tools.

The aim of this paper is to provide a useful step in pollen data analysis by merging GIS and predictive modelling into a combined palynological GIS application. The proposed methodology can be employed by palynologists to explore their area of research and capture it in a predictive model, to make reconstructions of past and future land-cover distributions under changing climatic conditions. This provides a better understanding of the vegetation responses to alternating environmental conditions which subsequently contributes to the interpretation of the pollen data. In the same database the palynological data can be implemented to use GIS to reconstruct and evaluate patterns of land-cover changes based on pollen counts.

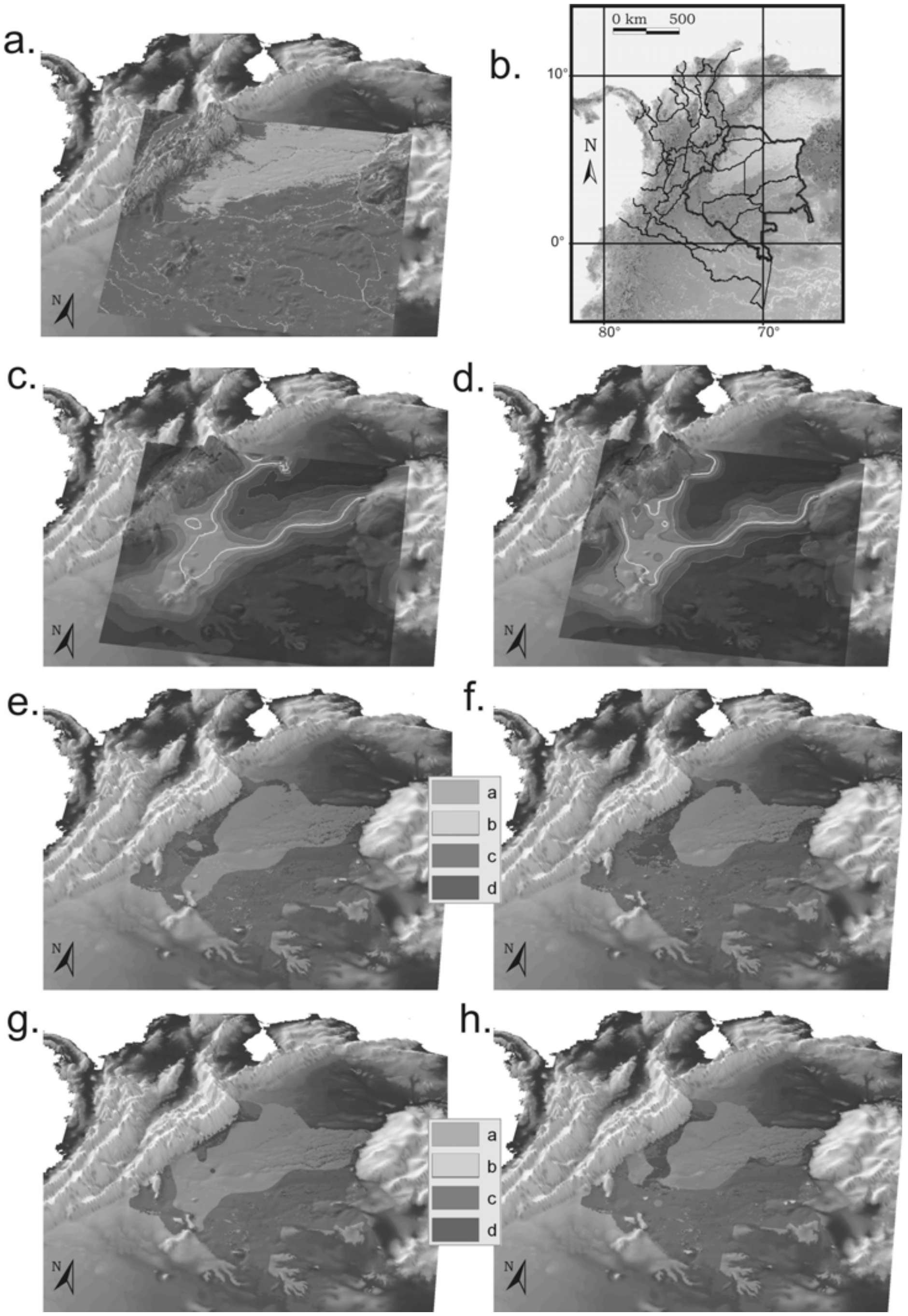

Figure 1: *Study area and outcomes of predicted land-cover distribution by logistic model. (a) Map of South-America indicating the location of the study area and the actual land-cover distribution; (b) Location of the Colombian savanna biome in between the Andes and the Guyana Shield (03 to 07 ºN, 68 to 71 ºW); (c) Probability map of savanna occurrence based on random data sampling; (d) Probability map of savanna occurrence based on regular sampling. Yellow lines indicate the 0.5 threshold whereas the red lines delineate the 0.6 cut-point; (e-h) Differences between actual land-cover distribution and predicted by the model; (e) Based on random sampling at 0.5 threshold; (f) Random sampling at 0.6 threshold; (g) Regular sampling at 0.5 threshold; (h) Regular sampling at 0.6 threshold. Legend-specification: (a) Indicates correctly predicted savanna [Dark yellow] and (b) represents where the model falsely predicted savanna [Bright green] (c) Indicates correctly predicted forest [Dark green], while (d) shows where the model failed to predict savanna [Red].*

To illustrate the implementation of the palynological GIS application, an area of palynological research is selected in the tropical lowlands of northern South-America. Colombia and Venezuela share an extended area of savannas, which expands from the Eastern Andes Cordillera all the way to the eastern coast of Venezuela (Fig. 1a,b). The southern boundary of the Colombian savanna which is transitional to tropical rainforest, has migrated through time, as these geographical shifts have been reconstructed from pollen records close to this zone (Behling and Hooghiemstra, 1998). These changes indicate that a certain level of vegetation dynamics has occurred, but the degree of environmental change is mostly expressed in general terms, such as "to some extent drier or wetter" conditions, or lacking specification regarding the seasonality, like "shorter" or "longer dry period". By using the palynological GIS application as analytic tool, a better understanding of the dynamics of the savanna distribution in Colombia can be realized, while furthermore contributing to a better understanding of future vegetation responses to global climate change.

The employment of GIS is basically divided into two different but related applications. The first application is to make a predictive model, in which the climatic variables are determined which influence the spatial distribution of the savanna vegetation in our area of the interest. The statistical model, derived from logistic regression, is subsequently implemented in GIS and used to create land-cover maps, which are compared to the actual land-cover distribution. The models deviations are made clear by spatial analysis of the predictor variables to assess the vegetation response to the climate. The second application introduces data from pollen records of the Colombian savanna into GIS to create land-cover maps through pollen percentages implementation and interpolation methods. An assessment is made of the suitability of the pollen data for a GIS analysis in which both limitations and recommendations are discussed (for more detailed results see in Flantua et al. 2007).

2. METHODOLOGY

Logistic regression is a variation of ordinary regression, which basically is a method used to determine the impact of independent variables on a dependent variable. In binary logistical regression the outcome is restricted to two values, representing the presence or absence of a specific event. It produces a formula that predicts the probability of the occurrence as a function of the independent variables. Depending on a chosen threshold probability value, everything above this threshold indicates one condition of the binomial outcome (i.e. the presence of savanna), while everything below equals the other condition (i.e. absence of savanna; in this case presence of forest).

A binomial land-cover GIS layer is created from the Global Land-cover Characteristics (GLCC) Data Base Version 2.0 (Loveland *et al.*, 2000). The monthly values of precipitation, temperature and potential evapotranspiration form the basis for the set of independent (predictor) variables in the model creation (Legates and Willmott, 1990a,b). By using a point layer raster that overlies all data layers in GIS, the underlying variables values at each point can be extracted and readily used for the statistical analysis and model creation. The resulting statistical formula of variables is introduced into GIS with layers of the most significant climate predictors as data source in order to get a map of the predicted land-cover distribution as result. This map is subsequently compared to the actually observed spatial distribution of savanna to visualize the areas in which the climatic conditions fall short in correctly predicting the vegetation pattern. Different sampling methods, threshold values and accuracy assessments methods are used to evaluate the difference in predictive capacity. Implementing the logistic regression outcome into GIS does not only test the models predictive capacity on a larger data set, but also provides insight into a vegetation distribution based on only climate variables, and therefore the models weaknesses.

To obtain a reconstruction of temporal land-cover changes in the past, pollen spectra at successive time slices are compared. The time slices of interest were selected based on the amount of available pollen data and the degree of change compared to earlier time slices to make meaningful intervals. Two different interpolation methods are used to create the land-cover reconstructions: Local Polynomial and Radial Basis Functions.

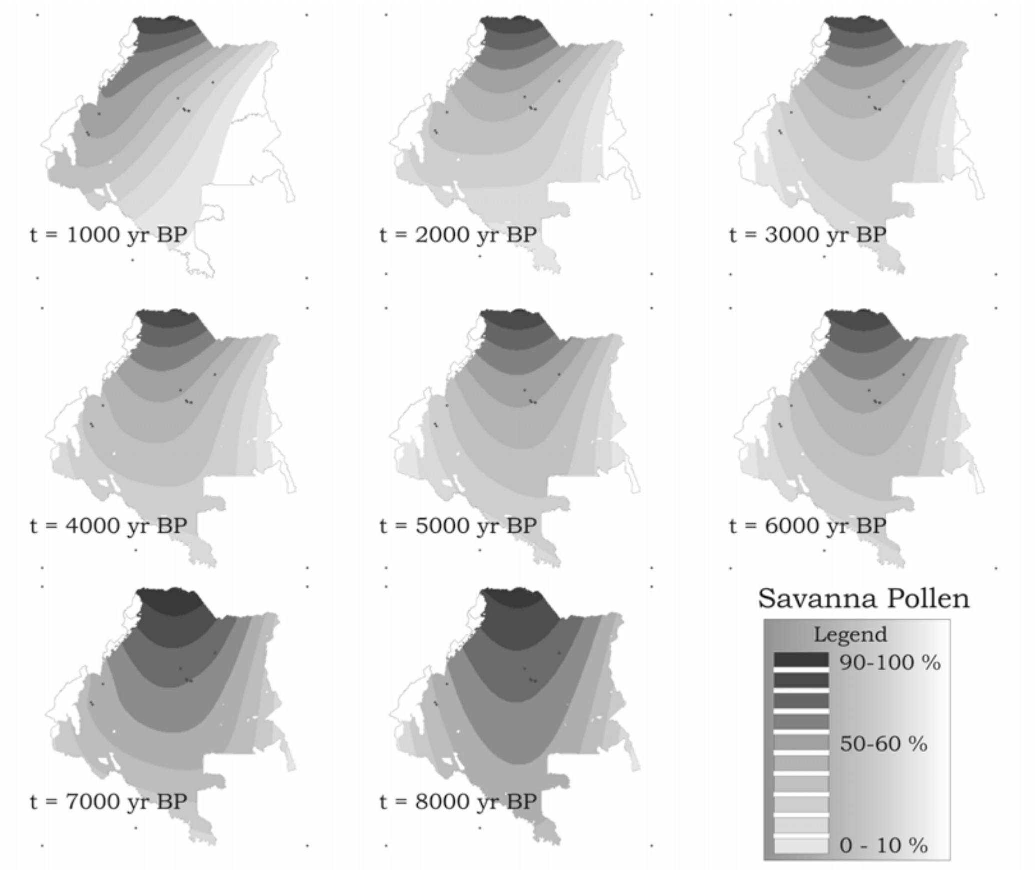

Figure 2: *Maps of interpolated pollen percentages of taxa reflecting savanna vegetation based on Local Polynomial Interpolation method. The interpolated area corresponds to the area delineated in Fig. 1b. Selected time slices range from 1000 to 8000 14C yr BP. (Interpolation specification: power = 2, Ideal weight distance activated)*

3. RESULTS

The variables indicated by the predictive model as determinants of the savanna distribution, correspond to earlier publications (Sarmiento, 1983; San Jose *et al*., 1998; Rippstein *et al*., 2001; Hooghiemstra *et al*., 2002). The spatial correlation and separate influence of the variables was tested as they were independently removed from the model, to evaluate its significant contribution to the model predictive accuracy. Based on the different accuracy measurements, all created models achieve an acceptable predictive power ranging from an overall accuracy of 0.81 to 0.86 (Fig. 1c-h). A regular sampling methodology (Fig. 1d, f, h) and a 0.6 threshold value (red line in Fig.1c, d) give more robust results than random point sampling (Fig. 1c, e, g) and the default 0.5 threshold (yellow line in Fig.1c, d) achieving combined a best fit model of 85,7% correctly predicted land-cover distribution.

This difficulty of interpreting the interpolated maps (Fig. 2 and 3) is caused by different factors, including the chosen interpolation method and the pollen transect orientation. Selecting a proper method basically means a trial-and-error application to see which method is best used on the specific dataset. The pollen transect fails to represent the past land-cover shifts, due to the dissimilar orientation compared to the occurred geographical shifts, and the presence of gallery forest which significantly prevents the pollen income of possibly dominant savanna land-cover.

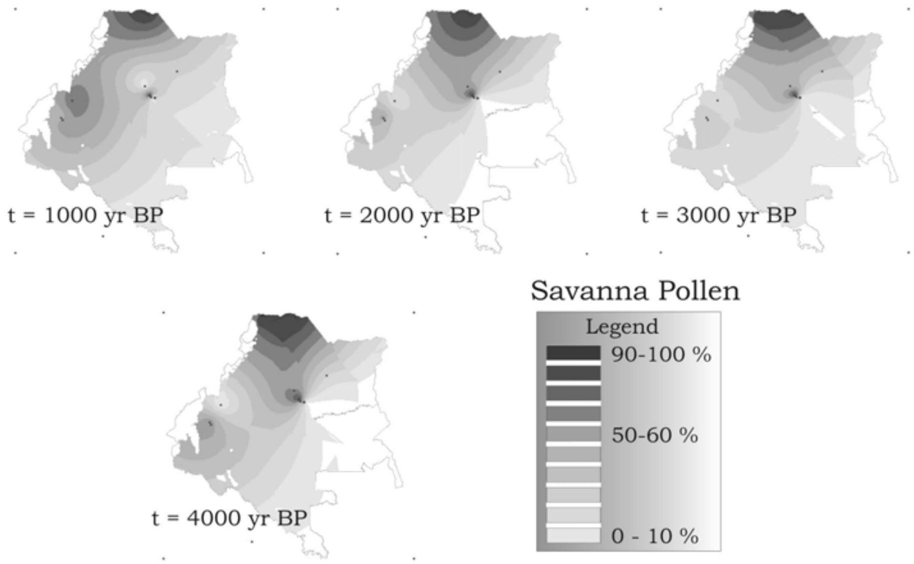

Figure 3: *Maps of interpolated pollen percentages of taxa reflecting savanna vegetation based on Radial Based Functions interpolation method. The interpolated area corresponds to the area delineated in Fig. 1b. Selected time slices range from 1000 to 4000 14C yr BP.*

4. ANALYSIS

By implementing the logistic regression model into GIS, the weaknesses of the model become evident. It is in this part of the ecological modelling that the usefulness of GIS is shown, seeing that the spatial patterns of the models are directly compared to the true land-cover patterns. Not only can the interpretation of the pattern of errors, contribute to an improvement of the model, but far more to an understanding of the responsiveness of the land-cover to different environmental conditions and therefore to the system as a whole. By a spatial analysis in GIS of this Colombian savanna model, the deviating predictions due to the influence of the total annual precipitation, the fire occurrence and human interference in the natural system are shown.

Comparing the resulting maps of different interpolations methods used (Fig. 2 and 3) shows that locations of pollen sites should be more evenly distributed over the study area to be able to improve the understanding of the geographical migration of land-cover boundaries in space and time with the help of GIS interpolation methods. Linear transects are better suitable for research areas with an altitudinal gradient where vegetation is migrating along slopes. The relevance of information on the modern pollen rain to understand the local conditions of a palynological research site, becomes strongly evident.

The combination of GIS with palynological data can further employed: to improve of site-specific information (e.g. matching estimated coordinates with satellite images), to locate potential drilling locations and to enhance the visual presentation of research proposals and/or results.

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Developing a Seabed Resurvey Strategy:

A GIS approach to modelling seabed changes and resurvey risk

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1. Introduction

The application of GIS systems to environmental contexts is well established with a multitude of examples (see Goodchild *et al*, 1993). It has only recently been applied in coastal and marine environments, which present challenges due to the dynamic nature of the spatial and temporal environment, the lack of data and issues of accuracy and scale (Wright and Bartlett, 2000). It still has not been utilised to evaluate the forces that determine sediment transport in connection with the volume moved, the resulting changes in the seabed morphology and relevant application factors. Examples of potential applications include maintaining navigation safety and evaluating risk to offshore cables and pipelines.

Sediment on the seabed is in a constant state of flux as a direct response to the forces exerted by hydrodynamic, meteorological and physical conditions in the form of tides, storm surges and waves. The amount of sediment material that is moved is further influenced by the physical characteristics of the sediment and water column. Therefore an understanding of the transport characteristics, seabed morphological response and interaction with factors specific to an application (such as coastal population density) is frequently required for planning and management decisions in the marine environment.

The problem directly addressed by this project is that faced by bodies responsible for resurveying areas of seabed to maintain navigation safety in British territorial waters. Survey areas and re-survey frequencies are currently determined from qualitative knowledge of sediment movement and navigation intensity (IHMC, 2004) and there is a need to quantify this approach so the information can be ascertained more easily by an end-user.

2. System Development

A survey decision tool has been developed which dynamically couples a GIS (ESRI ArcGIS) to a numerical sediment transport model (SEDTRANS05), a current model (POLPRED) and a wave dataset for the West Gabbard wave buoy (obtained from the WaveNET service). The methodology employed utilises the GIS as the principle mechanism to undertake the morphological modelling and navigation risk assessment to enable a re-survey decision. The GIS is used to acquire the modelling inputs, initiate the sediment transport calculations, distribute the calculated sediment flux to predict bed height changes, analyse the risk posed to navigation and visually display the results.

In order to evaluate the functionality of the tool it has been applied to a study region off the east coast of Norfolk between Caister-On-Sea and Orford Ness, within a bounding box where the coordinates for the northeast and southwest corners are 52.736N, 2.475E and 52.065N, 1.556E (WGS 84) respectively, Figure 1. The seabed within the selected site comprises of a number of sand banks and deeper channels; the analysis was undertaken for the period between March 2001 and June 2004.

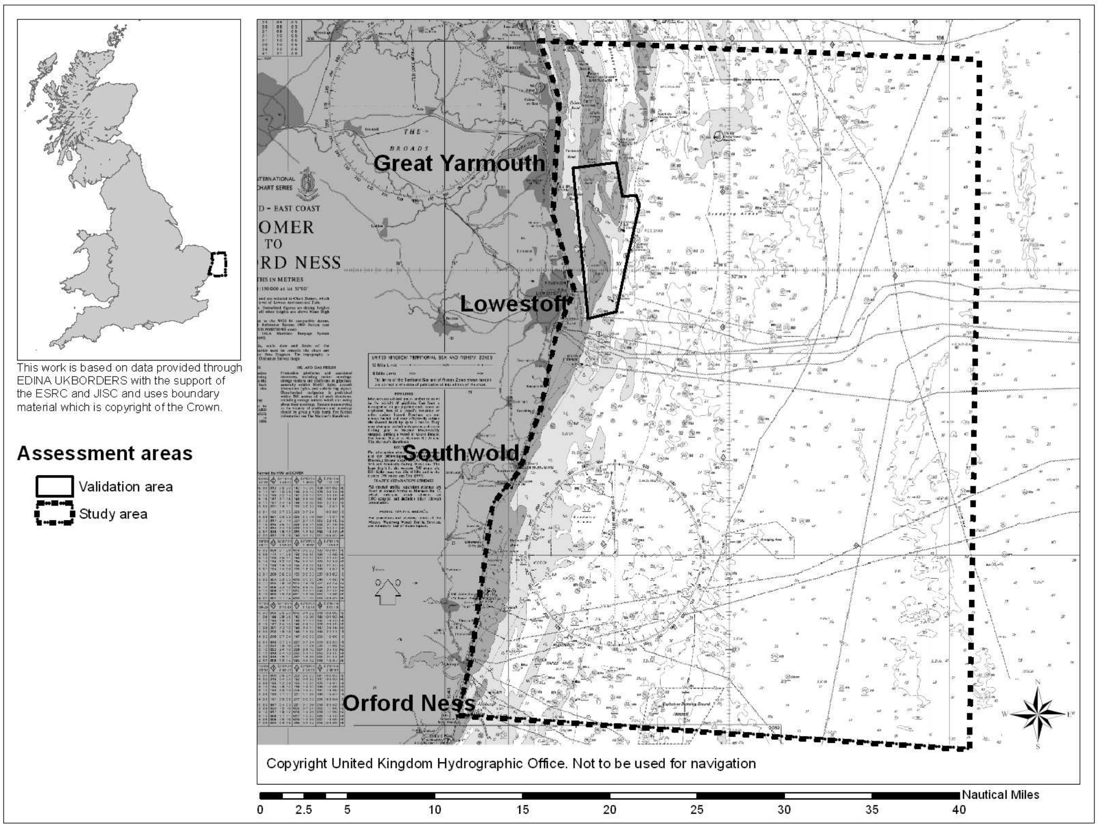

Figure 1: Study and validation areas in the Southern North Sea.

A fixed grid spatial data structure was used to represent and acquire the input data necessary for the sediment transport calculation. The data required included the current height, magnitude and flow direction from POLPRED, wave period, height and direction from the wave dataset, seabed depth from bathymetric data of the site and seabed sediment characteristics from a geology chart. Due to the point-based nature of SEDTRANS05 the flux prediction was calculated on a cell by cell basis. Tests within the GIS were then used to query the flux direction and then relocate the sediment between cells updating both the loosing and receiving cells with the resulting volume and seabed height. In addition checks were used within the tool to update the seabed height input into the transport calculation when the height of any individual cell evolved beyond a defined magnitude. The transport calculation and redistribution were repeated at regular time intervals for the assessment period.

The modelled seabed bathymetry and height change, vessel draft and clearance characteristics were reclassified to obtain risk levels based on defined user criteria thereby enabling a standard across sites. Risk levels for the seabed change were determined by evaluating the seabed bathymetry with the predicted height change so that areas with a significant height gain and a relatively shallow water depth posed the greatest risk. The navigation risk levels were ascertained by comparing the seabed bathymetry with the vessel drafts, so that areas with low clearance beneath the vessel provided the greatest risk. The two risk datasets were then evaluated together to identify the locations that required re-survey because of the risk posed to navigation, which were displayed in the GIS.

3. Implementation Results and Validation

The results from the model identified localised sediment gain on the sand banks within the validation area. The sediment increase occurred predominantly above the 5m depth contour relative to a base reference at the top of the bank at 1m. Changes were also observed for the region between the 5m and 10m contours with gains and losses both occurring. The seabed below the 10m contour was dominated by loss in the seabed height, Figure 2a.

The locations predicted to experience change were assessed in relation to the seabed bathymetric data for the validation area observed from field surveys of the site. The results showed that the coupled seabed change model was correctly identifying locations in the real world that were undergoing change. However it was under-predicting the magnitude and lateral extent of the change, Figure 2. This is most likely due to the limitations of the model in that storm surges are not included as a hydrodynamic input and a single set of wave values are used to represent the wave activity in the study region instead of varying spatially. This is because storm surges are known to move large volumes of sediment in the Southern North Sea and the study area (HR Wallingford, 2002 and Van der Molen 2002). Additionally, wave characteristics evolve as they move into shallow water through shoaling and refraction thereby influencing the transport volume (Sleath, 1984 and Soulsby, 1997).

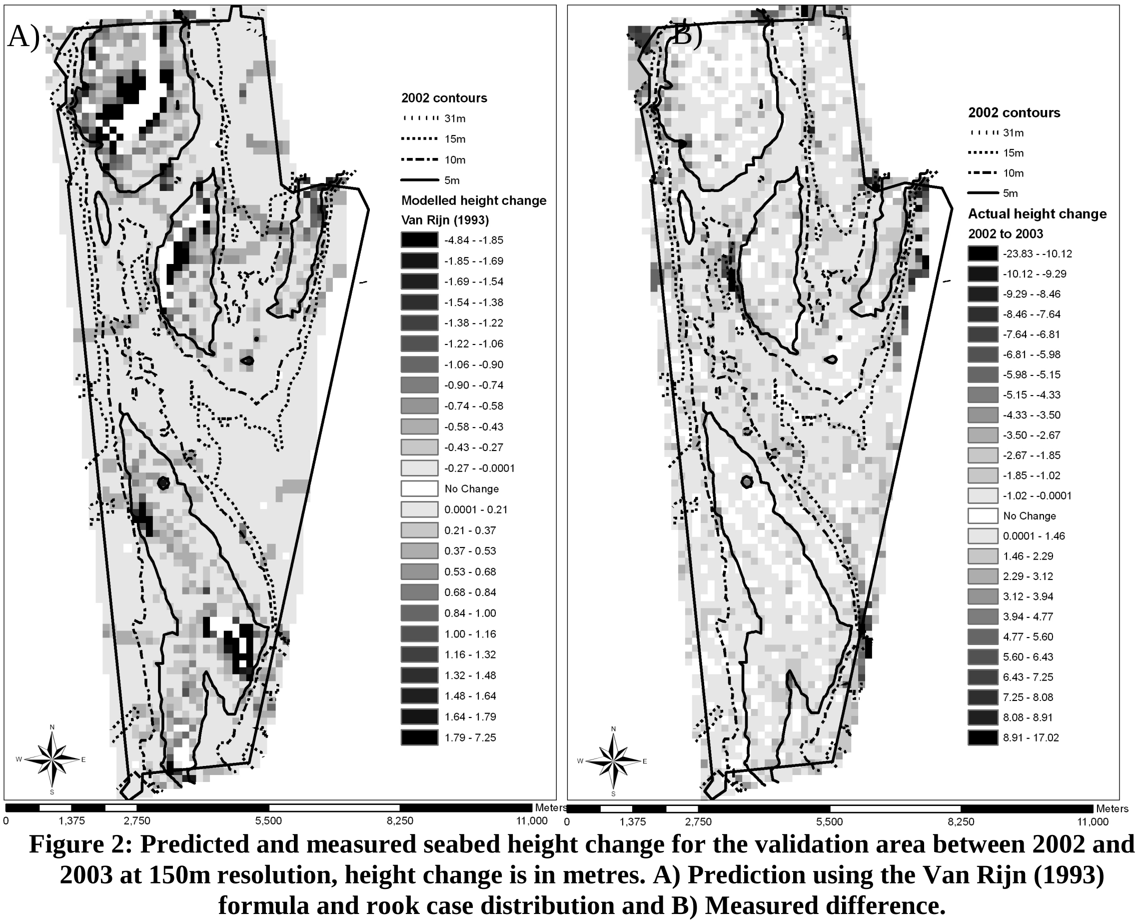

Figure 2: Predicted and measured seabed height change for the validation area between 2002 and 2003 at 150m resolution, height change is in metres. A) Prediction using the Van Rijn (1993) formula and rook case distribution and B) Measured difference.

Analyses of the locations identified for resurveying showed that the tool was also identifying the area of seabed that posed the greatest risk to navigation, which was between the 5m and 10m contours, Figure 3. However the decision tool was not identifying the full extent of the risk because of the under-predictions described earlier.

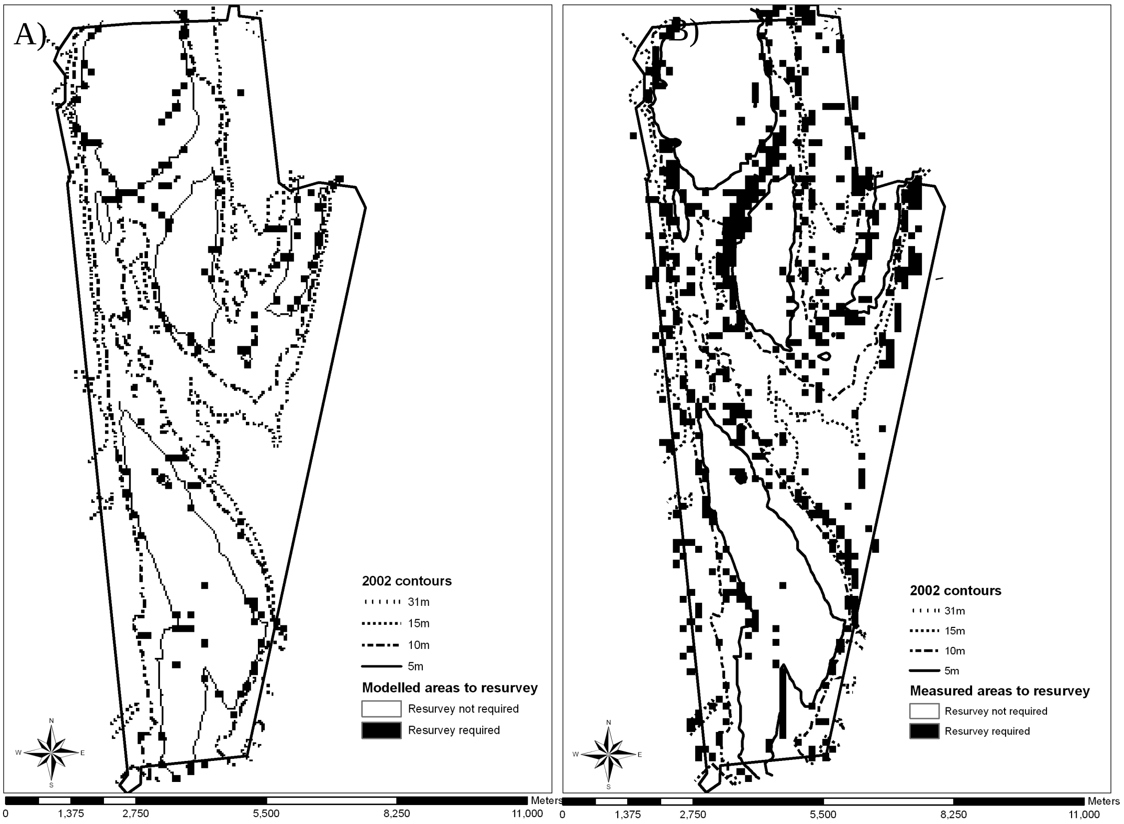

Figure 3: Seabed locations to resurvey based on A) predicted and B) observed changes in the seabed bathymetry, using the user-defined reclassification criteria.

A number of sensitivity tests were undertaken to evaluate the influence of input parameters on the prediction output which were assessed statistically. These included assessments of the sediment transport formulae, grid cell resolution, the prediction interval, sediment redistribution mechanism and the seasonal variation in transport.

- Five sediment transport formulae were investigated. The results showed that the Van Rijn (1993) bedload formula provided the best height agreement on the basis that it had the least statistical variance from the observed bathymetry.
- Two grid cell resolutions were evaluated, 500m and 150m (relating to the survey swath width). The latter provided a more accurate and precise prediction as the modelled result agreed with the observed change. Although the overall predicted degree of change was less than the observed, the height change value at the 150m resolution was only between factors two to five less than the observed case, Figure 2.
- Two time-step intervals were assessed, 3-hours and 1-hour. As anticipated the hourly time-step provided better results, which is primarily because less averaging of the tidal and wave characteristics occurred and the values were closer to reality.
- Two methods for sediment redistribution to the immediate neighbours of a cell using the direction calculated by the transport model were evaluated, namely the queen and rook cases for movement. The former involved sediment redistribution to one of eight neighbours surrounding a cell. In contrast the latter either moved sediment to a single cell or resolved the sediment flux between a pair of neighbours, thereby approximating a more realistic sediment flow across the seabed. Statistical analysis indicated that the latter approach provided marginally better results. This suggests that the under-prediction in the lateral extent of

seabed change is not solely due to the redistribution method and in turn implies that the representation of wave activity within the study area may be a significant contributing factor.

- The model accurately identified seasonal variation in the volume of sediment transported. The winter months (December to February) reported about half of the overall bottom change modelled for a year; this also coincides with research undertaken as part of the Southern North Sea Sediment Transport Study (HR Wallingford, 2002). Seabed height changes were also predicted in seasons 2 (March to May) and 3 (June to August) but to a lesser magnitude than season 1, while season 4 (September to November) modelled a similar pattern to the seabed change as season 1.

4. Conclusion

The coupling and analysis process undertaken during this project highlights the ability of the approach to predict sediment transport and change in bathymetry. However, the limitations of the results show the importance of accounting for surge and varying wave conditions, suggesting there is scope for further development.

The resulting survey decision tool and the outcome of the analysis indicate that a GIS is a viable and useful tool for managing and evaluating factors that determine sediment transport volume with issues specific to an application. In addition its capability to acquire and analyse disparate datasets and visualise the resulting outputs further supports its application as an end-user system in the marine environment.

5. Acknowledgements

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Biography

Anna-Marie Bakare is a first year doctoral student in the department of Geomatic Engineering (UCL). She holds a BSc (Hons) in Archaeology from the Institute of Archaeology (UCL) and an MSc in Geographic Information Science from the department of Geomatic Engineering (UCL). The research presented is a result of the MSc dissertation.

Extracting Dynamics of Multiple Indicators for Spatial recognition of Ecoclimatic zones in Circum-Saharan Africa

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1 Introduction

Focusing on ecoclimatic variations defined by the global physical and climatic conditions characterising arid and semi-arid zones the aim of this paper is to identify spatially the different patterns of ecoclimatic variations. For most of the indicators of arid or semi-arid zones, spatio-temporal variations through a typical year are observed . In order to take into account these dynamics in the clustering approach one must use a methodology that captures interactions between spatial-location, time of measurement and indicator measured. For this purpose a multiway analysis(Leibovici (2004)), generalising PCA, has been used on internationally recognised ecoclimatic indicators Lehouerou (2004, 1989) that characterise arid and semi-arid zones.

2 Clustering the dynamics of mutiple indicators

WORLDCLIM database Hijmans *et al.* (2005) (1950-2000, see www.worldclim.org/current.htm for the most recent one) at resolution 5 minutes of arc ($0.08dd$), was used to derive the necessary climatic parameters except for potential evapotranspiration of Penman-Monteih data provided from FAO. All the parameters were averaged for each month over 50 years in order to ensure large stability of the results in first approximation ignoring inter-annual variations. From these parameters Table 1 lists the monthly versions of the classical indicators used in the analysis.

2.1 Capturing the dynamics features

To take into account the dynamics of indicators we need a methodology that allows analysis, synthesis and extraction of interactions between $spatial\text{-}location$, $measurement\text{-}times$ and $indicators\text{-}measured$. The method used is taking advantage of the tensorial

Table 1: 10 indicator variables used in the analysis

Indicators	*Description*
P_m	monthly rainfall (mm)
T_{max}	monthly maximum of temperature$(°C)$
T_{min}	monthly minimum of temperature$(°C)$
T_{ave}	monthly average of temperature $(°C)$
ETo_m	monthly potential evapotranspiration of Penman-Monteih (mm)
P_m/ETo_m	monthly aridity index
Alt_{ave}	average altitude for the pixel grid considered(m)
$dM2T_{nb}$	number of of dry months according to the criterion $P_m < 2T_{ave}$
$Q3_m$	monthly simplified Emberger's pluviothermal index $Q3$ $Q3_m = 3.43P_m/(T_{max} - T_{min})$ $(mm.°C^{-1})$
$dMETo_{nb}$	number of of dry months according to the criterion $P_m/ETo_m < 0.35$

structure of the data and can be considered as one generalisation of PCA for multi-array data: the method PTAk Leibovici and Sabatier (1998). It has been programmed as an R add-on package and is available online (Leibovici (2004), Leibovici (2007)). PTAk offers a decomposition similar to what is obtained from a Principal Component Analysis, but working on multiple-entries table (seen as tensors), instead of matrices. In our current case there are three entries: *spatial-location*, *month*, *indicator*, and each cell of the table contains the value of one indicator for a given month at a specific location. In order to describe the generalisation proposed with PTAk model let us first rewrite the PCA method within a tensorial framework.

For a given matrix X of dimension $n \times p$, the first principal component is a linear combination (given by a p-dimensional vector φ_1) of the p columns ensuring maximum sum of squares of the coordinates of the n-dimensional vector obtained. The square root of this sum of square is called the first singular value σ_1. One has: ${}^t(X\varphi_1)X\varphi_1 = \sigma_1^2$ and $X\varphi_1/\sigma_1$ is the principal component normed to 1. This maximisation problem can be written either in matrix form or tensor form:

$$\begin{aligned}\sigma_1 &= \max_{\substack{\|\psi\|_n=1\\ \|\varphi\|_p=1}} ({}^t\psi X\varphi) = \max_{\substack{\|\psi\|_n=1\\ \|\varphi\|_p=1}} X..(\psi\otimes\varphi)\\ &= {}^t\psi_1 X\varphi_1 = X..(\psi_1\otimes\varphi_1)\end{aligned} \tag{1}$$

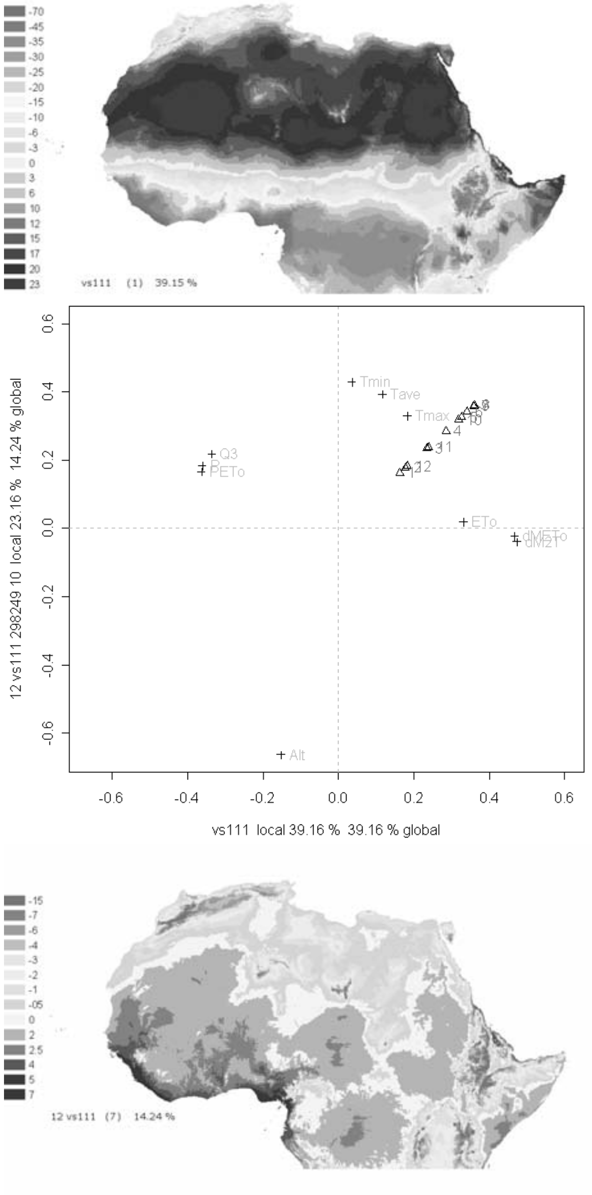
In equation 1 X is used either for the matrix or the tensor. An easy way of understanding computationally the operators ".." and "$\otimes$" is to see them as the following operations: $\psi_1\otimes\varphi_1$ is a np vector of the n blocks of the p vectors $\psi_{1i}\varphi_1$, $i=1,...n$; ".." called a contraction generalises the multiplication of a matrix by a vector, and in the case like here of equal dimensions of the two tensors (np), corresponds to the natural scalar product (X is then also seen an np vector). ψ_1 is termed first principal component, φ_1 first principal axis, $(\psi_1\otimes\varphi_1)$ is called first principal tensor. Now if X is a tensor of higher order, say 3 here with the modes: time or *month* ($t=12$),variable or *indicator* ($v=10$) and space or *spatial-location* ($s=298249$), we can look for the first principal tensor associated with the singular value with the optimisation form:

$$\begin{aligned}\sigma_1 &= \max_{\substack{\|\psi\|_s=1\\ \|\varphi\|_v=1\\ \|\phi\|_t=1}} X..(\psi\otimes\varphi\otimes\phi)\\ &= X..(\psi_1\otimes\varphi_1\otimes\phi_1)\end{aligned} \tag{2}$$

Adding an orthogonality constraint allows to carry on the algorithm. Following a recursive algorithm scheme Leibovici (2007) the decomposition obtained offers a way of synthesising the data according to uncorrelated sets of components ordered by the percent of total sum of squares.

On figure 1 we have the plots of components ("loadings") of two different tensors. Temporal variations and ecolimatic variables associations, *i.e.* the $month$ and $indicator$ modes are plotted on the same scatter plot and their $spatial\text{-}location$ mode component can be read simultaneously to explain the variability captured. For the tensor n°1 ($vs111$) one can see a spatial separation between the Saharan zone positively weighted, with North Maghreb, Sahelian zone and central Africa negatively weighted. This appears mainly like a latitude gradient North and South from the Sahara. This is associated with the opposition on one side of drought and extreme dry condition indicators (ETo_m, $dM2T_{nb}$, $dMETo_{nb}$, $Tmax$) and on the other side rain related indicators ($Q3m$, Pm, $PETom$) ; and this occurs all year around, and especially during rain seasons (May(5) to October(10)). The vertical axis on figure 1 shows an opposition between Altitude and temperature ($Tmin$ more strongly) also persistent all year and more likely during rainy seasons (May(5) to October(10)). This vertical axis is read with the bottom spatial picture showing high relief associated with it.

Figure 1: Spatio-temporal association of ecoclimatic indicators captured in the first principal tensor representing 39.16%(vs111) and on the first $month$ mode associated principal tensor representing 14.25% of variability.(*Labels of indicators are the first letters of the names given in Table 1; scatter plot and spatial values are the "loadings" or components values of the tensors*)

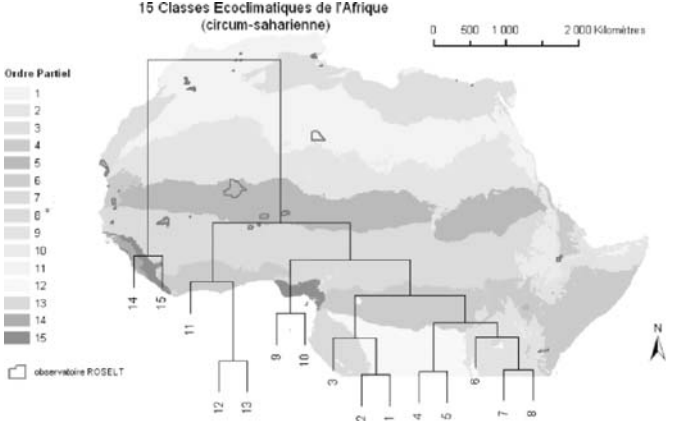


Other tensors will be shown at the conference expressing different spatio-temporal patterns altogether capturing various ecoclimatic aspects.

2.2 Ecoclimatic zones and their proximities

Once meaningful Principal Tensors are selected, it is possible to perform a multivariate clustering on the corresponding spatial components to obtain spatial classes of zones with similar ecoclimatic dynamics.Figure 2 shows the 15 classes we obtained with a $k$means procedure. In order to reinforce the ecoclimatic proximity of the classes obtained we performed a hierarchical clustering on the centroids of the classes. The dendogram obtained is also used to calibrate the colour range by matching it with a "pseudo" ordering of the classes read or computed from the dendogram history.

Figure 2: Ecoclimatic Classes with their aggregation tree illustrating hierarchical climatic proximities (based on WorldClim 2004 parameters) and 34 ROSELT pilots observatories polygons (Egypt(2), Tunisia(3), Algeria(5), Morocco(3), Mauritania(3), Cap-Verde(2), Senegal(3), Mali(3), Niger(4), Kenya(4), Ethiopia(2)).



3 Perspectives and Conclusion

The results are very encouraging but some issues may be relevant depending on the use of this classification. The ecoclimatic characteritics captured with the PTAk method would need physical process assessment for validation of the classification obtained at a biometeorological level . So far some experts including HN Le Houérou found coherence in the results but full validation in comparison with other known classifications has to be addressed. It is very interesting that the spatial coherence and homogeneity is well achieved with the herein method without any spatial constraint other than actual indicators measurements natural spatial multiple autocorrelation. Fuzziness of the borders can be addressed when dealing with ecoregion borders and some methods could be applied *a posteriori* Hargrove and Hoffman (1999), Hargrove and Hoffman (2002). Other fuzzy algorithms are available but the intensive computing needed for this massive dataset may preclude their use. Averaging initial parameters over 50 years for stability of results could be compared with an approach considering a more realistic range of different stable periods, say before 1970 and after at least. This modified approach would now consider adding a *period* mode, then a tensor of order 4 to analyse. PTAk can in fact decompose a tensor of any order (k>2). Some scale issues are relevant to this methodology either when looking at the available resolutions of the WorldClim data but also on the extent analysed.

4 Acknowledgements

The authors whishes to thank Henry Noël Le Houérou who showed a stimulating interest in this work and for helpful comments about the report Quillevere (2004). Warm thanks go also to Hélène Fonta who finalised an atlas Fonta (2005) available online within http://mdweb.roselt-oss.org and containing maps issued from this methodology also at National levels.

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Biography

Dr Leibovici has a PhD in Applied Mathematics from the University of Montpellier and worked for some years as a Statistician Researcher in epidemiological and medical imaging contexts in France and in England. More recently after completing a Masters degree in Information Technology he worked in geomatic modelling for landscape changes at the IRD (Institute of Research for Development) in France.

Understanding Disaster Risk on Volcanic Islands: a Research Agenda

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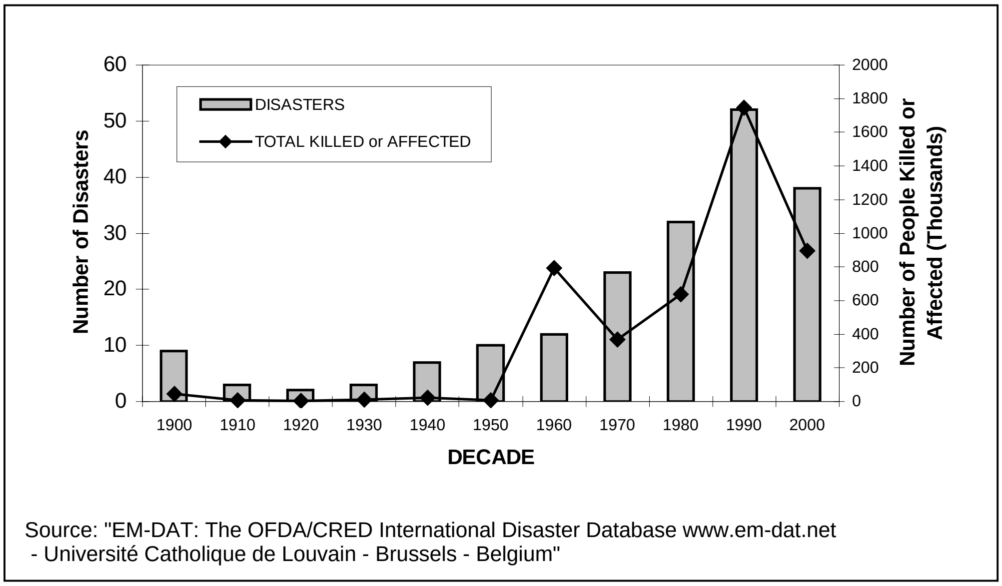
1. The significance of natural disasters

Disasters as a result of natural hazards are increasing in frequency and having a greater impact on populations and economies worldwide (World Bank, 2005, ISDR, 2004, Emergency Disasters Data Base). Therefore it is imperative for scientists and practitioners in hazardous areas to have a better understanding of the causes of disaster risk, and improved tools for assessing its impact on vulnerable populations.

This paper describes the creation of an operational tool for improved volcanic vulnerability and risk assessment. The research takes a multi-disciplinary approach creating a more comprehensive assessment of risk, taking into account the physical exposure of buildings and infrastructure to volcanic hazards, in addition to the social, economic and cultural characteristics of the population living in the hazardous areas. This research is being carried out in partnership with the emergency managers and planning officials at two study sites, in an explicit attempt to involve the end-users of risk assessments and to accommodate their views as to what information may be practical and useful.

According to CRED (Centre for Research on the Epidemiology of Disasters, 2004) over the last 30 years more than 5.1 billion individuals have been affected, of which 182 million were made homeless, and more than two million people have been killed by 6,367 natural disasters. These disasters have led to accumulated losses of US$1.38 trillion, all arising from interaction of natural hazard events with the human and economic elements exposed to the damage. Given that the frequencies with which events arising out of geological natural hazards appear to be constant, the increase in the numbers of disasters is attributed to people and places becoming more vulnerable (ISDR, 2004). This trend in increasing numbers of disasters is evident when considering volcanic eruptions, illustrated in figure 1.



Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium"

Figure 1: Number of Volcanic Disasters and People Affected 1900-2006

2. Disasters and risk

A disaster is the materialisation of risk: however, there is little consensus as to how to define risk and what elements should be included in its calculation. There are two main schools of thought with regards to studying disasters and risk– the technocratic approach and the vulnerability approach. The technocratic approach, according to Hewitt (1983), seeks to manage risk in three ways:

1. to anticipate and hence contain the extremes of nature through environmental engineering works (e.g. flood embankments);
2. to monitor and model extreme geophysical events; and
3. to create disaster plans and emergency responses.

The technocratic approach is hazard-focused, and aims to reduce disaster losses through control of the natural environment. In contrast, the vulnerability approach is people-focused and concentrates on the social, economic, political and cultural characteristics of people that make them more *vulnerable* to loss from a natural hazard event. The vulnerability view emerged in the 1970s from social scientists, particularly those working in developing countries, who had become frustrated at the slow progress in reducing disaster losses through the then dominant, technocratic approach.

The technocratic approach is evident in many national and international policies on natural hazards and disasters. For example the 1990s United Nation's International Decade for Natural Disaster Reduction (IDNDR) was very techno-centric in its approach during the early years. This is perhaps unsurprising as the initiative was the work of natural scientists from the outset. The initial focus of the IDNDR was to reduce disaster losses through the transfer of technology and methods from developed to developing countries (Chester et. al., 2002).

In addition, individual volcanic risk and vulnerability assessments have traditionally followed the technocratic approach. If vulnerability measures are included at all, they represent the physical vulnerability of buildings and people (e.g. Pomonis et. al., 1999 and Spence et. al., 2005). More recently, the principles of a bottom-up, societal approach have been integrated into volcanic disaster management. For example Dibben and Chester (1999) complemented the physical vulnerability assessment of Furnas Volcano in the Azores (Pomonis et. al., 1999) with a human vulnerability assessment.

This paper describes a new approach to assessing the risk factors that underlie volcanic emergency management. Key to this task is our ability to quantify risk in potential disaster settings. The Royal Society (1992) specifically define risk as *"the chance in quantitative terms of a defined hazard occurring"* (p. 4: emphasis added). The problem lies in devising methods of assigning values to a risk – e.g. driving above the speed limit – and the rewards associated with accepting this risk – e.g. arriving somewhere on time. In addition to this, how are risks compared? The example Adams (1995) uses is for road traffic accidents. How many dented bumpers equal one death on the road? (p. 22). Despite these limitations, scientists and policy makers continue to quantify risk, often to provide information for decision-making. For example, Soufriere Hills volcano on the island of Montserrat in the eastern Caribbean has been erupting since 1995, and scientists quantify risk using a combination of expert elicitation methods for probabilities of hazard occurrence with Monte Carlo simulations of risk to the population (MVO, 2006). The levels of risk to an individual living in different areas of the island are expressed in terms of the Chief Medical Officer's Risk Scale, which was originally devised for use in the health sector in the UK. Risk exposure levels are described by seven categories ranging from negligible to unknown, each with a numerical estimate attached, such as *High Risk - greater than 1 in 100 chance of event occurring* (p. 37).

The methods of quantitative risk assessment described above deal only with the likelihood of death, and do not answer the question of why people in certain areas suffer greater losses in a disaster than other areas despite apparently having equal risk exposure. To address this, one needs to examine individual houses or communities through some kind of vulnerability analysis. There is a vast amount of work by NGOs undertaking vulnerability and capacity analysis (VCA) at community level (e.g. Davis et al., 2004). These identify the characteristics of a community that increase their vulnerability to a natural hazard event, for example, seasonal employment in agriculture, and the factors that increase their ability to adapt and cope in a disaster, such as social networks.

3. GIS and quantitative risk assessment

Despite a large number of individual VCAs in a variety of locations there is still no consensus as to what characteristics of populations and places make them vulnerable, no standard methodology for undertaking VCAs and little with respect to how to quantify vulnerability indicators to be included in a risk assessment. This is where GIS is emerging as a useful tool.

One example of where GIS is key to a methodology to quantify vulnerability is the Social Vulnerability Index (SoVI) (Cutter et al., 2003). The authors used county-level census data in the United States to construct an index of vulnerability to environmental hazards and mapped the results to show counties with higher or lower vulnerability relative to a country average. Additional studies have combined social vulnerability data with hazard data to understand the geography of 'place vulnerability' (Cutter et al., 2000).

The research described in this paper has adapted these methodologies outlined by Cutter and tested the feasibility of using a GIS to map vulnerability and risk on the volcanic island of St. Vincent in the eastern Caribbean. A similar method to SoVI was adopted where the 2001 census was used to create 14 vulnerability indicators, which were mapped by census division. This vulnerability map was combined with volcanic hazard data for the island to produce a risk map using raster math and the simple equation *risk = hazard x vulnerability*. Further work is refining the vulnerability indicators and designing a risk equation based on the views of stakeholders at the two study sites.

A GIS has been chosen for this work for a number of reasons, specifically:

1. hazard, vulnerability and risk all have strong spatial components that can be displayed in a GIS; and
2. disasters are multi-dimensional, multi-disciplinary phenomena; therefore GIS techniques such as overlay are well suited for the analysis that is needed when combining a variety of data – what Hewitt (1997) calls "*the map of risk*" (p. 40).

In addition, the uniqueness of volcanic hazards in particular lends themselves to display and analysis in a GIS:

1. as the extents of hazards are often known providing mapable locations that can be used to overlay with vulnerability; and
2. as a volcanic crisis unfolds, and hazard maps are altered in response to changing activity, so use of a GIS allows new data to be input and an updated risk assessment to be created with ease.

GIS have previously been used for volcanic hazard and risk mapping (Lirer and Vitelli, 1998, Pareschi, 2002, Paleo and Trusdell, 2002, Gomez-Fernandez, 2000, Pareschi et. al., 2000). However, there are few methods for including the socio-economic vulnerability data into these maps that are crucial to a comprehensive analysis and decision-making tool. These studies highlight an additional problem - that of GIS use being largely restricted to wealthier countries (Davis, 2004). GIS software is becoming more widely available in developing countries, yet it is not utilised fully due to problems of a lack of time, training and expertise. Many tasks utilising a GIS are contracted out to external consultants. This research is addressing this problem by creating a simple tool designed around the user that takes into account:

1. the stakeholders understanding of hazard, vulnerability and risk;
2. the data available on the island; and

3. the purpose of undertaking the risk assessment – i.e. decision making for emergency management and planning.

The two study sites where this tool is being developed are the volcanic islands of St. Vincent and Dominica in the eastern Caribbean.

4. Consolidation

The importance of this research lies in the way in which it integrates the traditional natural science view of risk with the social science view that takes into account population characteristics, and in the design of a tool that is based around the user. This paper describes how this is likely to lead to the creation of more comprehensive risk assessment on small volcanic islands. In addition, this should allow local officials to be self-sufficient, both in pre-disaster planning and in crisis management, and allow realisation of the advantages that many wealthier countries already have in using GIS for vulnerability and risk assessment.

5. Acknowledgements

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Biography

Catherine Lowe is a PhD student in the Department of Geography and the Benfield UCL Hazard Research Centre at UCL. She holds a BSc (Hons) in Environmental Science from the University of East Anglia and has spent a year at the University of Oregon, USA (Geological Sciences). Having gained experience working at volcano observatories In both Montserrat, and Mexico, she completed an MSc GIS (Distinction) at UCL

A Framework for Network-based Vehicle Navigation Systems

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1. Introduction

A Vehicle Navigation System (VNS) is a driving assist system that combines digital maps, vehicle position, route optimization, route guidance, and other technologies. It is one of the most important components of advanced traffic and traveler information systems in Intelligent Transportation Systems (ITS) and is an important application and research field in Geographic Information Systems for Transportation (GIS-T) (Goodchild 1998, 2000).

With the increasing popularity of Global Position Systems (GPS) in the civilian market, automated vehicle navigation systems (AVNS) gradually occupy the market. Nevertheless, a VNS based on static road network has obvious deficiencies, such as 1) lack of up-to-date road network and real-time traffic information, 2) navigation without the consideration of changes of traffic and road network information, and 3) lack of the ability to interconnect with other service networks. In China, the requirements for solving traffic jam are becoming increasing prominent. Therefore, it is necessary to integrate vehicle navigation, wireless communication and network technologies for the development of a network-based vehicle navigation system, called as Network based Vehicle Navigation Systems (NVNS) (Li and Li 2001).

In this paper, we propose a framework for NVNS and elaborate two key technologies, namely the incremental updating for navigation data and the integration of real-time traffic information with road network, which are two fundamental functionalities in a NVNS. Finally, a prototype based on the proposed framework is illustrated and discussion is given at the end of this paper.

2. A Framework for Network based VNS

We propose a framework for network based VNS as illustrated in Figure 1. Four components are encompassed in the proposed framework, namely, the content supported layer, the service center, the communication layer, and navigation terminals.

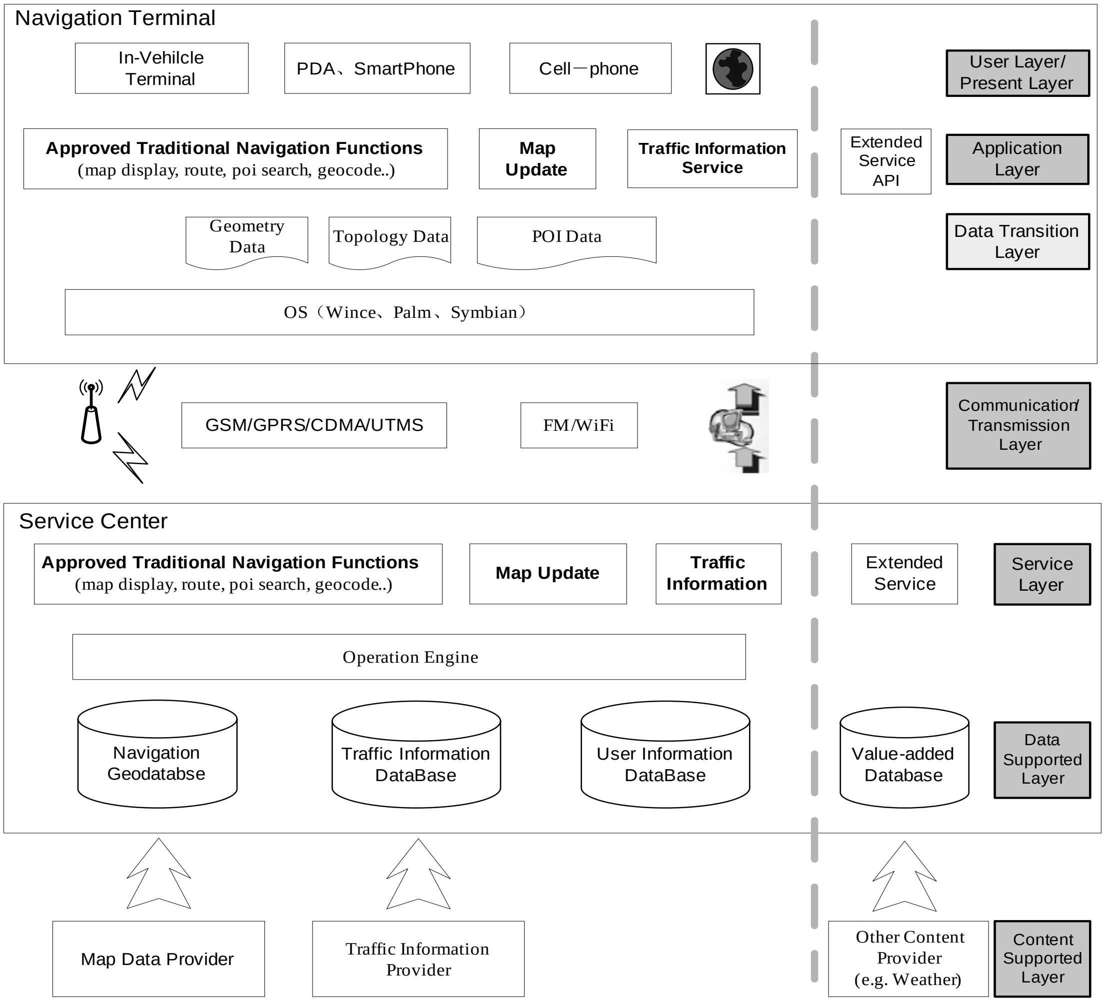

Figure 1. The framework of a network-based vehicle navigation system

1) The Content Supported Layer
This layer is the interface between the navigation service center and the content provider.

2) The Service Center
The Service Center is a distribution and processing center of all navigation information. Based on a navigation map database, it provides comprehensive navigation services, such as data management, information disseminating, and Location based Services (LBS). It is a "Server" for navigation terminal, and consists of data supported layer and service layer.
3) The Communication Layer
This layer is a link between service centers and mobile terminals to provide communications and data transmission channels.

4) Navigation Terminals
Navigation terminals are “Customers” for the service center. “Customers” could download necessary data by a "push" or "pull" mode. Therefore navigation terminals can use the latest navigation map data and obtain various navigation services form the service

center. Navigation Terminals have a strong scalability and consist of data transition layer, the application layer, and user / performance layer. The data transition layer represents the navigation map data stored in a navigation terminal. The application layer provides a range of navigation functions and some personalized functions. The User/Presentation Layer combines different modules provided by an application layer to meet the requirements of different users.

Why the data layer in the navigation terminal is called "transition" is that under the conditions of the existing wireless technology, only relying on data obtained from the server is unrealistic from the point of view of speed and economy. But with the development of communication technology, this transition layer will disappear, particularly in topology data and Point of Interest (POI) data.

Several functionalities were implemented in the proposed system architecture according to ISO/TC204 WG3 standard, such as *Route Planning and Route Guidance, Map Display, POI Search, Positioning, Dynamic Update of Digital Map, and Real-Time traffic information service.*

3. The implementation of key techniques

3.1 The incremental updating for navigation digital maps

An up-to-date navigation digital map is the basis and key component of a navigation system. We propose a new mechanism for the updating of navigation digital map, called the incremental updating (Xu et al 2006). The difference between the incremental updating and the traditional updating is shown in Figure 2.

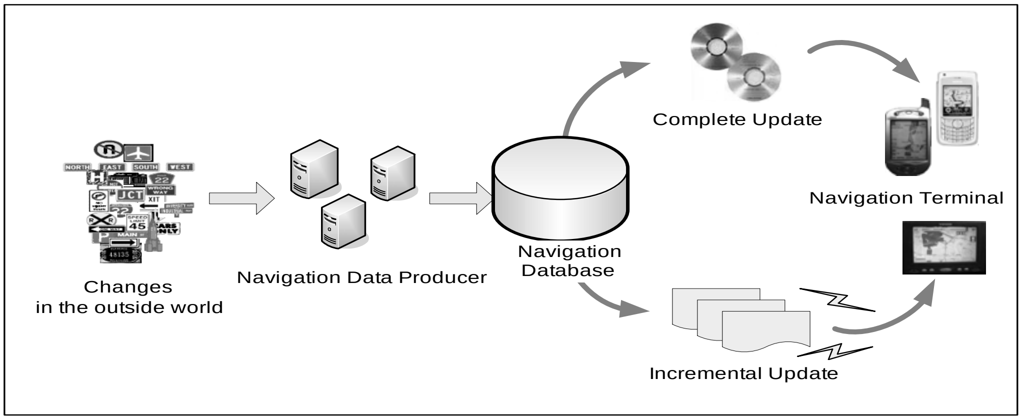

Figure 2. The difference between the incremental updating and the traditional updating

The so called increments refer to the new changes from the last update to the present data, including new data, deleted data and revised data. Corresponding to the real world, it can be represented as a new road, an expanded road, or removal of an inn. Therefore, whenever the map data are changed, the incremental map data update method would transfer new increments caused by the changes to the end users in wired or wireless networks so as to achieve the updating tasks for the stored navigation data by the mobile user.

To implement the incremental updating for entire map dataset, we design some strategies targeting at the special needs of dynamic updating as well as the characteristics of navigation data. It can be described as follows.

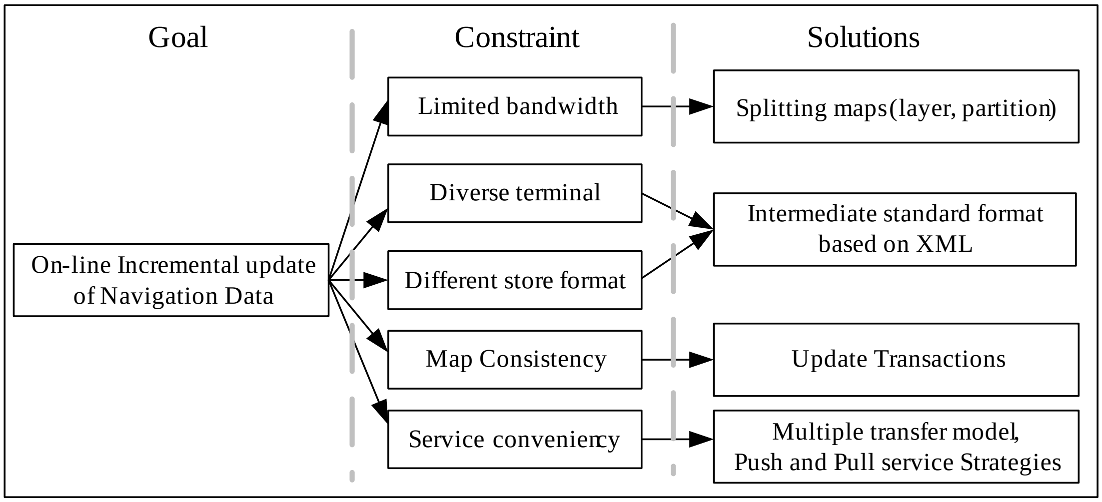

Figure 3. Incremental updating strategies

1) Splitting maps: An incremental update of a complete map with one month of changes may also grow in the orders of Megabytes. Size reduction is therefore of vital considering the limited wireless communication channel. One method for size reduction is to split a map in smaller blocks, which can be updated separately.

It makes sense to split the map data in parts (layer) that are used by different applications. E.g., the map matching needs only detailed road information around the vehicle, whereas the route planner needs a more global road network for a large area.

In most cases the in-vehicle applications only need an up-to-date map for a limited geographic region. Therefore it also makes sense to split the map data into geographic regions (so called partitions), e.g., based on administrative region.

2) Intermediate standard format: Every update supplier and update user has its own proprietary format to organize and store its map-related data. A standard intermediate standard format must be introduced to deal with a multitude of proprietary data formats.

GDF (Geographical Data File) 4.0 is a widely used ISO standard which includes navigation data model and data exchange format. We define intermediate standard format defining all kinds of changes based on GDF. Besides, the extensible marked language (XML) can be used to describe and exchange data taking into account the diversity of mobile user terminals.

3) Update Transactions: It is important that, after processing of a set of updates, the in-vehicle map can be used again by the applications, that it is still consistent.

Corresponding to one change in the real world, there can be a sequence of update operations. (e.g., Adding a new intersection means interrupting the original road data, then inserting a cross point, and re-constructing the road network topology at last.) These operations need to be processed all before the map is consistent again. Learning from DBMS, we can group this sequence into one update transaction. That means all these operations have either done or not done.

Updates must be assigned to a layer and a partition. However, there can be dependencies between layers or partitions that make it necessary to update more than one piece of the map to keep the whole map consistent.

4) Multiple Service Models: For the convenience of users, we will provide a wide range of services model.

Push model is based on the publish/subscribe/distribute paradigm. In this model, the service center first advertises what it supports, and what notifications it can send; the user then subscribes a client to the data he is interested in, specifies how often this client should receive this data, and disconnects. Then, the data provider takes the initiative to 'push' data to that client, either on a regular basis via a scheduler (e.g., for automatic updating) or asynchronously (e.g., to send notifications).

Pull model is based on the request/response paradigm, the client sends a request to the server, then the server answers, either synchronous or asynchronously. Therefore, information is sent to the user only if requested, so the client always initiates the data transfer.

In addition, it can be seen that the retrieval and receiving of the incremental data in the mobile user terminals are the critical components of the whole updating process. They are related to a set of complex theoretical and technical problems like the data model, data organization, the maintenance of data consistency. Now, our research group is conducting in-depth research on these problems.

3.2 The integration of traffic information and road network

Transportation network data can be categorized into two types, namely, static road network data and network-attached dynamic information (e.g. traffic flow, traffic accidents, moving objects et al.). A NVNS needs the support of dynamic information (Miller and Shaw 2001).We propose a transportation network model, which integrates road network data, traffic information and moving objects. The model is able to fulfill the following requirements, the multiple-representation/multi-layer abstraction of a road network, the representation of the temporal dependence on the transportation relations, and a uniform linear geo-reference framework based on node-arc structures. Figure 4 illustrates the basic principles of the data model, and further study is under way.

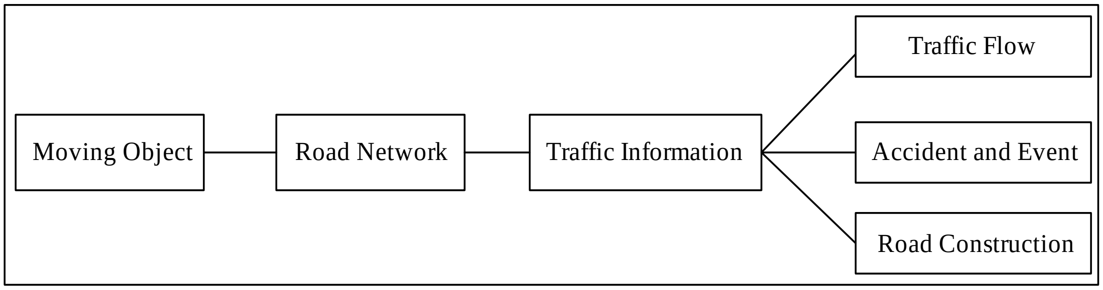

Figure 4. Integration of moving object, road network and traffic information.

4. The Design of Prototype

A prototype system is designed based on the proposed framework as illustrated in Figure 1. Figure 5 illustrates the data flow in the prototype system and the relationship between several subsystems.

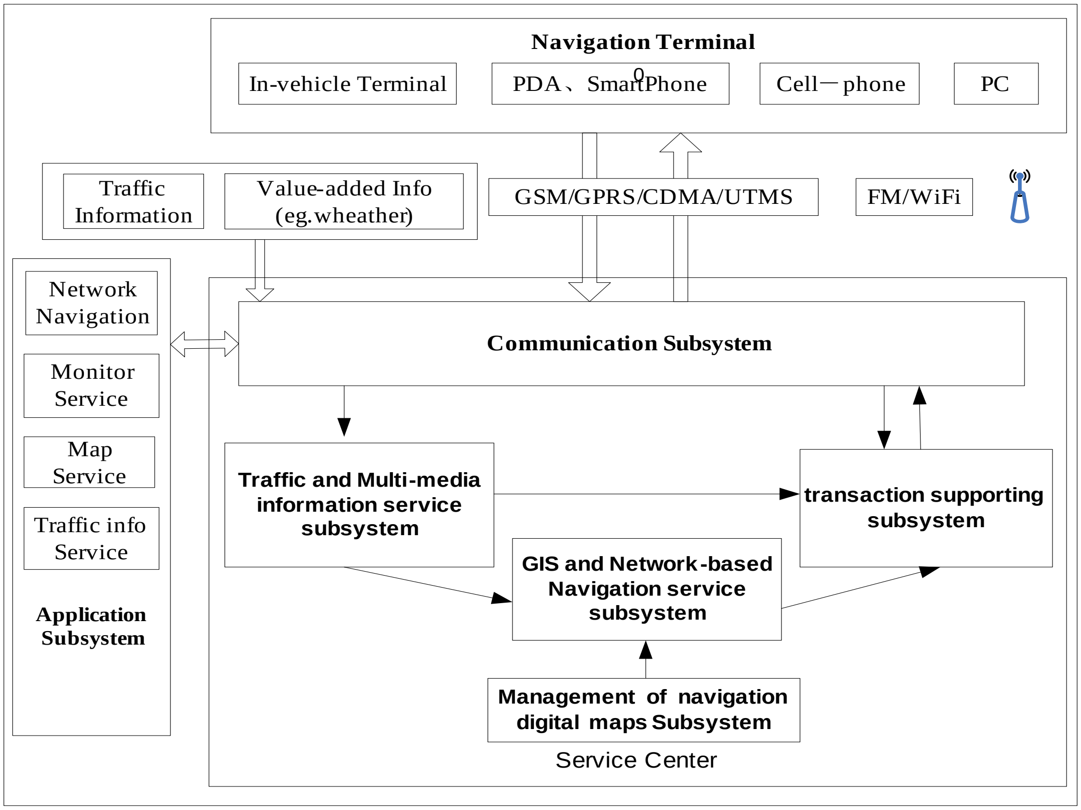

Figure 5. The data flow of the prototype system

5. Discussion

This paper analyzes the requirements of network-based vehicle navigation systems and explores the functionalities of a network-based vehicle navigation system. Then, a framework for the network based vehicle navigation system is presented and several fundamental functionalities are explored. Particularly, an incremental updating mechanism and the integration of road network data and real time traffic information are elaborated in detail. Finally, a prototype system is designed according to the framework.

A network based vehicle navigation system (NVNS) still faces many challenges. For example, personalized visualization for different users and terminals, dynamic navigation in a strange environment, high performance human computer interaction. We hope to present more progress in this project during the next GISRUK.

6. Acknowledgements

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Biography

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The application of Inter-Vehicle Communication system to ITS

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1. Introduction

Since the concept of ITS (Intelligent Transportation System) was put forward in 1991 by the U.S. Department of Transportation, it has been viewed as a promising way to tackle modern traffic problems. The creation of ITS depends on the integration of four components: travelers, control centers, intelligent vehicles and field infrastructure, which calls for effective communication architectures. To address the requests, U.S. came up with four communication systems as table 1: WAWC (Wide Area Wireless Communications, FFC (Fixed-point to Fixed-point Communications), IVC (Inter-vehicle Communications), and DSRC (Dedicated Short Range Communications). Among them, IVC is in the earliest research phase (US Department of Transportation, 1997).

Table 1. ITS Communication Architecture

	Travellers	**Control Centres**	**Intelligent vehicles**	**Field infrastructure**
Travellers	WAWC	FFC	WAWC	
Control Centers	FFC	FFC		FFC
Intelligent vehicles	WAWC		IVC	DSRC
Field infrastructure		FFC	DSRC	DSRC

Though many applications of IVC system have been identified, most researches have focused on the data transmission protocols (Kiyohito, 2001). On the other hand, how to further apply it to ITS, or the implementation of the application layer in the communication system, is rarely examined.

2. IVC

In an IVC system, vehicles form mobile ad-hoc networks and are communicated each other to get real time information, thus enable the driver to access information hard acquired or measured by on-board sensors. The study of IVC systems can be dated back to the 1980's. Since then some techniques as Internet, wireless LANs and GPS were not available, most of the proposed solutions are outdated. Besides, the main objective of early research was to enable data transmission between two vehicles, multi-hop systems were excluded (Fujimoto and Nakagawa, 1998; Yashiro and Kondo, 1993).

Recent research classifies IVC systems as single-hop IVC system (SIVC) and multi-hop one (MIVC) by whether or not the information is retransmitted at intermediate hops. SIVC can be used for applications like collision avoidance; while MIVC is suitable for those with long range communications, such as traffic monitoring, route guidance, and so on.

An IVC system has some important features. First, since it is highly distributed, it is greatly resilient to disruption and able to provide reliable information services. Second, no infrastructure is required. All needs are some IVE (in-vehicle equipment): CPU, wireless transceiver, GPS, system interface, memory, map data and certain sensors (depend on different applications). Moreover, its low delay on information satisfies real time applications, e.g. safety ones.

3. Applications to ITS

The intelligence of a transport system lies both in intelligent infrastructure and intelligent vehicles.

3.1 Intelligent vehicle

An intelligent vehicle can provide various assistances to driver. For example, collision notification, road warning, route guidance are typical applications, where IVC system plays an important role. In these applications, cars may disseminate information about collision or bad road condition, or local traffic information to other cars in a predetermined ZOR(zone of relevance, the area a data package should be sent to), either in event driven mode or in period one. In a route guidance application, the area of ZOR can be much larger than the first two applications, so that each car gathers enough traffic information on different roads to enable real time route optimization.

3.2 Intelligent infrastructure

Intelligent infrastructure is designed to deal with problems as emergency management, freeway management, etc. Traffic data collection and its processing are usually involved to decision making. The accuracy and efficiency of data collection are essential, especially in the case of traffic flow management. Various approaches for traffic data collection have been proposed, including fixed vehicle detectors, videos and probe vehicles (or so-called floating cars). Here the application of vehicle detectors is limited due to high investment costs. Probe vehicles could be good complement for fixed detectors, but their effectiveness depends on the right choice of the sampling area and sampling method.

Inter-vehicle communication, however, provides a new approach to the problem. In an IVC system, any vehicle equipped with IVE can work as a probe vehicle, without any other special equipment. It is due to the fact that each vehicle can receive real time data of the other vehicles like location, speed, acceleration. Thus it is capable of deducting accurate real time traffic information, at least within its vicinity. In a MIVC system, the known area can be large enough for traffic monitoring application. Then the information could be transmitted to roadside infrastructure or control centers for further data processing.

4. Key techniques

4.1 Data transmission protocol

As mentioned before, many efforts have been made in this area. Since there is no international standard yet, various schemes on each communication layers have been proposed. The choice of schemes usually depends on different applications, especially the routing and forwarding algorithm and the addressing strategy on the network layer.

4.2 Traffic modelling

Traffic modelling is crucial for a successful IVC application. A good model identifies necessary traffic parameters, including package contents to be transmitted among cars, transmission rate and frequency, ZOR and so on. Few work has been done in this area. Sihem and Mounir (2006) have made some efforts in similar sense, but only for collision warning application, which is far from enough. Most existing traffic modeling researches are for computer simulation purpose, like Victor and Benjamin (1994).

4.3 Data aggregation

An effective data aggregation strategy will not only decrease transmitted data volume and increase the network throughput, but also improve the accuracy and efficiency of the IVC system. For example, in an traffic monitoring application, the system concerns more about the speed of the traffic flow rather than a single car on that road segment. Here we propose a distributed segment-based data aggregation strategy which is employed by each car in the system.

4.4 Security and Privacy

It is essential to find the right balance between security and privacy of an IVC system once it becomes pervasive. However, very few papers have dicussed these issues, mostly for very specific problems (Hubaux and Capkun, 2004). More general security architectures are needed.

5. Experiment

The above mentioned techniques will be applied to an IVC system to deliver a typical ITS application, dynamic route guidance. Due to the cost and difficulties involved in deploying large vehicular test beds, we will evaluate their performance via a wireless network simulator JiST/SWANS, along with a mobility module for vehicles on city streets, STRAW. Since this research is based on our former work in multicast IVC protocol, a distributed robust geocast protocol will be employed in the simulation.

5.1 JiST

JiST (Java in Simulation Time) is a Java-based discrete-event simulator that runs over a standard Java Virtual Machine (JVM). In JVM's execution model, referred to as actual time execution, the application progress and the passing time are independent. In order to execute applications with more predictable performance models, real time execution model is introduced, in which the program's progress is dependent on the passing time. In simulation time execution, however, the time progress depends on the application one. The model is especially useful for evaluating the application performance where the consumed time is a key index.

By simulation development in a JiST environment, we can write normal Java codes, while it takes strict control of the advanced time via the sleep(n) system call. In essence, every instruction takes zero time to process procedures except sleep, which advances the simulation clock forward by exactly n simulated time quanta (Rimon, 2004).

5.2 SWANS

SWANS is a Scalable Wireless Ad hoc Network Simulator built, which is based on the JiST platform, a general-purpose discrete event simulation engine (Rimon, 2004). In an IVC system, vehicles (nodes) communicating each other form a wireless ad hoc network. And SWANS contains software components to form complete wireless network configurations. Different amounts of mobile nodes can be placed on a field and form a network configured by SWANS. Various IVC protocols can be employed and tested in SWANS to improve the efficiency of data communication in the network.

Our former work focused on developing an efficient protocol for the IVC system, and a distributed robust geocast protocol has been implemented in SWANS, which constitutes the basis of this research (Joshi, 2006).

5.3 STRAW

STRAW (Street Random Waypoint) is a mobility model for vehicular ad hoc networks, which constrains node movement to streets defined by map data and limits their mobility according to vehicular congestion and simplified traffic control mechanisms (David and Fabian, 2005). As an add-on module to SWANS, STRAW makes the modeling of vehicles more accurate and realistic.

The delivery of the application, dynamic route guidance, involves a lot of interaction with both SWANS and this module.

6. Acknowledgements

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Biography

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GIS based approach to Predicting Road Surface Temperatures

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1. Introduction

Treatment of transport networks of the winter period is a key responsibility of maintenance teams whether in the private or public sector. With tightening budgets and increasing statutory requirements, maintenance teams are looking to improve the treatment of networks by improving ice prediction techniques. Improved forecasting techniques leads to financial savings, reduction in environmental damage and degradation of road surfaces and reduces potential litigation cases.

The use of Network Forecasting has become a principal component in helping a highway engineer to make an informed decision on whether to grit a route on a given night. Traditionally this network forecast has relied on a thermal survey of the road network as a main input to a forecast model. Although recording actual surface temperatures thermal mapping is expensive and requires repeating to achieve a representative set of climate scenarios. Recent work in the field has seen a move away from thermal mapping to better categorise and model local climate conditions. Work by Thornes et al (2005) has described the use of GIS in this field yet the technique described still requires some form of manual survey – in the form of measuring sky view Factor and thermal mapping – as an input to their model. This paper outlines a GIS desktop based approach to surveying a route and the results of integration into Aerospace and Marine International's GRIP (Geographical Road Ice Predictor) model in recent trials held across the county of Hampshire as to the effectiveness of the methods used.

Ice prediction models have been developed in many countries where a temperate climate results in marginal temperatures - when temperatures are at or below freezing and a gritting run would be advised- at night. A variety of techniques have been developed with the aim of better predicting ice on road networks across the world.

Network forecasting models can be broken down into two key concept areas:

1. Temporal component that consists of a standard road weather prediction model. This uses forecast meteorological data to produce a *Road Surface Temperature* (RST) forecast curve.
2. Spatial component that uses geographical attribute data to modify the forecast curve on a site-specific basis.

1.1 Temporal Component

Thornes' (1984) model uses a zero-dimensional energy balance approach. The model uses standard 3-hourly forecast meteorological data to produce the 24-h RST forecast curve. This forecast is provided to the winter maintenance engineer at midday so that early decisions can be made regarding the salting of the road network. In the model a forecast for a particular night may be marginal with regard to temperatures – i.e. just below freezing. Should the surface receive an input of moisture, the forecast site will need salting, however, large sections of the road network will not. A sensitivity test of the model is described in Thornes and Shao (1991) and the temporal forecasting ability of the model is covered in Parmenter and Thornes (1986). Both studies indicated that Thornes' 1984 model has significant forecasting ability and compares favourably with other road weather models. The model used in this research is Davy's (2000) GRIP model which produces a forecast at higher frequencies – three instances per hour – and at finer resolutions - 100m spacing along a network.

1.2 Spatial Component

Davy (2000) first introduced a spatial component into the weather model by replacing geographical constants with variables. This work was further explored by Chapman et al. (2001b) who also added a spatial component to the Thornes (1984) model. In the original models, latitude, land use, and road construction were all constant. In Davy's GRIP model and the revised model described in Chapman and Thornes (2006), these variables along with altitude and traffic are parameterised.

2. Ice Prediction Forecasts

The aim of this research is to replace more traditional ice prediction techniques – in particular the surveying aspect used in these techniques - with a desktop model. By modelling the road network - and the surrounding area (a Road Canopy Model) - in 3D using a variety of new and well established GIS techniques this research has dispensed with the need for thermal mapping and sky view surveys as described in previous work by Chapman and Thornes.

Working with Hampshire County Council (HCC) provided an ideal opportunity to develop, test and refine the modelling technique and monitor the results in terms of forecast accuracy in a live trial. Using the inputs from the GIS model the forecaster was able to provide 20 minute updates via an internet mapping service to HCC, and predicted road surface temperatures to the highway managers – upon which they were able to make informed decision on whether to grit a route. An example of a forecast map from the night of the ninth and morning of the tenth of December is shown in figures 1a and 1b.

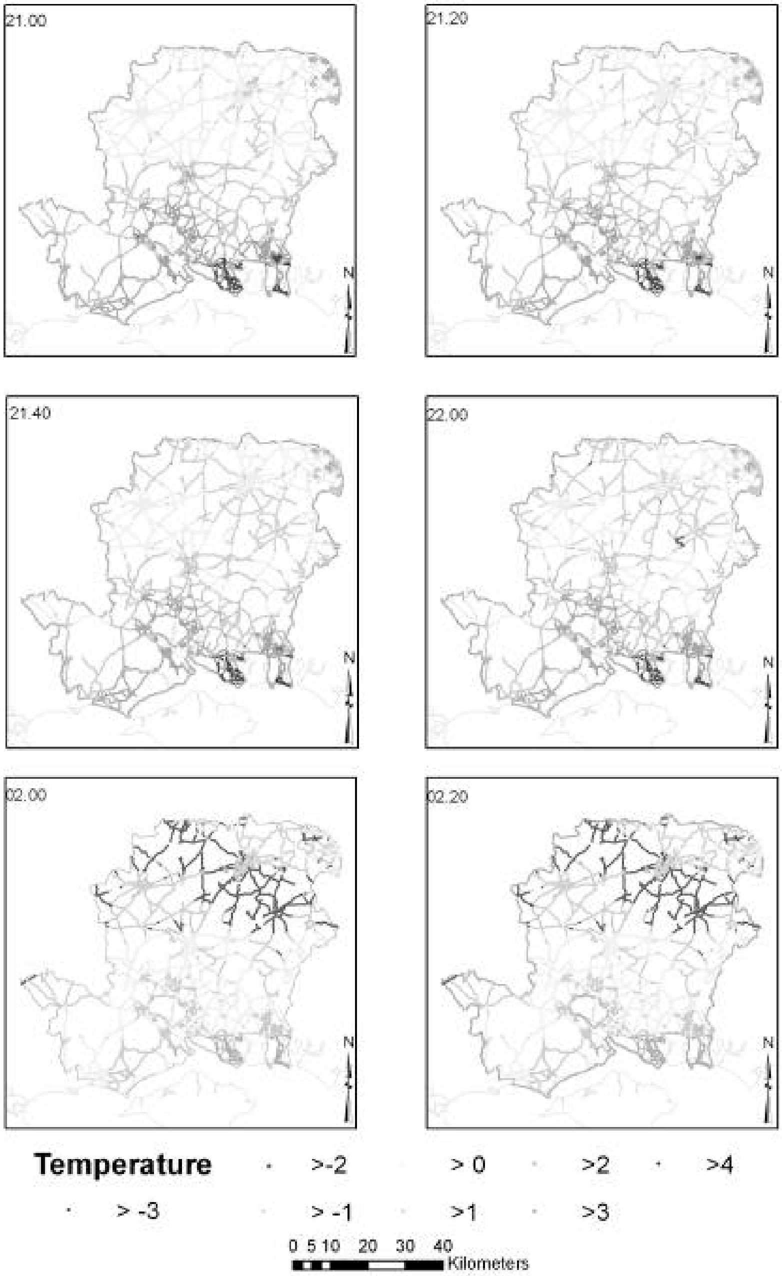

Figure 1a: Network Forecasts for the 9th/10th December 2006

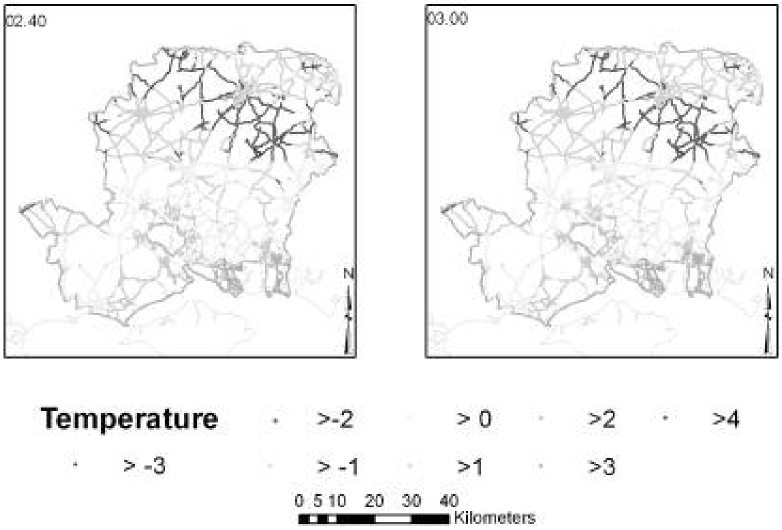

Figure 1b: Network Forecasts for the 9th/10th December 2006

Figure 2 shows minimum forecast RST plotted against actual minimum RST – as recorded by Wootton Weather Station - over a period of 22 nights in November and December 2006. Forecast errors may be divided into two types. Type 1 errors are defined as instances where the RST at monitoring stations falls below 0°C when the temperature was forecast to remain above 0°C. Type 2 errors are defined as instances where RST at monitoring stations remains above zero when the temperature was predicted to fall below 0°C.

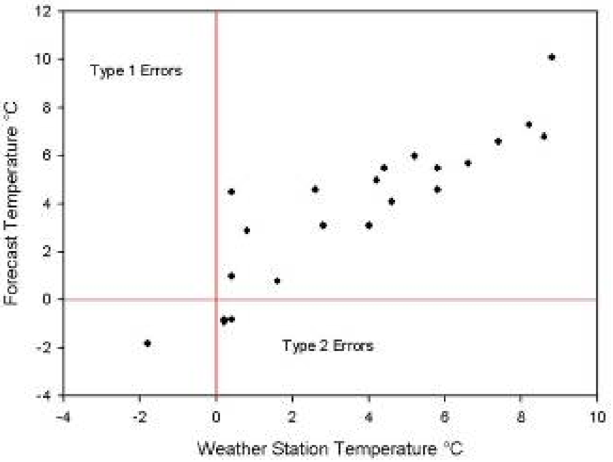

Figure 2: Minimum forecast RST plotted against actual minimum RST

Figure 2 also shows there are no Type 1 errors so far in this trial and only three type 2 errors. The forecast successfully predicted every marginal night from the sample of 22 nights. Current fieldwork will provide a wider range of temperature readings across the network and a larger sample to analyse. This analysis will be reported on in due course.

3. Conclusions and Further Work

The initial results from the Hampshire trials indicate that the GIS techniques used to create the 3D model can enhance, if not replace, the surveying techniques used in previous ice prediction models. The model has saved several unnecessary gritting runs already this season which will, given a continued reduction in unnecessary gritting runs, reduce the environmental impact of gritting, reduce road maintenance needs, reduce accidents caused by over gritting and ultimately save money.

However, the model is not perfect and with the increase in the quality and accessibility of spatial data, coupled with the improvement in GIS techniques and computing power, the accuracy of the model should increase.

Further work is being carried out on the technique outlined in this paper. These include trials in different counties, further validation of results and refinement in techniques. The main area of research focuses on improving the accuracy of the road canopy model and measuring the results of these improvements.

5. Acknowledgements

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Burning Algorithm for Route Planning of Multi-Mode Public Transport Networks

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1. Introduction

Effective public transportation is being paid more attention by transportation administration and travellers, since the increasingly terrible traffic jams in cities. Improving the efficiency of public transportation route planning is the focus of research of intelligent public transportation systems and location based services. With the wide operation of urban light railway, public transportation network changes from traditional single bus line networks into multi-mode public transport networks. Research of route planning algorithms based on multi-mode public transport networks is to address this new situation. However, this does not change the nature of the problem. That is to get the optimized route between two points. The restrictions still include number of transfers, travel time and cost factors. The difference in features of various public transportation networks must also be taken into account. Typical algorithms for route planning are improved Dijkstra algorithms and heuristic examples, such as A*. If the number of stations is large, the efficiency of Dijkstra algorithms decreases sharply. The key of heuristic algorithms is to describe and define an evaluation function and this will play an important role to obtain the final results.

There are two ways to improve the efficiency of the route planning algorithms. One is to improve these traditional algorithms. The other is to put forward new algorithms. This paper discusses the burning algorithm, which is a natural algorithm to improve the efficiency of route planning based on multi-mode public transport networks.

2. Features and modelling of multi-mode transport networks

We can summarize the features of multi-mode public transport networks as follows:

- The public transportation system includes many stations. For example, Beijing has more than four thousand different stations.
- The number of stations that have direct connections between lines is only small compared to the total number of stations. That means it is a sparse matrix.
- For the same mode of public transportation, the distances between neighbouring stations are nearly constant in the same area. Even if the distances are different in various regions, the travel time can be closer.
- Stations in different modes of public transportation have different distances between two neighbour stations.

- To reduce the cost in money and time spent on travel, the optimal route should minimize the number of transfers.
- For an individual journey, the maximum number of transfers should be less than 5.
- For route planning based on multi-mode public transport networks, the cost relies on the number of transfers and the distance.

Based on the above features, we can infer the form of a model for multi-mode public transport networks. The most important inferences are listed below:

- The distance between any two stations can be described as the number of stations between them.
- When looking for the optimal route with minimum cost, first consider the minimum number of transfers. Then minimise the number of stations passed through.
- The maximum number of transfers should be no more than 5.

3. Burning Algorithm

The Burning Algorithm is a kind of algorithm similar to point diffusion. It starts from one designated point and diffuses to adjacent connected points until it finds the other target. Originally, the burning algorithm is used in networks without weight. This allows it to be used in multi-mode public transport networks efficiently but with some lost of accuracy. However, the process is reasonable and effective in application. Since it takes human decision-making behaviour into consideration, it can provide more satisfactory service for end users. Before executing the algorithm, it needs to pre-process the data of the public transport networks. Traditionally, data of public transport networks is recorded as every route and the stations it passes. Here, we generate an adjacency table from the data. The table includes two structures. The head structure is like this.

VexName	FirstArc

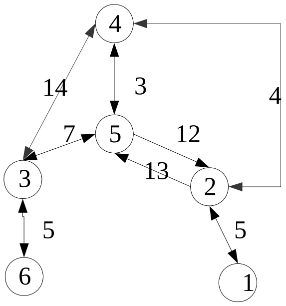
VexName is the identifier of the station and FirstArc is the pointer that refers to table structure of the other vertex in the first arc. The other structure is a table structure such as.

AdjVexID	NextArc	Weight

AdjVexID is used to record the other vertex ID in the arc. NextArc records the pointer of next arc. Weight is instead of the impedance of the arc. Its measurement is the number of stations. For different public transport networks, the travel time between adjacent stations varies. This research uses that typical of bus lines as the standard. Those of others modes are converted to accord with it. The algorithm procedure comprises six steps, as illustrated in the following example.

4. Application example

The example demonstrates the two typical situations in multi-mode public transport networks, static and dynamic. The application example illustrates the execution steps using figures and some explanation to show how the burning algorithm can be applied to multi-mode public transport networks. The basic multi-mode public transport networks of the example are as follows.



The goal is to find the shortest route. Most arcs refer to bus lines except arc 4, which represents a subway. For the dynamic situation, real-time data would be used to give the impedance of arcs. Based on the above networks, we can compare the burning algorithm with that of Dijkstra.

5. Comparison between burning algorithm and Dijkstra

It is critical to consider the computing efficiency of burning algorithm. In this research, Dijkstra algorism is taken as a reference. The comparison is made from four aspects: applicable range, accuracy, storage complexity and algorithm complexity. For calculating an optimized route between a pair of points, the algorithm complexity of burning algorithm is only $O(n)$ and that of Dijkstra is $O(n^2)$. If it wants to get all the shortest routes between every pair of points, the algorithm complexity of burning algorithm is $O(n^2)$ and that of Dijkstra is $O(n^3)$.

6. Conclusions

The method described uses the algorithm for transportation network with weights. Through analysis of the algorithm and the examples we conclude: burning algorithm is effective and efficient for route planning based on multi-mode public transport networks.

7. Acknowledgements

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Biography

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GIS Support for Sustainable Regional Transport System

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1. Introduction

Sustainability is a long term and strategic objective. Sustainable transportation planning on a regional scale can be divided into at least three levels: strategic, tactical (traditional four-step model) and operational (detailed) or alternatively macro, medium and micro, each with varied foci and functions but they will require different data and modeling detail. The strategic level of regional urban transportation planning is policy driven and works at an aggregate level of analysis. The policies that are normally implemented are aimed at the balance of transportation and land use on one hand and, on the other hand, the balance of private and public transportation. A sustainable transportation system should encourage the use of economically efficient, environmentally clean and socially acceptable trip model. A direct result from this principle is attracting people to walk, cycle and, in particular, to use transit systems. Perhaps the most widely used model is the transit-oriented development model which encourages development along the transit line or modal interchange nodes (Kwok and Yeh, 2004). This paper, using a case study of Amsterdam urban region, presents an empirical sketch- planning transport model that is aimed at support for sustainable regional transport systems under a GIS analytical environment.

2. Methodology

In traditional transportation modeling, the four-step model (trip generation, trip distribution, modal split and trip assignment) is the primary tool for forecasting future demand and performance of regional transportation systems. This full-scale transport modeling, given a transport network and a set of data representing the spatial distribution of urban activities and their intensities, can provide valuable insight into the effectiveness of transportation policy on the performance of the transportation infrastructure by testing various 'what-if' scenarios. However, its development and application in empirical settings often face critical obstacles. The first difficulty is related to the fact that conventional strategies apply sequential modeling of the four transport model components. A second difficulty is a result of the need to manage the spatial data required for a regional scale transport modeling. On most occasions, required data sets are not sufficiently available at specialized level and in preferred detail. Consequently, at strategic level, the reasonably simplified process of the full-scale modeling can not only improve the effectiveness of modeling but also quickly test the thoughts of users as a conceptually experimental lab using limited data sets.

Sketch planning, in the field of urban design, is a subset of planning but with some modifications, which is focused on a certain degree of abstraction. Sketch planning is the preliminary screening of possible configurations or concepts. Singh (1999) reported a potential application of GIS techniques for such sketch planning. Harris (2001) described a sketch-plan-based planning support system. Sketch-planning modelling aims to realize highlighted objectives based on simplified process, released parameters estimation, and using data sets at rougher level or with coarser resolution. In comparison with a full-scale model, it can offer such merits as quick response, ease of use and understanding, and low cost development. The key idea of sketch planning method is to facilitate the generation of alternatives quickly and easily. The development and test of a new sketch-planning model is a challenging task, given the requirement to produce reasonably accurate results with relatively aggregate level inputs (Batty, 2004).

In this study, sketch-planning modelling is intended as “rules of thumb” to provide the regional planners with a general picture of the problems against sustainable transportation systems. Sketch-planning tools were developed specifically as a quick response model to analyze:

- Regional activity centres;
- Identify areas with the potential for successful transit service but where service currently does not exist;
- Identify areas that currently or in the future may be underserved by transit and for which service improvements may be needed.

The main steps in the defined sketch-planning modeling can be summarized as follows:

- Adopting the logic structure of the traditional transportation modeling process;
- Limiting the purposes of trips (working and visiting) and trip modes (car and transit);
- Zones (residents and activities) grouping;
- Network aggregating;
- Modest model calibration.

GIS is employed here primarily for data processing, data integration (aggregation and dis-aggregation), network analysis (shortest path) and communication with users. Figure 1 shows its flow chart.

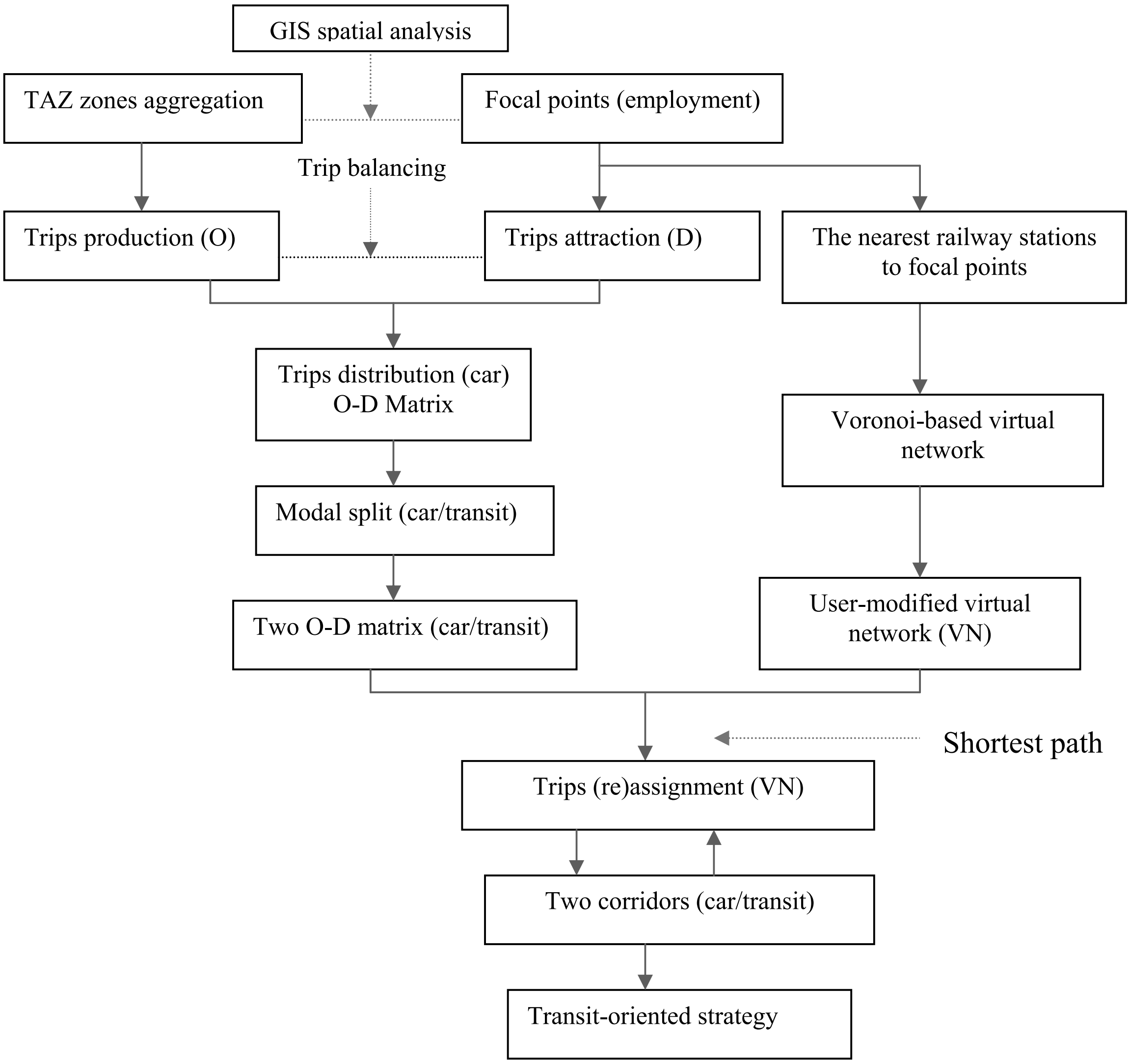

Figure 1. A sketch-planning model for transit-oriented development strategy

3. Results

Amsterdam urban region consists of the ‘mother’ city of Amsterdam and other smaller cities around it, which have become specialized centres in the region. Today, with increasing specialization and the expansion of activities, the challenge is rather the development of a regional transit system and the introduction of hierarchies in the motorway system, which will allow for the fact that different cities, towns and major exurban activity concentrations function as complementary centres in a more horizontal fashion. The sketch-planning modelling should be developed such that it is entirely based on readily and generally available statistical and survey information. No dedicated data collection is involved: most data can be freely downloaded or purchased at a low cost

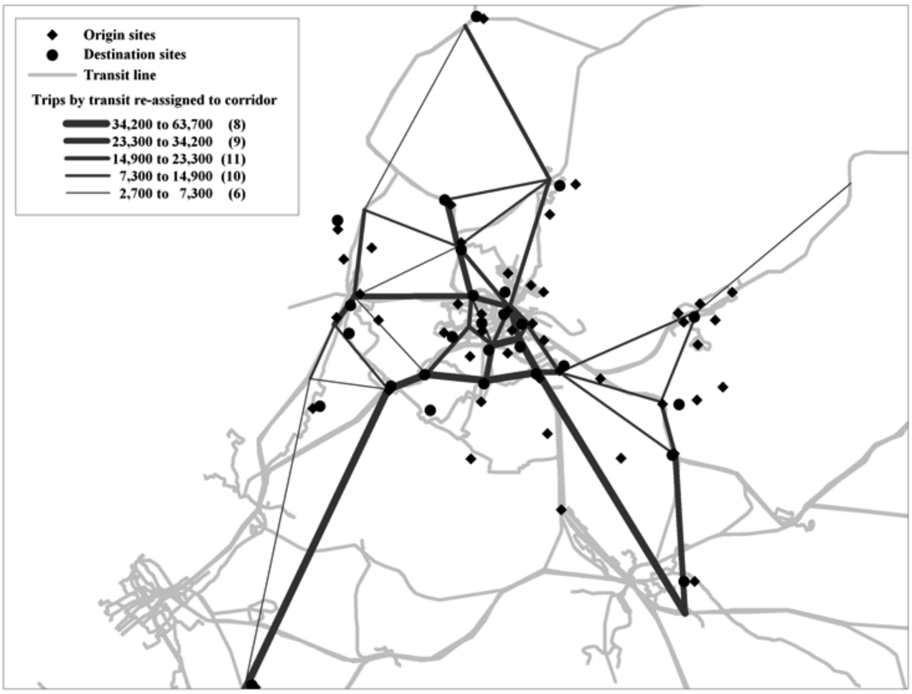

Figure 2. Transit corridor and re-assigned trips

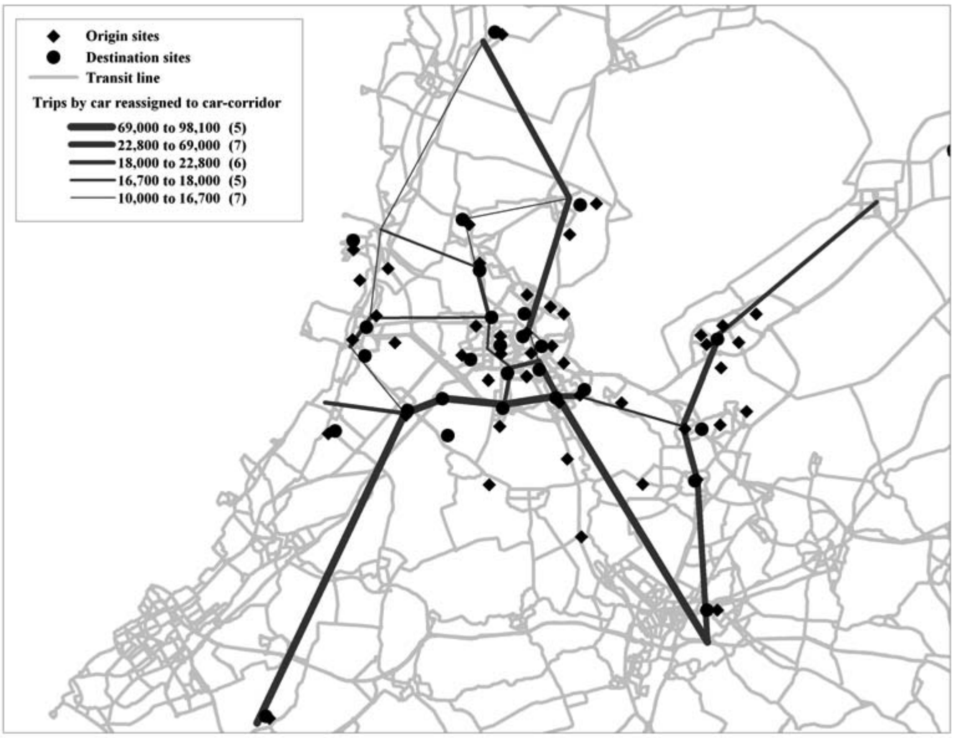

Figure 3. Car corridor and re-assigned trips

from official commercial and noncommercial sources. Major data currently available are as follows:

- Road network: four classes (e.g. motor-way), and having attributes (e.g. speed and direction);
- Transit network: four classes (bus, tram, metro and train) and including attributes (e.g. average speed);
- Bus stops and railway stations;
- Demographic: sex, age, household, income etc. at neighbourhood level;
- Employment: types, number, floor-space etc. at postcode level.

Taking home-based work trips as examples, analyses are designed and implemented including focal points (clusters of employment) based on local G measure, TAZ zones aggregation, definition of virtual network based on user participation, and trip assignment and corridor search based on the shortest path algorithm. The parameters used in the models of trip generation, trip distribution and modal split are gained from previous projects and inputs of local knowledge. The main intermediate steps are shown in figure 2 and 3. Figure 4 indicates the final classification of the corridors where Class 1 displays the corridor that is greater than average visual speed and lower than average transit share and class 2 (greater than average visual speed and greater than average transit share), class 3 (lower than average visual speed and lower than average transit share) and class 4 (lower than average visual speed and greater than average transit share).

4. Conclusions

The tested methodology is able to provide sketch-level estimate of the interaction between transportation and land use systems. However, this paper does not mean that sketch-planning modeling can replace a full-scale one, the latter should represent the long-term pursuits in this area. This paper concludes that the sketch-planning modelling can be focused on a strategic level such as that required by a regional development plan and then offer a intermediate stage and guide for the next detailed modeling in practice. The validation of modeling needs the local knowledge and experiences from professionals. In this project, the research group includes the local professionals in urban planning, transportation planning and transportation modeling respectively. The development of spatial analysis and modeling must be understood and accepted by them first. Then the results from modeling will be compared with their mental images. The divergence can be clarified during planned workshops. The planner usually remains in the sketch-planning mode until s/he completes the comparisons of possibilities or finds a strategic plan worthy of consideration at a finer level of detail.

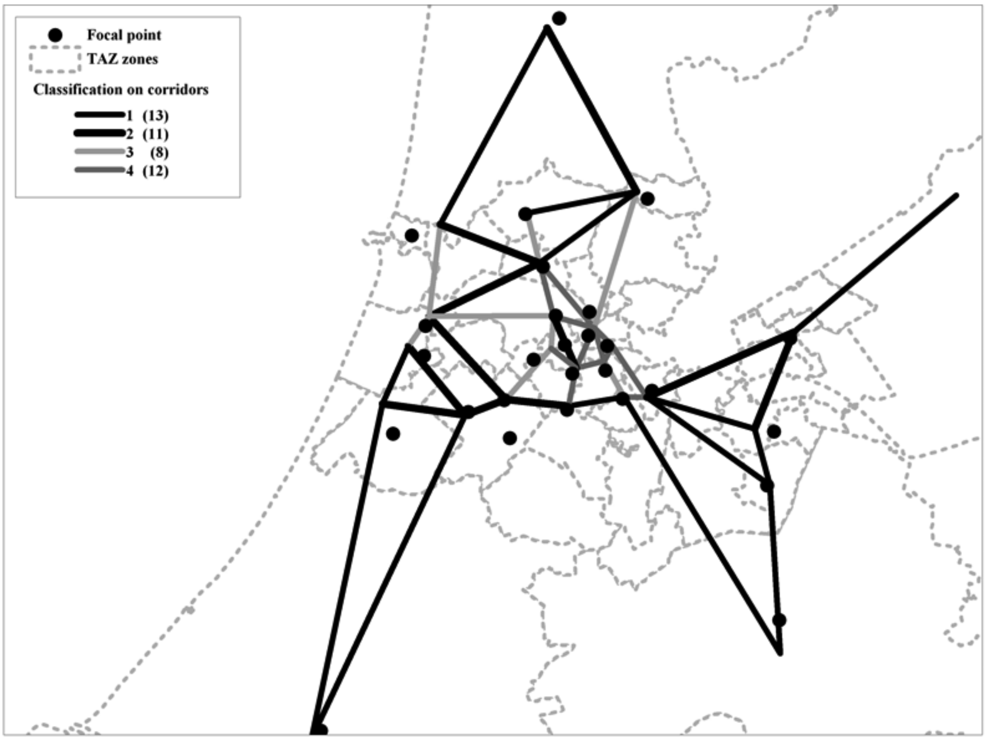

Figure 4. Classification of corridors

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Biography

Dr. Jianquan Cheng is a lecturer and has main interests in developing GIS socio-economic applications including transport. Dr. Luca Bertolini is an associate professor in urban and transport planning.

Putting geography back into geodemographics

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1. Summary

This paper investigates for the first time the geographical properties of the Office of National Statistic’s Output Area Classification system (OAC).

2. Background

Formal classifications of areas using demographics from the census have been developing over the last 50 years or so. The methods for creating these systems have now stabilised and usually involve the application of some form of cluster analysis to selected census variables (Webber et al, 1978). The output of this process is a smallish number of groups with an appropriate set of nominal variables to label them.

Considerable impetus was given to developing these systems when it was discovered that it was possible to estimate the average behaviour of people living in a place associated with a particular areal group (Bermingham et al, 1979). This had profound implications in terms of resource allocation and is the reason the term *geodemographic systems* is used to describe them rather than more conventional *areal classifications*.

OAC is a geodemographic system that has been created using the standard methods by the Office of National Statistics. Unlike most commercial systems, it is completely open. The method used is published and, just as importantly, the original database of variables used is freely downloadable: the system itself has no undue licence restrictions (Vickers et al, 2006).

As an example, the average household income in pounds sterling for each of the 52 sub-groups of OAC - OAC has a threefold hierarchy ranging from 7 super groups, 21 groups to 52 sub-groups - are plotted. The line of the x-axis is positioned to cut the ordinate at the average of the sub-groups’ incomes, which, in this survey, was £26,000. The values were derived from a cross tabulation of data from a separate lifestyle survey of 998,731 respondents. Figure 1 shows the substantial variation in the modelled average household income of each of the OAC 52 sub-groups, which vary from just over £14,000 to just under £45,000.

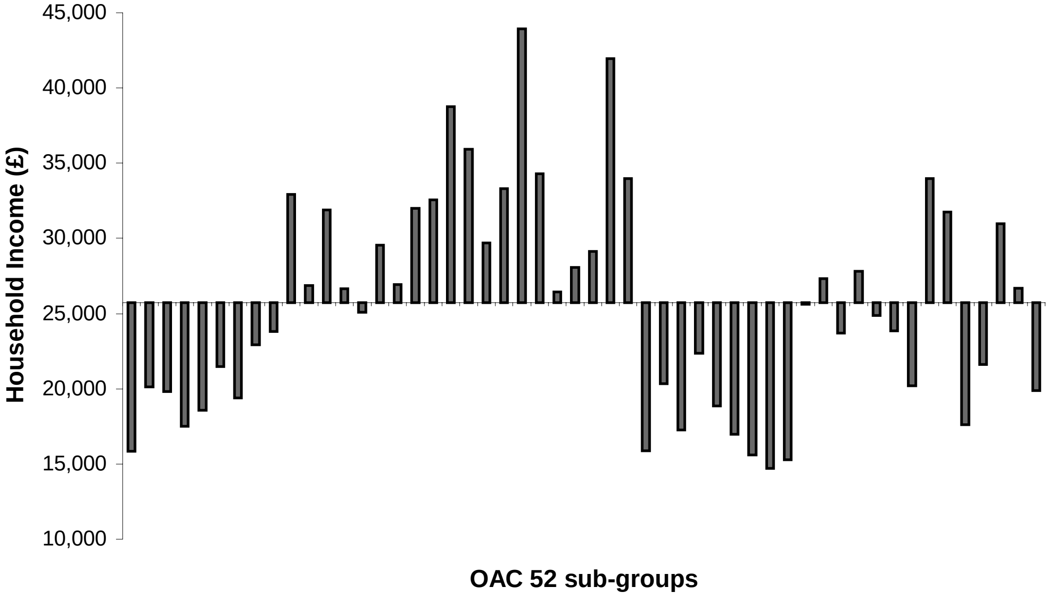

Figure 1. Mean household income for each OAC sub-group

3. The objective

Charts like this are well known and have been used for at least 25 years, see Harris et al. 2005. However, these applications have exclusively been in ascribing *people's* behaviour to the geodemographic codes. The question to be addressed in this paper is quite different and has not been examined before: are there any variations in the *geographical* properties that are associated with different geodemographic types? This question is of interest as OAC has been formed from demographic variables not geographic ones.

4. The findings

We find that:

- Codes spatially autocorrelate
- Their spatial dispersion across the UK varies by type
- They vary by their mean height above sea level
- They vary by coastal proximity
- The worker/resident ratio they contain varies by OAC sub-group

Within settlements, there is distinct bias in the locations of OAC codes with respect to:

- The population of the settlements they occupy
- Their proximity to the centre of the settlement
- And an east-west bias within their settlement

An example of one of these geographical properties, that of the variation in height above sea level of the OAC sub-groups, is shown below. This chart shows that the mean height of each OAC 52 group varies within a range of about 40 metres to 110 metres above sea level. For interest, the two clusters of sub-groups that are below the line (this being the mean elevation of all the OAC sub-groups – 68 m) are both biased towards the town centre.

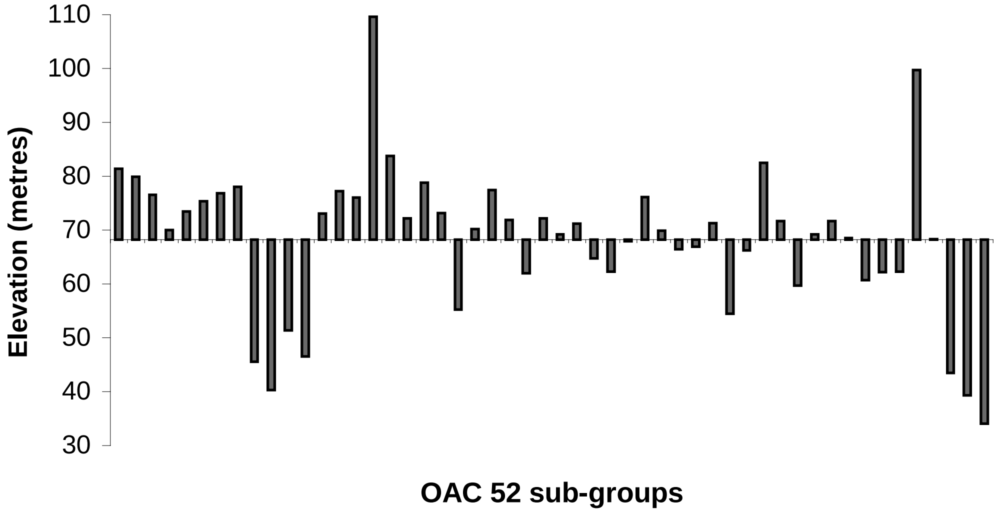

Figure 2. Mean height above sea level for each OAC sub-group

5. The method

The analysis was conducted on 218,038 OAC classified output areas of England, Wales and Scotland as follows:

1. Spatial autocorrelation was clearly shown by maps at the super group level.

2. Variations in spatial distribution were shown by analysis of the locations of the centre of gravity occupied by each sub-group again supported by maps.

3. The height effect was show by transforming a digital elevation database to each of the 218,038 output areas to give each a mean height from which the mean for each OAC sub-group was calculated.

4. Coastal proximity was measured by first coding coastal output areas of England and Wales as ‘coastal’ or ‘not’ (Scottish output area files helpfully come with a coast code). A 100m buffer was constructed around the coast and then intersected with the output area

boundary files. A ‘coastal index’ for each OAC sub-group was calculated by comparing the proportion of each OAC 52 sub-group in the coastal set to that present nationally.

5. The definition of settlements was taken from an ONS output area-to-urban area look-up table provided as part of the UK 2001 census, which defined 4570 settlements in England and Wales, and the equivalent file from the General Register Office of Scotland, which defined 587 settlements. Using these files, the population size for each settlement was obtained and from this, the mean settlement population for each sub-group easily calculated.

6. In addition, a population-weighted centroid was calculated for each settlement from its constituent output area centroids. Each output area (together with its associated OAC sub-group) could then be referenced to the centre of the settlement in which it was located and its crow-flying distance from the centre calculated by Pythagoras.

7. The spatial extent of each settlement was calculated by summing the areas of its component output areas and, by assuming that the settlement was circular, an equivalent diameter estimated. An indication as to the degree that this (circularity) assumption was true was taken to be the R-squared of the line separately put through the x, y coordinates of the output areas centroids of each of the 5157 settlements – an R-squared of zero was taken to indicate that the settlement was perfectly circular and of 1 that it was perfectly linear. The value of obtaining an equivalent diameter of the settlement is that the distance figures of the output areas from the centre could be indexed on the radius to give an indication of its relative position within the settlement.

8. However, as mean settlement populations varied across the sub-groups, the analyses for the east-west biases and the distance from the centre took place on the settlements with sizes most appropriate for them. Had this not been done, London, Glasgow and Birmingham, in particular, would have had a dominant affect on the findings.

9. The worker/resident ratio was calculated for each output area using the total resident counts from the main 2001 census data and from the little used workplace statistics file (where people have been relocated to their place of work).

6. A caveat

However, there is a fairly obvious reason why the effects shown so far may be an artefact arising from the set of variables used in the construction of OAC.

Amongst the 41 OAC variables, is population density, and it is possible that it is the presence of this non-demographic variable that is causing some or all of these associations.

We found that across the OAC 52 groups, there was a strong correlation with settlement size, very weak association with three of the properties and no association with the other three.

Given this, it is reasonable to conclude that the geographical associations reported earlier in this paper are only partly explained by population density.

75. Conclusion

It is clear that at least some locational properties are associated with areal types formed from demographic profiles. This is interesting as it implies that people of different *demography* are associated with areas of different *geography*. One might well argue that this association would be obvious, and has been claimed by social geographers for many years. However, this effect has been shown using modern methods and on a national scale. Perhaps of more interest than these particular findings, is the implication that OAC could be used as a general tool to investigate underlying geographical structures.

There are many other properties that could be examined, examples of which are: the nature of the *objects* to which these properties are applied, Unwin (2001); the influence of the *cluster hierarchy*; the role of the *cluster distance* variable as a measure of uncertainty, Fisher (2006); investigations into the *homogeneity* of the groups, Barr (2006) and the opportunity of further studying the *MAUP*. Doubtless there are more.

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Biography

Martin Callingham is a Visiting Professor at Birkbeck College, University of London where his research interests are areal classification and flow data. He has been involved with geodemographic systems since their inception and was a member of the ONS working party for the creation of their Output Area Classification

Health Applications for Open Geodemographics

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1. Introduction

Health geodemographics is a fast developing research applications area that focuses on the development and application of neighbourhood classifications to targeted interventions in the health care arena. Population health intervention concerns immediate threats from infectious diseases or much longer term effects of chronic diseases like heart diseases or diabetes (Fielding 1999). In this paper we describe how the development of geodemographic tools both provides a framework for improving our understanding of chronic diseases and at same time presents a useful tool for targeting of public health intervention.

Health inequalities with regard to the incidence and effects of chronic diseases reflect complex social structuring in sex, age, life course exposure, phenotype and lifestyle (McKinlay and Marceau 2000, Davey Smith 2003, Siegrist and Marmot 2006). The concept of 'lifestyle' provides an umbrella term for the various behaviours that may have an impact on health: what we eat, our use of stimulants, our leisure time use and exercise levels, etc.

Previous research has sought to trace the underlying causes of many chronic diseases using simplistic statistical designs to produce circumstantial evidence linking a multitude of factors, under a 'black box' paradigm that has prevailed in the epidemiological literature since 1950s (Susser 2004). Rather than contemplating the seemingly infinite permutations of risk factors that might be put into the 'black box' we should also explore the opportunities arising from linking large georeferenced health care databases to socio-economic data. Geodemographic profiles offer a snapshot of the distribution of health outcomes in the population and allows for broader interpretations about the unfolding of chronic diseases.

Geodemographic systems have been developed for different purposes and at different scales (Sleight 2004, Harris et al. 2005). For marketing purposes geodemographics has been a convenient way to extrapolate consumer survey knowledge to new geographic markets. The creation of an open source geodemographic system by the Office for National Statistics (Vickers et al. 2005), Output Area Classifcation (OAC) marks a turning point in geodemographics, which now has an open source and is accessible to non-profit organisations.

Many questions however remain unanswered: how useful are these systems for the health care sector (public sector in general) and how do we improve and evaluate them for their new purposes? In this paper we present an alternative Output Area Classification for Greater London (LOAC) and a method to evaluate the actual and maximal market penetration potential of geodemographic systems.

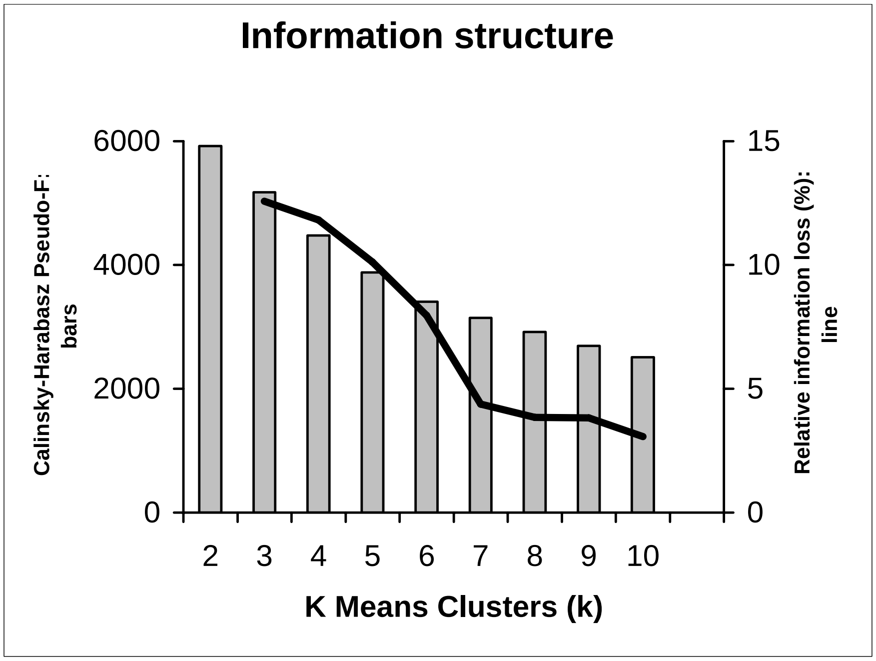

Figure 1 Stopping rule applied in the creation of London Output Area Classification

2. Output Area Classification

The OAC is based on a selection of 41 Census 2001 variables ranging from age to ethnicity, family structure, tenure, education, occupation, transportation, and health (Vickers et al. 2005)[1]. The variables were logarithmically and range-transformed to reduce the impact of outliers. The data set was first divided into 7 Supergroups using k-means clustering. The stopping rule for the generation of Supergroups was guided by the decreasing mean centroid distance in subsequent clustering (k+1) and to the fact that it is difficult to differentiate between much more than 7 colours when the classification is mapped.

3. Creating an Output Area Classification for London

A single national system enables a level of comparison across the system, so that e.g. national surveys may be projected to most areas. Yet in our work with planning at a local level in an inner-city borough of London (Southwark) the OAC appears overly vague, with swathes of central London ascribed to a single dominant “Multicultural” category. The greatest differentiation seems in contrast to be in the suburban boroughs. We suggest that this - in part - is an artefact in the way the OAC was created. While most of London is unified in being different to most other parts of the country, local level differences become subordinate in the classification. This is as much a general observation for capital cities as explained by rank size rules (Batty 2006) and central place theory (Webber 2004), but is also well-documented in the UK (Dorling and Thomas 2004). In order to explore whether greater differentiation could be obtained for London neighbourhoods, we repeated the classification with two modifications:

1. Reduced the data set and its range standardisation to Greater London

2. Deployed a cluster stopping rule based on within and between cluster variability, Callinsky-Harabaz pseudo-F, (Rabe-Hesketh and Everitt 2004)

Seven Supergroups were formed according to a distinct threshold in the information structure (Figure 1). Each LOAC Supergroup was divided into a Group level following the same procedure. The 7 LOAC Supergroups was thus subdivided into a total of 49 LOAC Groups. This makes the LOAC comparable to the OAC Subgroup level with 50 subgroups contained in Greater London.

4. Market penetration potential for OAC vs LOAC

The market penetration potential of geodemographic systems can be assessed in *the degree to which a given system can represent the overall variation in a market with the lowest number of groups*. This minimum of groups can again be measured by the degree the system uncovers variability for a given attribute[2]. Rank order inequality measures have been suggested to measure this variability (Callingham 2006). For this study we have used the Gini-coefficient as a way of assessing this market penetration potential (Novak et al. 1992). In the extreme a system with 24,140 groups for London's 24,140 output areas would have the *maximal* market penetration potential (shown as the outer boundary in the radial diagrams, Figure 2 and Figure 3). However a large number of groups would be impractical and would work against the quintessential force of geodemographic systems: *to 'borrow' strength from other areas to extrapolate knowledge about particular attributes*. In assessing the market penetration potential we could have chosen any number of variables of relevance to social structuring and health. We have chosen to evaluate the OAC (and LOAC) variables, because it at the same time tells us something of the leverage effects of these variables in the classifications.

Examining the market penetration potential of the OAC (and LOAC) attribute variables in this way we found evidence for the two main gradients: ethnicity and tenure (Figure 2, Figure 3). The LOAC has a greater market penetration potential than the OAC at Supergroup level (n=7) and also at the higher level (n=49 and 50, respectively) (Figure 2 and Figure 3).

A comparison of the actual vs the maximal market penetration potential also revealed variables for which the OAC (and to a lesser degree the LOAC) system would be less efficient, *viz*. 0-4 yr olds, single pensioner households, no central heating, working from home, provide unpaid care, manufacturing, hotel/catering and health/social care employment.

5. Longterm Limiting Illness

The prevalence of limiting longterm illness is of particular interest for health care authorities, because it represents population groups with high and complex health care needs (Wagner 1998, Bodenheimer et al. 2002, DH 2004, Saxena et al. 2006). Better social and geographical detection of this group will aid outreach activities, facilitate case management and reduce emergency hospital admissions.

The OAC uses the Standardised Illness Ratio (SIR) for longterm limiting illness. This emphasises illness above the effects of ageing. Correlating the SIR with the Census variables used in OAC shows a positive correlation with variables associated with low-income housing, e.g. renting public, lone parent household, routine occupation, etc. These areas are on the other hand not associated with the level of all unpaid care (r=0.03). Comparing the standardised (SIR) with the proportion of longterm ill, i.e.

Variables	Longterm limiting ilness (Standardised Illness Ratio)	Variables	Longterm limiting illness (proportion, no age standardisation)
Longterm limiting illness (proportion)	0.73	Longterm limiting ilness (Standardised Illness Ratio)	0.73
Rent (public)	0.72	Age 65+	0.61
Lone parent household	0.59	Single pensioner household (pensioner)	0.58
Routine/Semi-Routine occupation	0.58	Rent (public)	0.48
Unemployed	0.58	Rate of unpaid care providers (50+ hr/week)*	0.43
People per room	0.56	Routine/Semi-Routine occupation	0.37
Black African, Black Caribbean or Black Other	0.49	Divorced	0.34
Divorced	0.48	Rate of all unpaid care providers*	0.22
Rate of unpaid care providers (50+ hr/week)*	0.41	Age 25-44	-0.36
Hotel & catering employment	0.38	Two adult no children	-0.41
Economically inactive looking after family	0.37	HE qualifications	-0.42
All Flats	0.31		
Rate of all unpaid care providers*	0.03		
Age 45-64	-0.34		
Financial intermediation employment	-0.42		
HE qualifications	-0.43		
Rooms per household	-0.49		
2+ Car household	-0.52		
Two adult no children	-0.55		

Table 1. Pearson’s population weighted correlations between the prevalence of Longterm Limiting Illness (Standardised Illness Ration vs unstandardised rate) and other Census variables used in the creation of OAC. Only correlations above +/- 0.30 are shown. *) Calculated from Census 2001 health data (ONS 2006)

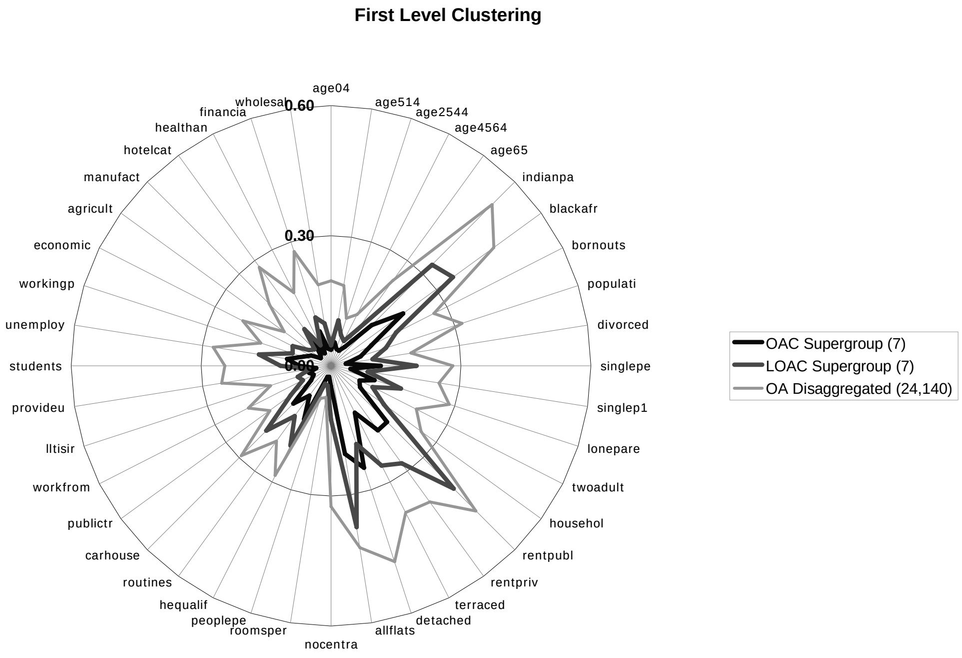

Figure 2. Market penetration potential at 1st level clustering: OAC vs LOAC

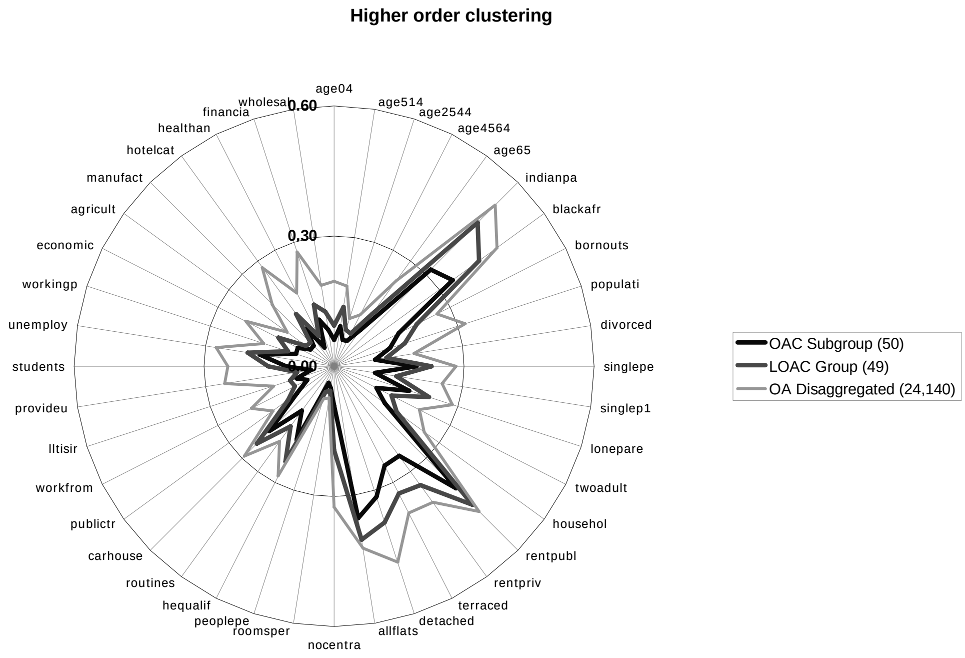

Figure 3. Market penetration potential at higher order clustering: OAC vs LOAC

not standardised for age,[3] we see greater association with old age, i.e. age 65+ and single pensioner households. In both cases the rate of unpaid care of 50+ hr weekly is positively associated (r=0.41 and 0.43) and so to a degree confirms the ‘positive care law’ for informal care in the home or the neighbourhood as defined by a small area unit like the OA (Shaw and Dorling 2004): *those with the greatest needs live near those most committed to provide unpaid care*. Comparing the SIR and crude proportions indicates that they represent different, but genuine groups with high health care needs.

6. Conclusion

The national Output Area Classification system (OAC) did not represent the variation measured as market penetration potential across 41 Census variables in Greater London very well. A simple classification only at regional level (Greater London) outperformed the OAC across all attribute variables. Of course, this improvement is achieved at the expense of making Greater London a ‘special case’, but the results of this preliminary analysis and health care application suggest that this is a price worth paying in exchange for the benefits of detecting greater variability.

We suggest that geodemographics provides a useful framework for studying the prevalence of diseases. The power of geodemographic systems, however, is likely to arise from extrapolating behaviours from surveys of health, consumption and leisure time use. Future work will lie in validating the predictions that can be made in combining lifestyle surveys and large georeferenced health care databases as well as developing new geodemographic systems based on health care data.

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8. Author biography

Jakob Petersen is researching in health care applications and geodemographics in a knowledge exchange collaboration between Southwark Primary Care Trust (NHS) and University College London (UCL). He is studying for a phd at Centre for Advanced Spatial Analysis (UCL) and is supervised by professor Paul Longley, Dr David Ashby and Dr Philip Atkinson (NHS).

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1 Clustering variables (Census 2001): Age 0 – 4, Age 5 –14, Age 25 – 44, Age 45 – 64, Age 65+, Indian/Pakistani/Bangladeshi, Black African, Black Caribbean or Black Other, Born outside UK, Population density, Divorced, Single person household (not pensioner), Single pensioner household (pensioner), Lone parent household, Two adult no children, Households with non-dependent children, Rent (public), Rent (private), Terraced Housing, Detached Housing, All Flats, No central heating, Rooms per household, People per room, HE qualifications, Routine/Semi-Routine occupation, 2+ Car household, Public transport to work, Work from home, Long Term Limiting Illness, (Standardised Illness Ratio), Provide unpaid care, Students (full time), Unemployed, Working part-time, Economically inactive looking after family, Agriculture/fishing employment, Mining/quarrying/construction employment, Manufacturing employment, Hotel & catering employment, Health/social work employment, Financial intermediation employment, Wholesale/retail employment

2 Is this variability spatial? In a system with a finite number of regions, greater attribute variability also has to infer a degree of spatial variability although the Gini measure deployed here would give the same result no matter the spatial arrangement of the same observations. In this way the proposed technique is not spatial by the definition given by Longley et al. (2001)

3 Proportions calculated from Census 2001 health table and denominators at OA level

TravelStyle: Berlin's First Geodemographic Profiling Tool

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1. Introduction

Berlin is under pressure to improve its economy, efficiency and effectiveness in public transport service delivery. Steer Davies Gleave and kcw were commissioned by Senatsverwaltung für Stadtentwicklung (SenStadt) Berlin as project coordinators in the preparation of their Nahverkehrsplan (NVP) 2006 – 2009. This document is similar to the Local Transport Plans produced by Local Authorities in England. It outlines a five-year integrated transport strategy, prepared in partnership with the community, seeking funding to help provide local transport projects. The plan sets out the resources predicted for delivery of the targets identified in the strategy.

In order to meet the aims of the NVP, primarily relating to social inclusion, we used our innovative geodemographic profiling tool – TravelStyle – unique in the transport sector. Steer Davies Gleave has long recognised the value of geodemographic profiling in that it was designed to differentiate people with different lifestyles and spending patterns. It also provides an alternative perspective on the general population since it incorporates different data sources (see **Figure 1**) and can be used at varying levels of geography. Our general approach is to take the existing geodemographic classification system which differentiates best between groups with differing travel behaviour on the dimensions of interest, then to add onto this relevant travel related data.

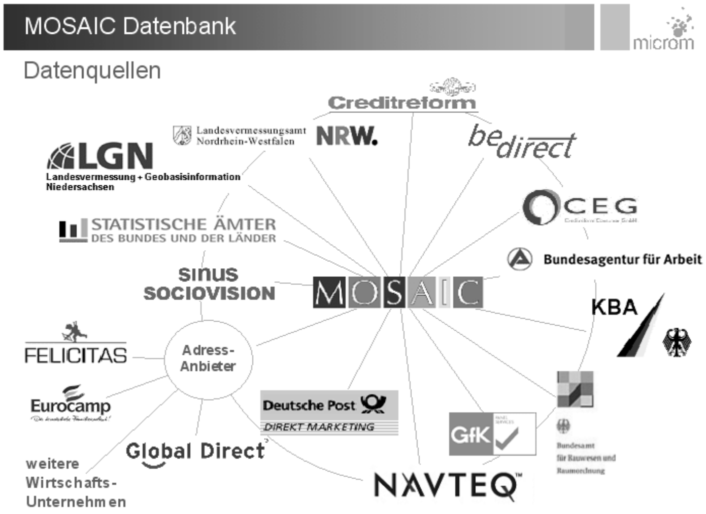

Figure 1: German MOSAIC Data Sources[1]

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[1] Please refer to MOSAIC Data Source Glossary section at the end of this abstract for a description/English translation.

In Berlin we used MOSAIC as the base and added to this data on car ownership and some additional demographic data provided by SenStadt. In the UK we have also used MOSAIC, and ACORN and most recently have been looking at using the ONS's Output Area Classification (OAC) which is now freely available.

Evaluating schemes or service changes in terms of their social impacts poses considerable challenges when compared with evaluating accessibility or economic impacts because of the difficulty of measuring something which by its nature is hard to define in precise terms. We used TravelStyle to evaluate the impact of change to public transport services on social inclusion and on those that are particularly dependent on public transport. This enabled relative need to be assessed across Berlin, and for different service/timetable scenario options to be tested in terms of whether or not they provide a better or worse service to locations where the need is highest. At the same time, it can be used to help define options which addressed social needs more effectively.

2. Development of TravelStyle and the Transport Needs Index

TravelStyle is a way of classifying people and localities in terms of transport need. It is based on the microm/Experian MOSAIC geodemographic classification system for Germany. We then tailored it to reflect key transport-related and social inclusion dimensions. These variables were selected due to their importance within the NVP and also their influence on travel behaviour and public transport need.

The standard German MOSAIC system classifies the general population into 39 Types with only 25 of these having a significant representation in Berlin of at least 3,000 households. These 39 Types are then combined into 10 lifestyle Groups.

The descriptive information from microm was summarised on a number of key attributes by assigning a simple five-point ordinal scale: well below average, below average, average, above average, well above average. The focus was on attributes relating to the two dimensions of interest: wealth and age/life-stage. In practice, ratings were given for income, presence of people aged 65+ and presence of children (ratings were also given for car ownership, presence of students and presence of non-Germans, but these factors were not used in the initial allocation of MOSAIC Types to segments).

What we have done to create the Berlin TravelStyle is to combine these Types in a unique way based on a common spatial geography – in our case a network of hexcells i.e. interlocking grid of hexagons. This enabled us to compare street-level MOSAIC data with census data at housing block level with an appreciation of attribute differences between central and outer Berlin. Types with particular combinations of attributes (e.g. low income + high senior citizens) were grouped together in an initial "first cut" of the segmentation. Remaining Types were then allocated to their nearest segment, with income taking priority to avoid having segments that included too wide a range of incomes (this also reflected greater variation in terms of age / life-stage within the MOSAIC Types than in terms of income). Segments which ended up being too small (less than 5%) were scrapped and the constituent Types reallocated.

TravelStyle provides a way of linking lifestyle and demographic segmentation – useful during validation process - although there is no direct correspondence because lifestyle segmentation has more dimensions and is more "fuzzy" whilst demographic segmentation has fewer dimensions but is more precise.

Figure 2 illustrates the perceptual map and clearly demonstrates that there is greater diversity within the segments in terms of age/life-stage than in terms of income.

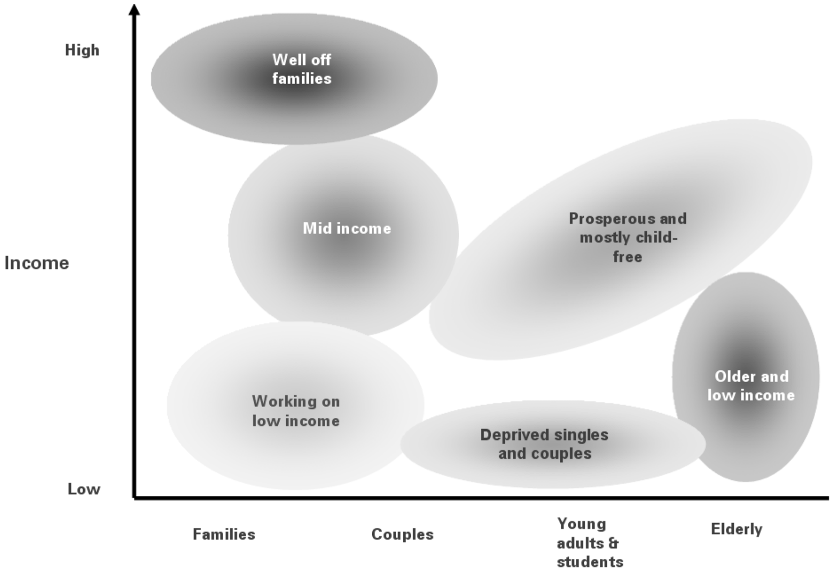

Figure 2: Perceptual Map for Berlin TravelStyle Segments

The aim of the transport needs index is to reflect the relative need for public transport for each TravelStyle segment. **Table 1** illustrates how these indices were derived. The weights used are to a degree a matter of judgement, informed by the aims of the NVP and by our knowledge of what drives the need for public transport services. Wealth, car ownership and presence of children are all important factors and therefore given a weight of 1. Senior citizens have been identified in the NVP as a key group, and therefore given twice the weight. This counter-balances the fact that car ownership and income are closely related and when combined also produce a double weight. In other words, someone who is a senior citizen has been given the same level of transport need as someone on a low income without a car. Students and non-Germans have both been allocated a weight of 0. It is considered that these factors do not generate an extra need for public transport over and above car ownership, wealth and presence of children.

Table 1. Transport Needs Indices for Each TravelStyle Segment

TravelStyle Segment	Average Weight	Wealth	Car Ownership	Senior Citizens	Children	Students	Non-Germans
Weight given to attribute		1	1	2	1	0	0
Older and Low Income	1.45	2	1	2	0.25	0.25	0.5
Working on Low Income	1.00	1.5	1.5	0.5	1	0.5	1.5
Mid Income	0.90	1	1	0.5	1.5	1	2
Prosperous and Mostly Child-free	0.95	0.5	0.25	1.5	1	0.25	0.25
Well-off Families	0.80	0.25	0.25	1	1.5	0.5	0.25
Deprived Singles and Couples	1.10	2	2	0.25	1	2	1

We investigated a number of alternative weighting systems but the one selected performed well in terms of passing a basic "sense test"; being relatively simple to understand and apply, and having an appropriate range of values and degree of difference between the segments.

Nevertheless, there are some limitations with MOSAIC (exaggerated by the unique history of Berlin) that we have looked to minimise by using other data sources to help calibrate our TravelStyle segments. These limitations are:

- In categorising the population into just six segments, a degree of simplification is inevitable, and
- There is an underlying assumption of homogeneity within a single housing block that in some cases can be an over-simplification (though this effect is reduced with the size of area being investigated).

3. TravelStyle Segment Descriptions

Table 2 shows the main neighbourhood characteristics exhibited by each of the TravelStyle segments.

	Description	*First Most Important MOSAIC Type*	*Second Most Important MOSAIC Type*
Older and low income	Mainly older people and pensioners, often living on their own and generally living on a low income.	Urban areas of ordinary ribbon development (61%)	Common single pensioners (29%)
Working on low income	Predominantly comprised of people on fairly low incomes and middle-aged, often without a car. Includes quite a high proportion of non-Germans.	Urban areas of ordinary ribbon development (83%)	Areas of social focus (13%)
Mid income	Includes quite a broad age range but all in the mid-income bracket. Includes some families with children and quite a high proportion of non-Germans.	Older social housing (45%)	Well-off seniors in suburbs (25%)
Prosperous and mostly child-free	Professionals and other groups on good incomes, generally without dependent (young) children living at home. Includes some well-off pensioners.	Attractive city centre buildings (36%)	Older families in the suburbs (18%)
Well-off families	Professionals, managers and self-employee people on high incomes, generally middle aged and married, often with children.	Solid older detached houses (35%)	Ordinary houses in the country (32%)
Deprived singles and couples	Younger people on low incomes and often single with some couples. Includes students and some non-Germans. Characterised by very low car ownership.	Blocks of flats of lower standard (69%)	Multi-cultural inner city areas (15%)

Table 2: Summary Profile for Each TravelStyle Segment

Figures 3 and 4 clearly illustrate that Berlin has a high proportion of disadvantaged residents with 73% being either deprived or on low income. The most dominant in this group needing public transport accessibility are the elderly with a significantly higher transport needs index of 1.45 (1.0 being average). Therefore, ensuring that their public transport needs are met and maintained is an important consideration in the next NPV.

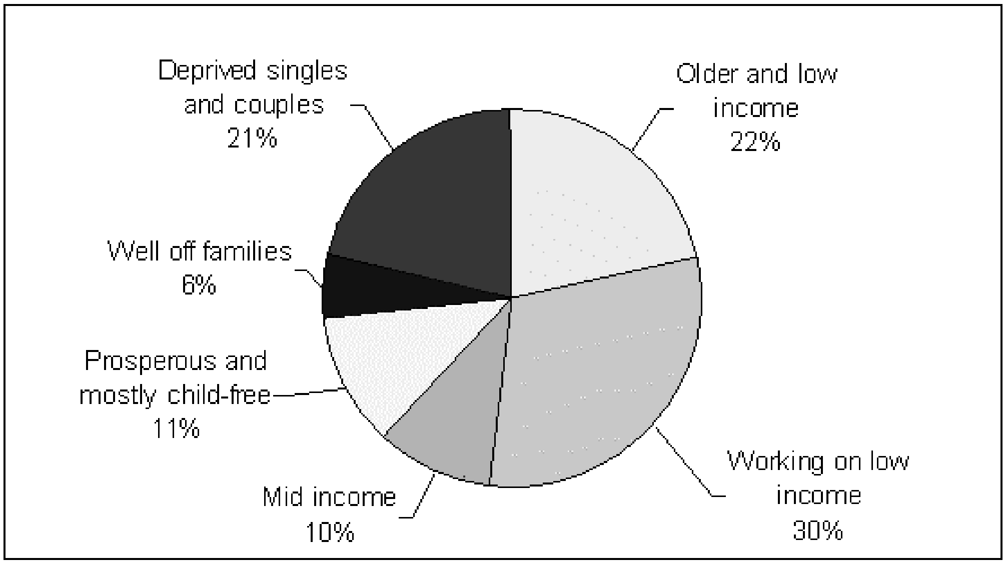

Figure 3: Constituents and Size of TravelStyle Segments

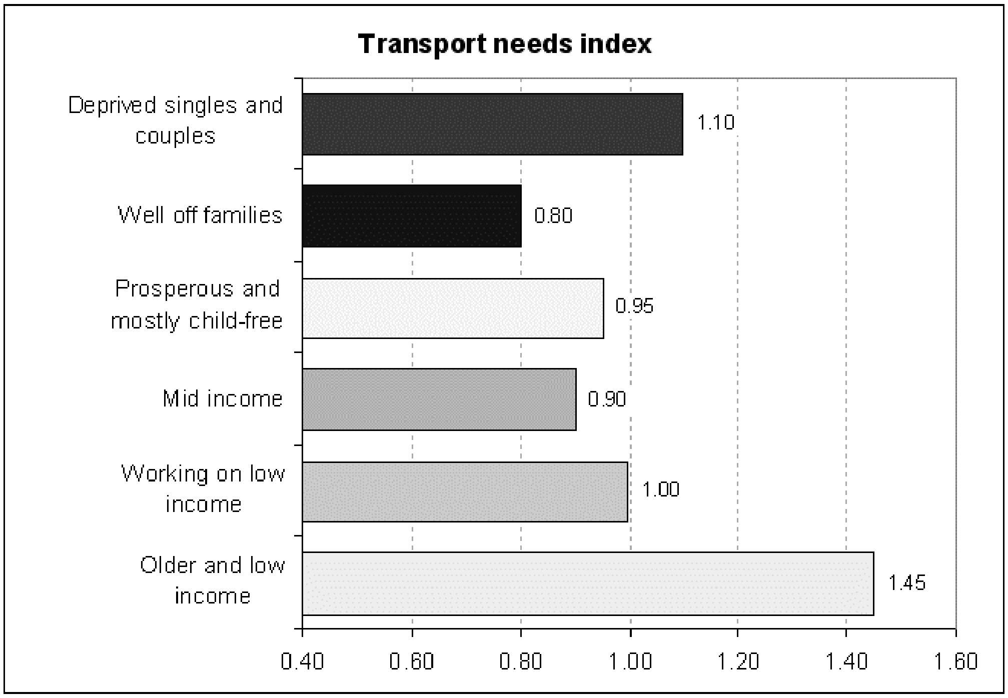

Figure 4: Transport Needs Index across TravelStyle Segments

Summary pages were derived for each TravelStyle segment, detailing brief description, how their characteristics based on selected attributes (income, car ownership, age (senior citizens) and presence of children) varied from the Berlin average and photographs showing typical housing types.

4. Application of TravelStyle

We have applied the Berlin TravelStyle for:

- Planning – help specify timetable/service options that aim to improve the level of service in places where there is greatest need (or reduce the level of service where there is less need) and
- Evaluation – assess the impact of timetable options in terms of whether they improve the level of service in places where there is greatest need.

In addition, the derived "transport need index" can also be used to provide an overall understanding of the nature of different parts of Berlin and this is the aim of the TravelStyle Profile maps.

We have developed and refined TravelStyle over a number of years: applications of the technique have included understanding and reducing 'car dependency' for Transport for London and forecasting demand for new rail services. We are currently developing a version of TravelStyle to forecast take-up in travel behaviour change programmes for a local authority in Yorkshire.

5. Conclusions

It is very clear that different groups of people behave and think in different ways and segmentation allows population differences to be built into the thinking, planning and implementation processes. At the same time, it is clear that the fundamentals of a public transport system which people want to use (including safety, reliability, frequency and affordability) are consistent across the segments, although what does vary is the need and desire to travel by public transport.

Our TravelStyle profiling tool was developed primarily to explore how social dimensions influence people's transport needs in a relatively objective and consistent manner. Its main strengths are:

- It is multidimensional – taking into consideration income, age, lifestage/family circumstances and car ownership and is therefore able to differentiate some major interactions between these factors, such as distinguishing between types of people who do not have a car through a lifestyle choice from those who cannot afford a car. It has also reduced the need to examine effects on a relatively large number of individual variables, and
- It can be used at a very disaggregate level of geography and therefore assess the impact of very specific changes, down to the level of individual routes, stops and stations.

Our TravelStyle maps have proved to be a great success and an innovative concept solution to help rationalise Germany's largest city's public transport system.

6. Acknowledgements

We would like to acknowledge our client Senatsverwaltung für Stadtentwicklung (SenStadt) Berlin and kcw who have supported us in this project and have given permission for this work to be publicised.

Biography

Tony Duckenfield (Associate) leads our Market Research Team, providing advice on research methods with a particular interest in consumer decision-making and what underlies data on attitudes and behaviour. He is also on the Steering Group of ONS's Output Area Classification (OAC) User Group, suggesting initiatives to develop geodemographic analysis and applications.

Sheila Quan (Senior Consultant) is a very knowledgeable and experienced spatial analyst with over 12 years' experience using GIS technology throughout UK, Europe and worldwide. She assisted Tony in the development of our TravelStyle profiling tool, extracting the most from individual data sets as well as capitalising on inter-relationships between data sets.

Nicole Rudolf (Principal Consultant) has helped Steer Davies Gleave to expand into the German transport market. She has a broad skills-base since she is both a transport consultant as well as a German lawyer. Her main strengths lie in project management and in the fields of legal/policy, economics, financial modelling and passenger transport.

MOSAIC Data Source Glossary

Data Source	**Description/ English Translation**
Be direct	Direct mailing company
Bundesagentur für Arbeit	Federal Employment Agency
Bundesamt für Bauwesen und Raumordnung	Federal Bureau for Building Industry and Area Planning
CEG Creditreform Consumer GmbH, Creditreform	Credit rating and debt collection agency
Deutsche Post	Mail communication, dialog marketing and efficient outsourcing and system solutions for the mail business. Equivalent to Royal Mail (UK).
Eurocamp	Camping vacation company
Felicitas Direktwerbung GmBH	Direct advertising company
GfK Panel Services	Market research and consultancy company
Global Direct	Market research and consultancy company
KBA (Kraftfahrt-Bundesamt)	Federal Bureau of Motor Vehicles and Drivers
Landesvermessung + Geobasisinformation Niedersachsen (LGN)	Office for Land Surveying Niedersachsen
Landesvermessungsamt Nordrhein-Westfalen	Office for Land Surveying North Rhine-Westphalia
NAVTEQ	Provider of comprehensive digital map information for automotive navigation systems, mobile navigation devices and internet-based mapping applications.
sinus sociovision	Market research and consultancy company
Statistische Amter des Bundes und der Lander	Federal Statistics Office and the individual Landers Statistics Office

Assessing Population Surface Models using the Northern Ireland Census Grid Square Resource

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1. Introduction

Direct comparison of populations using census data for different time periods is usually problematic because of (i) change in the zonal units used to report counts and (ii) change in the questions asked or the categories used for producing census outputs. This paper is concerned with the first of these two problems. In the absence of consistent zonal units, it is often necessary to reallocate counts from one set of zones to another or to generate a population surface which can be used in its own right or the counts aggregated in another set of zones. Assessment of the performance of areal interpolation procedures often relies on using synthetic data. In the case of population surface models direct assessment of estimates on a cell-by-cell basis is usually impossible due to the absence of actual population counts. The present paper makes use of gridded counts provided as an output of the 2001 Northern Ireland Census of Population to assess the performance of methods for generation of population surfaces.

A variety of routines for generation of population surfaces have been developed (for example, Tobler, 1979; Martin, 1989). In this paper the approach of Martin (1989, 1996) is applied and assessed. Through use of Northern Ireland grid square census data, different kinds of errors are identified and the importance of selection of an appropriate data neighbourhood and distance decay function is assessed. The paper closes with some preliminary recommendations for those who wish to generate population surface models but do not have access to grid square data.

2. Data and methods

2.1 Data

Total population surfaces were generated from Output Area population weighted centroids. These surfaces were compared to counts provided within 100 m^2 grid cells. In 1971 grid square counts were provided in Great Britain and Northern Ireland, but only in Northern Ireland was release of grid-square data continued beyond that census. In 1971, 1981 and 1991, 1 km^2 grid squares were available for the whole of Northern Ireland while 100 m^2 grid squares were provided only for urban areas. In 2001, both 1 km^2 grid squares and 100 m^2 grid squares were made available for the whole of Northern Ireland. The grid-square product is described by Shuttleworth and Lloyd (submitted).

2.2 Population surface modelling

Martin (1989) outlines a method for mapping population from zone centroids. With this approach, each zone centroid is visited in turn and the mean intercentroid distance is calculated within a predefined search radius. This measure indicates the unknown areal extent of zones in the region and it is used to calibrate a distance-decay function that assigns weights to cells in the output grid. The cells that are closest to the zone centroid receive the largest weights, while those cells estimated to be located in the maximum areal extent of the zone receive the smallest weights. The population is then redistributed in the surrounding region using these weights. A given cell in the output grid may receive population values from one or more centroids, or may remain unpopulated as it is beyond the area of influence of any of the centroid locations. Bracken and Martin (1995) apply the method for linking 1981 and 1991 censuses of Britain, producing a dataset available at http://census.ac.uk/cdu/software/surpop/.

Using this approach, population is preserved globally (the sum of populations in the zones is the same as the sum of populations in the population surface), but the sum of the number of people in a given zone does not necessarily correspond to the overlapping area in the population surface. That is, no account is taken of zone boundary location and population may be gained from or lost into neighbouring zones through applying the method. For this reason, Martin (1996) presented an adapted version of the method. In this modified version, a rasterised zone map with the same cell size as the required output surface is acquired first. As population is redistributed, the weights for cells located outside the current zone are automatically set to zero — it is locally mass preserving. Both the original (global mass preservation) and updated (local mass preservation) versions of the method are applied and assessed in this paper.

3. Results

The analysis was based on 2001 OA population weighted centroids using total population, reallocating counts to a grid with 50m spacing with the same minimum and maximum x and y co-ordinates as the 100m grid data. The counts on 50m cells were then aggregated to form 100m grid cells that could be compared directly with the grid square count data. Table 1 gives, for the whole of Northern Ireland, summary statistics when the estimated surfaces were subtracted from the 100m grid data counts (so, negative values indicate under-estimation) for search radii of 250 m and 500 m and for both global and local versions of the routine. The mean error suggests that the as the search radius is increased the tendency to under-estimate tends to increase.

Type mass preserve.	Search radius	Max. neg. error	Max. pos error	Mean error	Std. dev.
Global	250	-2561.021	495.987	-7.351	24.501
Global	500	-2529.398	152.559	-8.055	22.748
Local	250	-2560.856	206.859	-7.455	24.205
Local	500	-2515.798	137.366	-8.139	22.890

Table 1. Northern Ireland: population surface estimation errors (estimates – 100m grid cell counts), distance decay parameter = 1. Local = mass preservation within OAs.

The results in Table 1 are for a distance decay parameter of 1, which approximates to linear distance decay. Alternative distance decay parameters are likely to yield more accurate estimates in different situations. In densely populated urban areas a large distance decay parameter value is likely to be more appropriate than in sparsely populated rural areas. In Table 2, error summary statistics are given for a search radius of 500 m and with distance decay parameter values of 0.25 and 2.

Type mass preserve.	Distance decay par.	Max. neg. error	Max. pos error	Mean error	Std. dev.
Global	0.25	-2543.217	105.572	-8.445	23.025
Global	2	-2526.193	187.487	-7.729	22.863
Local	0.25	-2521.212	143.382	-8.417	22.984
Local	2	-2519.405	146.720	-7.894	23.012

Table 2. Northern Ireland: population surface estimation errors (estimates – 100m grid cell counts), search radius = 500. Local = mass preservation within OAs.

Tables 3 and 4 are the equivalent of Tables 1 and 2 respectively but for the Belfast Local Government District rather than for Northern Ireland as a whole.

Type mass preserve.	Search radius	Max. neg. error	Max. pos error	Mean error	Std. dev.
Global	250	-1268.321	362.673	-7.991	44.350
Global	500	-1234.875	101.938	-10.460	41.441
Local	250	-1262.994	206.859	-8.422	44.394
Local	500	-1230.042	137.366	-9.846	42.518

Table 3. Belfast: population surface estimation errors (estimates – 100m grid cell counts), distance decay parameter = 1. Local = mass preservation within OAs.

Type mass preserve.	Distance decay par.	Max. neg. error	Max. pos error	Mean error	Std. dev.
Global	0.25	-1239.084	97.099	-11.805	42.568
Global	2	-1241.165	108.311	-9.375	41.013
Local	0.25	-1225.985	143.382	-10.375	42.614
Local	2	-1237.622	146.720	-9.340	42.727

Table 4. Belfast: population surface estimation errors (estimates – 100m grid cell counts), search radius = 500. Local = mass preservation within OAs.

The figures suggest that, as expected, a large distance decay parameter is more appropriate in densely occupied urban areas as the mean errors tend to be closer to zero for large values (i.e., 1, 2) than for a value of 0.25. The local mass preserving approach gives less accurate estimates, judging by the mean and the standard deviation of the errors, than does the original global mass preserving approach. This may be partly due to the size of the grid used — 50 m cells sometimes straddle two OAs and forcing all of the population of that cell to belong to one OA is erroneous. Future work will assess the impact of using smaller grid sizes.

Figure 1 shows, for the Belfast area, estimation errors for a search radius of 500 m with local mass preservation. The estimation errors appear visually random. There is some suggestion that errors are larger (whether negative or positive) in areas where the density of OA centroids is greater. It also appears that there is a tendency to underestimate where the population densities are larger and this is intuitively sensible.

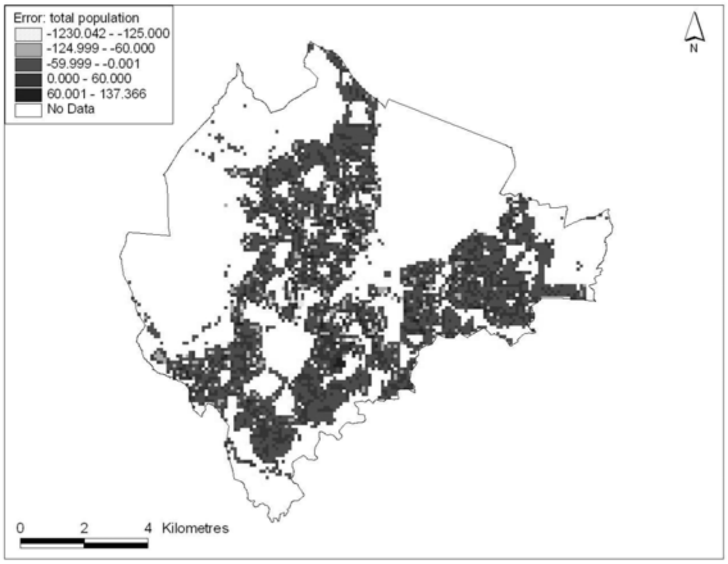

Figure 1. Population surface estimation errors (estimates – 100m grid cell counts): 500 m search radius, local mass preservation.

4. Conclusions and future work

This brief paper provides results from preliminary analyses. The intention is to provide results that other users with no access to grid square data can use to inform the approach that they employ. By assessing differences due to method, parameters (e.g., search bandwidth) and underlying population characteristics gaining an insight into appropriate procedures in particular situations is feasible.

Future work will focus on assessing spatial variation in estimation errors. Detailed examination of the impact locally of applying different search radii and different distance decay parameters will be conducted. Following this work, the possibility of using, for example, different distance decay parameters can be considered.

5. Acknowledgements

The Northern Ireland Statistics and Research Agency (NISRA) are thanked for the provision of 2001 Northern Ireland Census of Population grid square data.

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Synthesis and Modification of Remotely Sensed Imagery

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1. Introduction

The impact of remotely sensed imagery is growing and its utility is reaching an increasingly broadly-based audience. The study of the earth extensively makes use of satellite imagery and most geospatial software systems incorporate it as a fundamental component. For example, 3D GIS such as Terrafly (Rishe et al., 1999) and GeoZui3D (Ware et al., 2001), offer the ability overlay satellite imagery onto terrains. In addition, textured terrains can also be used by GIS specialists as tools for the presentation of spatial data to non–experts (MacEachren, 1994). Recently, satellite imagery has extended to popular applications such as Google Earth.

The aim of this work is to increase the utility and flexibility of satellite imagery. The system being presented is able to completely synthesize new satellite imagery using data from existing images or seamlessly alter an existing image according to specified constraints. The proposed applications of this technology include the visualization of alterations to terrains, for both past re-construction and future prediction. Our system may also permit the generation of hypothetical geography for illustrative purposes in GIS education. The technical contribution of the work is a non-parametric method for the controlled synthesis of satellite images which combines pixel-based texture synthesis and non-linear image compositing.

2. The Concept of Image Re-synthesis

We wish to construct new satellite imagery incrementally and do so according to constraints. First, let us consider an example of synthesizing a new image based on data found in an existing image. In figure 1, a real satellite image is shown to the left. We will refer to this as the *input_image*. From the pixel data contained in this image we will construct the new image, shown in figure 2, left. We will refer to this as the *output_image*. Note that this second image is a fictitious terrain that does not exist.

There are two issues that must be explained. The first regards exactly how the pattern of the landscape is defined in the output image. As we will now discuss, the output image's terrain pattern is defined with a set of constraints which take the form of a *mask*. The second regards how the synthesis process is conducted, given the *mask* constraints. We will address this second issue in section 3.

In order to be useful, we need to be able to specify that a given portion of the output image will be a particular type of terrain. For example, in the *output_image* shown in figure 2, we have two explicit terrain types, namely water and land. We have used only two types for illustrative simplicity. The question becomes how to specify where the water is synthesized and where the land is synthesized.

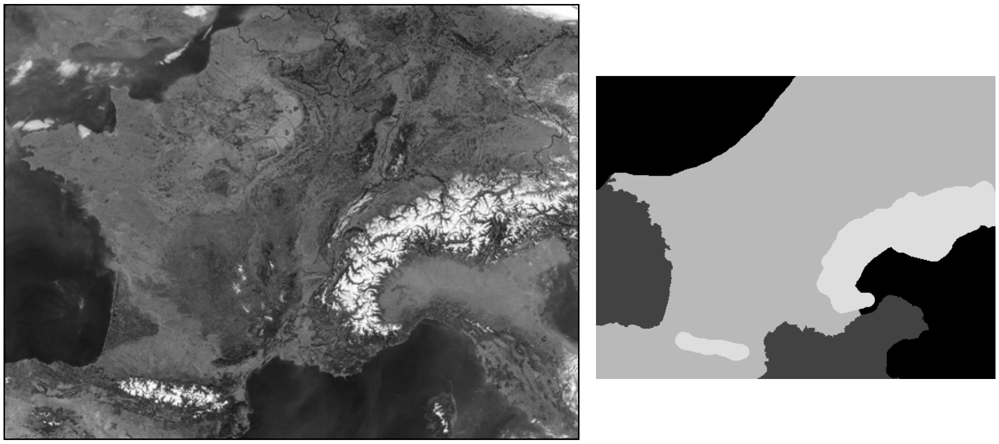

Figure 1: A real satellite image shown left. To the right is a mask that segments the satellite image into coherent regions.

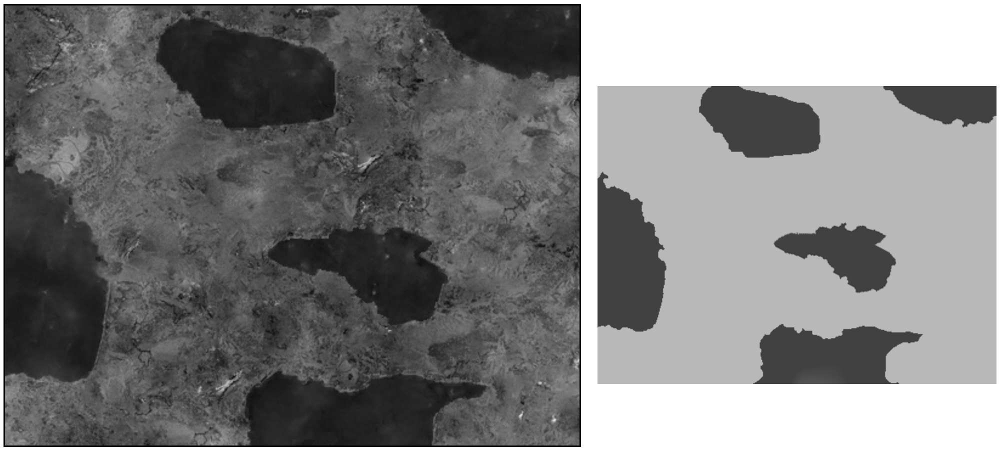

Figure 2: A newly synthesized image is shown left. To the right is a mask of the synthesized image that was used to constrain the synthesis process.

We can constrain the placement of terrain types with masks. Specifically, we require a mask for the input image (figure 1, right) and a second mask for the output image (figure 2, right). Note that the masks are shown smaller to fit the page width; in reality the masks and satellite images are the same dimensions. Informally, the input mask tells the system where each terrain type is “coming from”, while the output mask indicates where each terrain type is “going to”.

This set of four images form two analogous pairs. Specifically, we wish to find the analogous *output_image* that relates to the *output_mask* as the *input_image* relates to the *input_mask*. For now we will leave aside how the masks themselves are constructed, assume they are given and consider how the output image is synthesized under the mask constraints.

3. The Synthesis Process

We now propose a non-parametric method for the controlled synthesis of satellite imagery. This approach operates in two stages and combines pixel-based texture synthesis and non-linear image compositing. By non-parametric, we mean that it does not require parameter tweaking to achieve high-quality results. This contrasts the earlier work on texture synthesis by Hertzmann et al. (2001) which requires a non-intuitive parameter to be set by the user, called the coherence parameter, κ. As our system does not require obscure parameters to be set by the user, it is easier to apply as it does not require the user to be familiar with the inner workings of the algorithm.

3.1 Generating an Initial Approximation

The first stage generates a rough approximation of the final result and could be considered a "base-coat". Pixel-based texture synthesis is used to construct this approximation. We first produce a blurred version of the input image using a Gaussian lowpass filter of size 18 pixels with standard deviation of 3 pixels. Using the blurred input image, called *blur_image* (figure 3, left), we next generate the approximate solution, called *approx_image* (figure 3, right), using texture synthesis. We produce a blurred undercoat so that it does not introduce high-frequency artefacts into the final result.

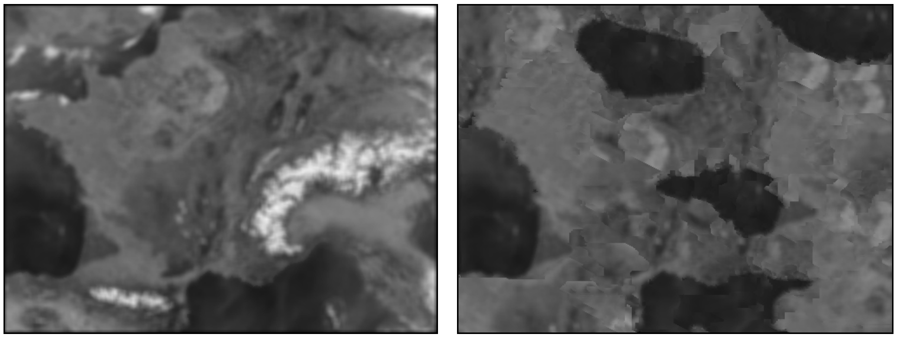

Figure 3: Blurred image satellite image (left). An initial approximation generated with pixel-based texture synthesis (right).

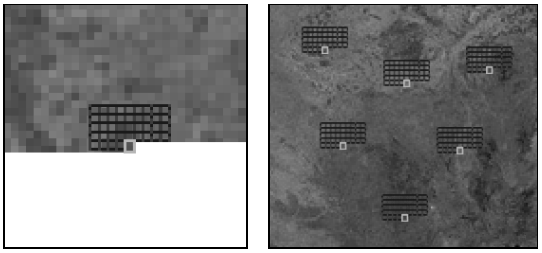

Figure 4: Synthesizing the next pixel (shown centre) in the output image (left). The next pixel is chosen from a selection of candidates with similar local neighbourhoods (right).

The algorithm generates each new pixel in the output image in sequential scan-line order. This is illustrated in figure 4 (left) with a newly synthesized pixel highlighted along with its local neighbourhood. To determine the new pixel's colour, the pixel values of its local neighbourhood are compared against multiple local neighbourhoods in the input image (figure 4, right). The colour of the pixel with the best matching neighbourhood is used as the colour of the newly synthesized pixel. This pixel generation process is also subject to the constraints of the *input_mask* and *output_mask*. For example, new pixels generated in a water region of the *approx_image* will only be sampled from a water area in the *blur_image*.

This discussion of the synthesis algorithm has been simplified for brevity. For more details the reader is referred to Hertzmann et al. (2001). In particular we use a fixed coherence parameter, $\kappa = 1$. Our results are not sensitive to the parameter since we are only using texture synthesis as a basis for the final image synthesis.

3.2 Constructing the Final Result

The *approx_image* contains the basic structure of the final image, but lacks detail and clarity. We now build directly upon the approximation. This phase requires an iterative algorithm which inserts detail into the *approx_image* using a sequence of non-linear optimization processes (Pérez et al., 2003).

But before this, we first need to identify region boundaries in the *output_mask*, using a Canny edge detector (Canny, 1986). The result of which is shown in figure 5, left. The edges are then expanded with a morphological dilation using a disk of diameter 10 pixels, shown in figure 5, right.

Figure 5: Canny edge detection on the *output_mask* (left) and subsequent dilation (right).

The next stage of the process is an iterative cycle which integrates detail into the non-boundary areas (shown black in figure 5, right) of the *approx_image*. At each iteration, details are extracted from a suitable region of the original *input_image* and seamlessly integrated into a subset of a non-boundary region of the *approx_image.* The algorithm iterates until all pixels within all non-boundary regions are processed.

Each iteration requires a separate optimization process to introduce new content into a subset, Ω, of existing the image, *approx_image* = h. It computes a new intermediate image, *inter_image* = f, whose gradient, ∇f, within Ω is closest to the gradient ∇g, taken from *input_image* = g. The original boundary, $\partial\Omega$, of region Ω from h is also used as a constraint. It is this additional constraint that ensures that the region Ω blends with the surrounding content, h. The resulting image contains an interpolation of the boundary conditions, $\partial\Omega$, inwards while conforming to the spatial changes of the guidance field from g as closely as possible within Ω. The minimization problem is written as:

$$\min_{f} \iint_{\Omega} |\nabla f - \nabla g|^2 \text{ with } f|_{\partial\Omega} = h|_{\partial\Omega} \tag{1}$$

At the end of each iteration, *approx_image* is set to *inter_image*, meaning that each iteration builds detail onto the output of the previous iteration. After all iterations the final result is produced as shown in figure 2, left.

In this section we have generated an entirely new image. However, it is important to note that a more common application of this technology would likely be the modification of existing satellite images, in which case the *input_mask* and *output_mask* would be similar but not identical. We also note that the system can generate imagery with an arbitrary number of terrain types, rather than just the two (water and land) used in this proof-of-concept illustration.

4. Conclusions and Future Work

In this work we have achieved our first goal: to create a non-parametric system which generates new satellite imagery from exiting images, according to constraints. The proposed applications include the visualization of terrain change, for both past re-construction and future prediction, as well as GIS education. But, there remains significant scope for extending the system.

At present the *input_mask* and *output_mask* are manually constructed. Further work is required to integrate image synthesis with complementary systems which would generate the constraint masks based on analysis and prediction. For example, a system which predicts land erosion could be adapted to automatically produce masks that would be used to generate the altered terrain image. More finely detailed control of the synthesis process could also be introduced. In practice, this would mean using continuously changing masks.

5. Acknowledgements

This work was supported by NSERC and the Canadian Foundation for Innovation.

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Biography

Stephen Brooks is an Assistant Professor at Dalhousie University in Canada. Prior to this, he acquired a Ph.D. from the University of Cambridge in 2004 and a M.Sc. from the University of British Columbia in 2000.

Satellite Image Data Service – Providing New Geodata Services and Satellite Imagery

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1. Introduction

The Satellite Image Data Service (SIDS) provides web-based access to and support for a range of satellite imagery for the British Isles for research and teaching purposes. The data archive includes a set of orthorectified satellite images from five satellites, Landsat 5, Landsat 7, Satellite Pour l'Observation de la Terre (SPOT), ENVISAT Advanced Synthetic Aperture Radar (ASAR) and European Remote Sensing (ERS). The data archive covers the UK and Republic of Ireland over a range of temporal periods from the mid 1980s to present. The data is available for download from the Landmap website for those attending a subscribed institute. The satellite imagery archive is projected to British National Grid (UK data) or Irish National Grid (Republic of Ireland data) and can be used in image processing software, in association with user's data or other mapping data such as Ordnance Survey data in a Geographical Information System (GIS) (Landmap 2006). In addition, a Digital Elevation Model (DEM) of the whole of the British Isles at 25 meter resolution is available derived from interferometric methods using ERS 1 and ERS 2 data (Kitmitto 1999).

This paper provides details of the main areas of development currently occurring at SIDS. The first is the ongoing development of the interactive mapping service (OGC and MapServer) and image streaming service (ER Mapping Image Web Server). The second is the processing of raw ASAR ENVISAT data for use by the UK academic community. If there is demand for ASAR data from institutes in the Republic of Ireland SIDS would be prepared to negotiate with ESA a license to make this data available in the future.

1.1 Providing Data Services

The traditional method of viewing and accessing data at the SIDS is to click a thumbnail tile of an image on the website and see a static screenshot. The drawback of this approach is that the data cannot really be explored prior to download or integrated with other datasets. To provide our end users with a more flexible approach of using the SIDS data archive two new services have been developed. The first was to create Open Geospatial Consortium (OGC) Web Map Services (WMS) and Web Coverage Services (WCS). The second method was to provide the SIDS archive via Image Streaming using ER Mapper's Image Web Server.

1.1.1 OGC Interactive Mapping Service

Part of the work conducted by the SIDS is to acquire, create, maintain and disseminate data to academia. The use of OGC web services enables the dissemination of data in a standard interoperable form. WMS provide online maps of georeferenced data which is a visual representation of the satellite data stored on the server. The response from the server is to provide a temporary image either in JPEG, PNG or GIF format (OGC 2006*;* Kim *et al.,* 2005). The WMS operations that an end user can request are: -

GetCapabilities – Provides metadata about the WMS
GetMap – Returns a map image in JPEG, PNG, GIF
GetFeatureInfo – Allows the end user to request information about features on the map (Kolodziej, 2003).

Additionally SIDS has created WCS which require data representing space-varying phenomena (Lee *et al.,* 2005). Obviously satellite imagery fits this description and therefore SIDS is providing sample WCS, however further development work needs to be achieved such as trying to find a solution to authenticate users that have downloaded the satellite imagery via WCS. The end user can submit a GetCapabilities, DescribeCoverage and GetCoverage request to the WCS via Hypertext Transfer Protocol (HTTP) (Cox, 2003).

1.1.2 Image Streaming Service

The Image Streaming Service is available for all the datasets in the SIDS archive via the URLs http://ims1.landmap.ac.uk/ or http://ims2.landmap.ac.uk/ . The data is in Enhanced Compressed Wavelet (ECW) format which allows compression of imagery up to 50:1 with almost no visual loss of information. This means that images that were previously too large to serve online can now be easily used and distributed with the support of ER Mappers Image Web Server. SIDS implemented the ECW ArcXML Server which processes requests in the ArcXML format to serve imagery for use by client software such as ArcExplorer and ArcGIS that supports the ArcXML protocol. An ISAPI extension to Image Web Server is required which allows detection of the standard ESRI interface calls to report the image layers available and to service an image extraction request and return a JPEG image to the requesting application in the prescribed ArcXML protocol (Image Web Server, 2005).

1.2 Expanding the Data Archive

Currently SIDS is expanding the data archive with provision of Envisat ASAR data acquired from the European Space Agency (ESA). The data was acquired as part of the Catergory -1 Principal Investigator (PI) Project ‘Monitoring the state of the British Isles with ASAR’. The main objectives of the project are:

- Provide ASAR data on the Landmap website for download in GeoTiff format projected to British National Grid
- Derive further produces from ASAR
- Create on-line educational materials for academics unfamiliar with using radar data.
- Provide the ASAR data in an interoperable form as WMS and WCS

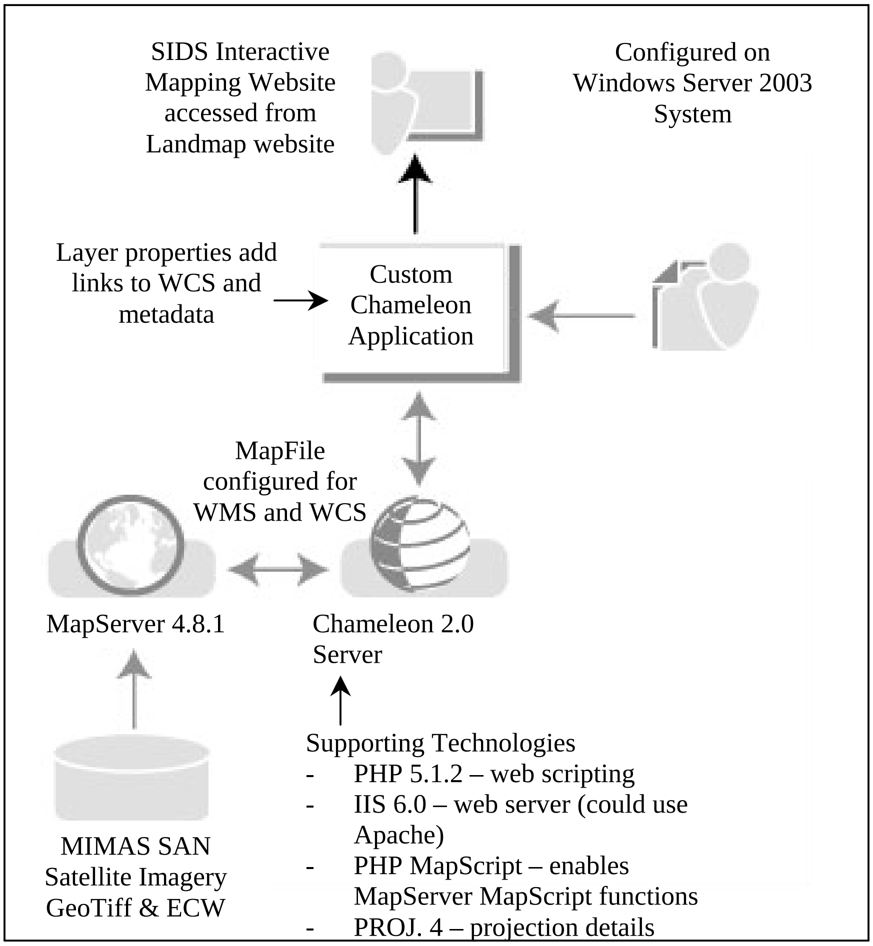


Figure 1. Configuration of MapServer and Chameleon for SIDS mapping client. Adapted from DM Solutions Group Inc. (2005 on-line http://www.dmsolutions.ca/technology/chameleon.html).

SIDS is acquiring ASAR data as the imagery is provided in five different modes providing valuable scientific data to assess and understand both natural and man-made phenomena (ESA, 2005). ASAR has enhanced capabilities compared to ERS (available for Republic of Ireland) due to acquisition in a range of polarizations and incidence angles. Also ASAR being an active sensor can obtain imagery during periods of cloud cover and at much greater temporal frequencies than optical data.

2. Methodology

2.1 WMS and WCS Mapping Configuration

The WMS and WCS on the Landmap website were configured using MapServer and Internet Information Server 6.0 as illustrated in Figure 1. SIDS customised the Chameleon 2.0 client originally developed by DM Solutions Group to provide the front end to WMS and WCS on the website http://landmap.mimas.ac.uk/download/wms.htm .

The configuration is using all open source tools freely available from the internet apart from the web server IIS 6.0 alternatively the web server Apache could be used. This setup allows us to serve all our data as OGC services, WMS and WCS. The WMS are available through the Chameleon interface; these services can also be cascaded for those who want to integrate their data with data served from SIDS. Some WCS services are available for data at lower resolutions. Full WCS services will be coming after we have implemented authentication and extraction services.

2.2 Image Streaming Configuration

The web client RightWebMap (RWM) 7.0 was customised to provide the Graphical User Interface (GUI) for the Image Streaming Service. This RWM client is a thin client requiring the installation of an Active X control that allows the streaming of images to browsers. Regrettably this is only available for Internet Explorer 6 and above and Firefox. However, the image streaming is available to ArcGIS® and other software that connect to ArcIMS services. In addition there are many available plug-ins http://www.ermapper.com/downloads/plugins.aspx that allow for the incorporation of streamed images in various software including, MapInfo®, AutoCAD® and Microsoft Office® documents.

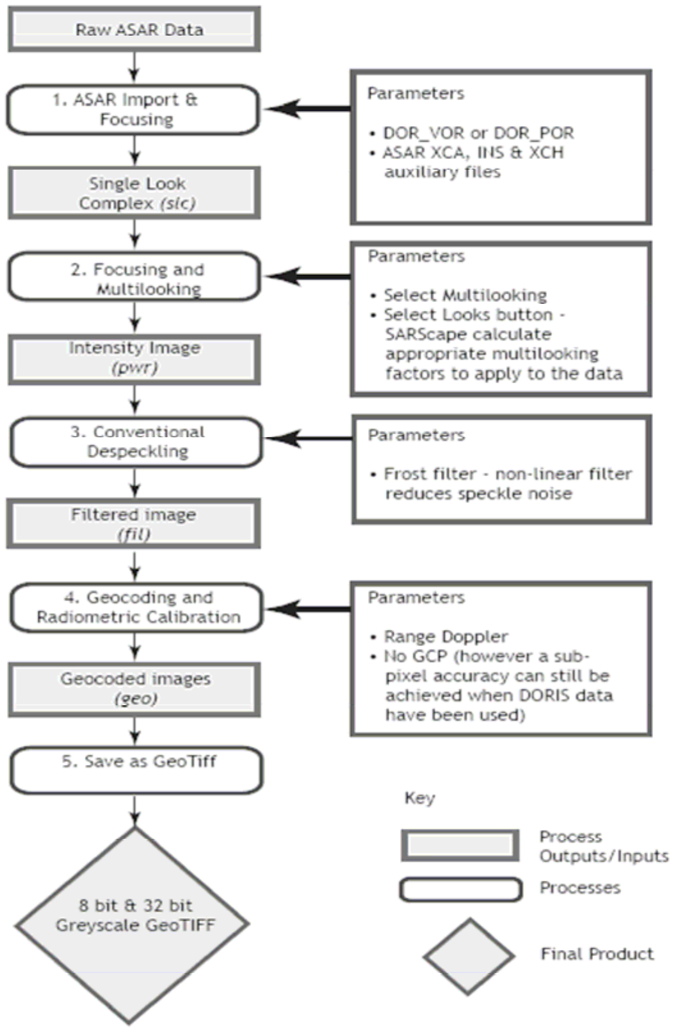
2.3 Image Processing Chain for Envisat ASAR data

The raw ASAR data was processed using SARScape which uses ENVI 4.3. as the user interface and associated image processing environment. Figure 2 provides details of the processing chain applied to the ASAR data to produce greyscale 8 bit and 32 bit imagery and 8 bit colour composite imagery.

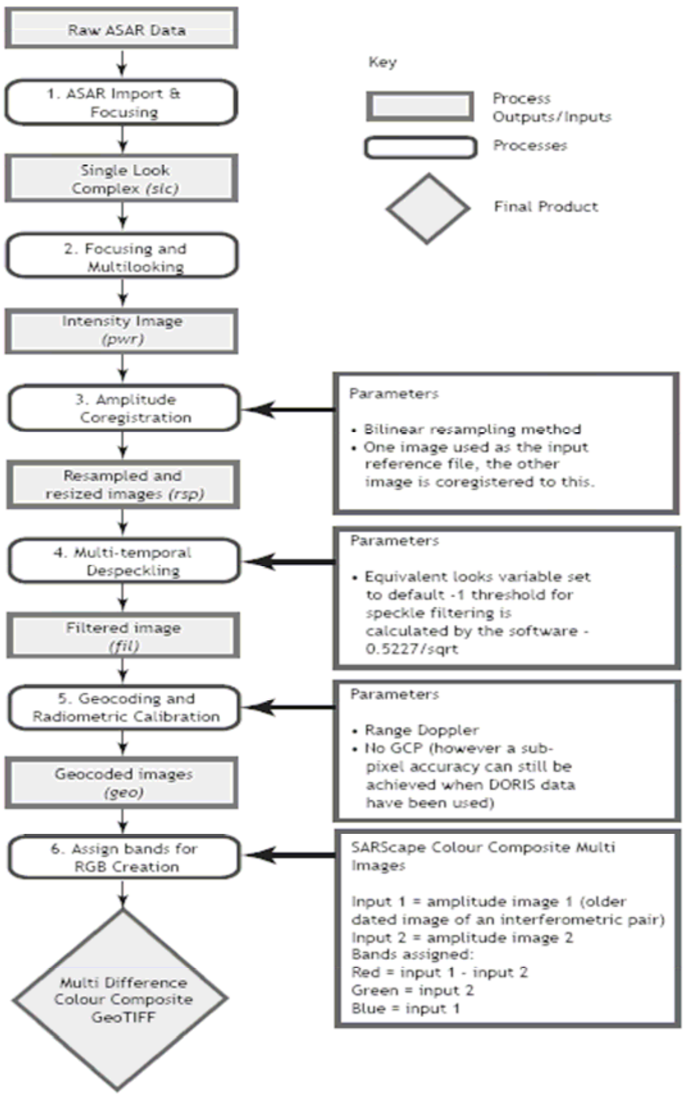
Colour Composite Images were created to provide users of radar data with instant visual indication of the change in the environment between the two images of the same area separated by time. The two images selected were for the same year separated by about six month providing contrasts between winter and summer.

SIDS is committed to acquire more ASAR data for the UK. We welcome suggestions for data and areas to be acquired for the UK. We will then produce the data so that it can be used for teaching purposes and for research. For researchers requiring a specific area with different processing methods than those applied in Figure 2 e.g. different filter during the despeckling process or different resampling method the SIDS will adapt the process to meet user’s needs. If there is demand for ASAR data from institutes in the Republic of Ireland, SIDS would be prepared to negotiate with ESA a licensing agreement to make this data available as GeoTiff’s in Irish National Grid in the future.

Product 1 - Greyscale ASAR Images

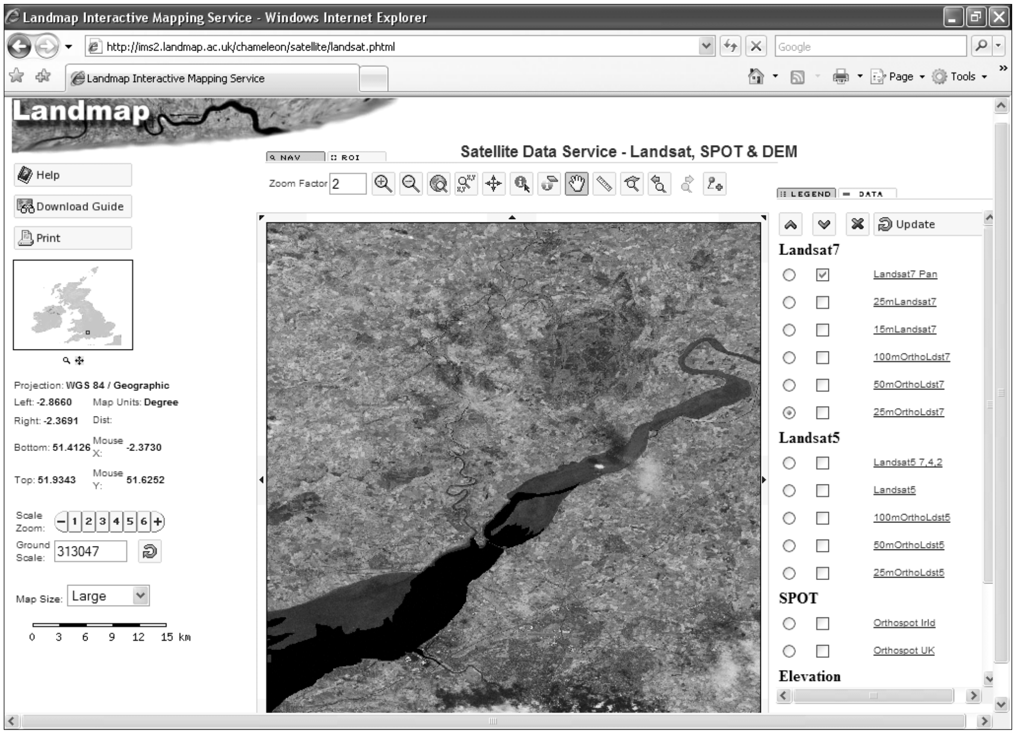


Product 2 - Colour Composite Images



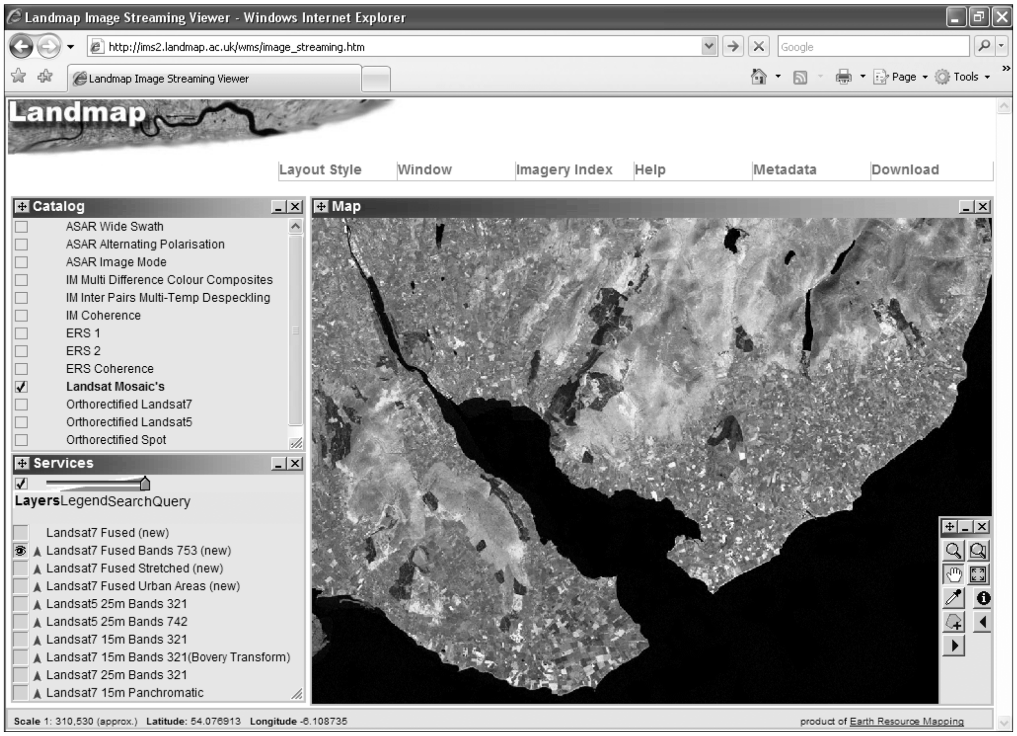
4. Discussion and Conclusion

SIDS has provided two new services for the academic community the WMS and WCS (Figure 3) and also Image Streaming Service (Figure 4).



Zoom Factor: 2

Projection: WGS 84 / Geographic
Left: -2.8660 Map Units: Degree
Right: -2.3691 Dist:
Bottom: 51.4126 Mouse X: -2.3730
Top: 51.9343 Mouse Y: 51.6252
Scale Zoom: − 1 2 3 4 5 6 +
Ground Scale: 313047
Map Size: Large



Catalog:
- ☐ ASAR Wide Swath
- ☐ ASAR Alternating Polarisation
- ☐ ASAR Image Mode
- ☐ IM Multi Difference Colour Composites
- ☐ IM Inter Pairs Multi-Temp Despeckling
- ☐ IM Coherence
- ☐ ERS 1
- ☐ ERS 2
- ☐ ERS Coherence
- ☑ **Landsat Mosaic's**
- ☐ Orthorectified Landsat7
- ☐ Orthorectified Landsat5
- ☐ Orthorectified Spot

Layers:
- Landsat7 Fused (new)
- Landsat7 Fused Bands 753 (new)
- Landsat7 Fused Stretched (new)
- Landsat7 Fused Urban Areas (new)
- Landsat5 25m Bands 321
- Landsat5 25m Bands 742
- Landsat7 15m Bands 321
- Landsat7 15m Bands 321(Bovery Transform)
- Landsat7 25m Bands 321
- Landsat7 15m Panchromatic

Scale 1: 310,530 (approx.) Latitude: 54.076913 Longitude -6.108735

Figure 3. Customised Chameleon client for WMS and WCS.
Figure 4. Customised RightWebMap client for Image Streaming Service.

The on-line mapping services have attracted a total of 1.5 million hits, from approximately 9000 unique IP addresses, in the past year. Future plans are to extend the interfaces further by integrating the metadata XML files for each dataset into the viewers and also by creating a dynamic map extract tool. The extract tool will allow users to download via WCS the satellite imagery that appears in the viewer so that the download process is more user specific. The associated recently updated metadata file will also be downloaded and all data provided in a zip file to the end user. Possible solutions for authentication will also be explored during the forthcoming year so that SIDS can monitor who is using the WCS.

Focused on developing further the SIDS geodata infrastructure, in the forthcoming year development activities will be taking place to grid enable the SIDS archive as part of the Grid Enabling MIMAS Services (GEMS) II project funded by JISC. A demonstration use case of urban-rural change detection using data from different time epochs will be developed to show how the grid can be implemented for CPU intensive processing which would be unmanageable on a desktop.

Further data acquisition is also a priority; with plans to order additional ASAR data from ESA and provide the data online as WMS, WCS, Image Streaming and as ortho-rectified GeoTiff’s. A request to JISC to provide funding to acquire annual UK coverage of optical data for 5 years has been submitted. We hope that by the time this paper is presented at GISRUK 2007 positive news about the expansion of the SIDS service would be forthcoming.

Acknowledgements

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Segmentation Evaluation for Object Based Remotely Sensed Image Analysis

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KEYWORDS: OBIA, Segmentation, Texture, Evaluation.

1. Introduction

Object based image analysis (OBIA) is a relatively new form of remote sensing which aims to overcome the failings of traditional pixel based techniques at providing accurate land-use classification for high resolution data. The failure of pixel based techniques is due to the fact that these techniques are based on the assumption that individual classes contain uniform visual properties. As we increase the spatial resolution of data the intra-class variation increases and this property of class uniformity is broken leading to very poor performance (Blaschke 2003). The human visual system (HVS) can interpret high resolution data very easily and accurately. If a truly accurate and robust automated land-use classification system is to be achieved, it must draw from research in the area of cognitive psychology and attempt to model how we as humans interpret aerial imagery. This is the aim of research in the area of OBIA.

Traditionally OBIA comprises two steps. First a segmentation of the given scene is performed which defines the different objects or land-covers. This is then used as input to a land-use classifier. In a recent paper (Corcoran and Winstanley 2006) we discussed a model to define land-cover objects which agrees more with current theories of visual perception about how we perceive such objects then previous approaches. In this model, segmentation is performed in two stages. First a bottom-up feature extraction of visual properties and segmentation is performed, where each area of uniform properties is represented once within a single segmentation. This is motivated by the principle of uniform connectedness which states that adjacent regions of uniform visual properties are perceived initially as single perceptual units in early vision, and serve as entry level visual stimulus (Palmer and Rock 1994; Pylyshyn 1999). This low level segmentation is then affected by top-down and bottom-up influences where objects are aggregated to form segmentation at a higher scale. In (Vecera and Farah 1997) it was shown that such top-down factors do influence the segmentation process. Therefore different levels of segmentation exist, one where each area of uniform properties is represented as a single object and others where these objects influenced by top-down and bottom-up factors are aggregated to form segmentation at a larger scale. When attempting to evaluate a segmentation algorithm using a particular evaluation method we must be aware of this fact, and ensure the evaluation method targets the corresponding level of segmentation which we are attempting to model.

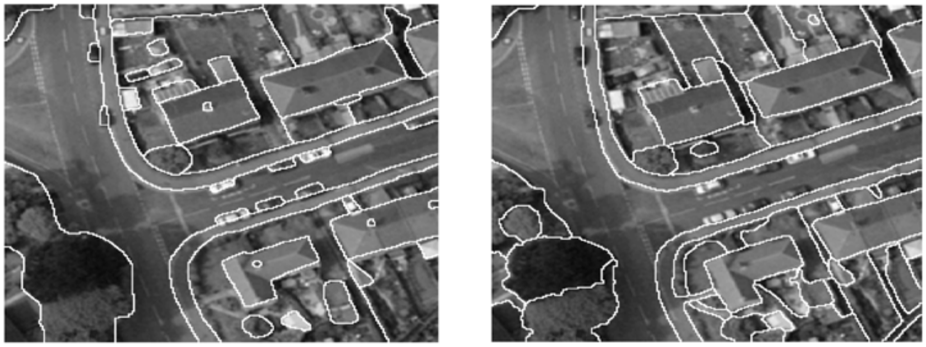
The aim of my overall research is to model the early vision process of representing each area of uniform properties as a single object. The research question I attempt to answer here is how best to evaluate such a model. We now discuss the different forms of supervised and unsupervised evaluation which may be used. A novel form of unsupervised evaluation is introduced which incorporates a set of features which complement as opposed to compete against each other as is standard in previous approaches.

2. Supervised Evaluation

In an experiment to assess the extent of top-down and bottom-up influenced object aggregation in human visual segmentation, we asked a number of subjects who were unaware of the research background to segment a number of aerial scenes. They were untrained photograph interpreters but familiar with aerial photography. The instructions to the subjects were brief and similar to those used in (Martin, Fowlkes et al. 2001) to capture the Berkeley segmentation dataset of natural scenes:

> *You will be presented with a photographic image. Divide the image into some number of segments, where the segments represent "things" or "parts of things" in the scene. The number of segments is up to you, as it depends on the image.*

Figure 1 show examples of the segmentation results returned from two individuals for the same image. From these images we can see that aggregation of objects with uniform properties has played a major factor in the segmentation process. Although large scale conceptual objects such as trees, buildings, roads and sidewalks are segmented, a large amount of individual objects of uniform properties are not represented. Although only two images are shown here, this property was uniform across the whole data set captured.



(a) (b)

Figure 1: Segmentation results returned by two individuals are shown in (a) and (b). Object boundaries are represented by the colour white.
Ordnance Survey (c) Crown Copyright. All rights reserved.

Traditional remote sensing classification algorithms are evaluated in a supervised manner using ground truth (Congalton and Green 1998). Supervised evaluation requires the capturing of ground truth and a method for comparing a segmentation result to this ground truth. As can be seen in figure 1, when asked to produce ground truths, human subjects tend to produce segmentation at a larger scale, where individual objects are merged, then we desired. Capturing of ground truth where each object of uniform properties is represented would require a great effort on the interpreter's part and may not be even possible due to the fact that we tend to merge objects unconsciously. To date no such data set exists. Using existing land-use classifications as ground truth is also not an option because these will also contain aggregated objects. Another point to note is that although each individual's segmentation shares similarities with others, they also have significant differences. This is due to the fact that each individual's interpretation of a given scene and how objects should be merged will vary. Another form of supervised evaluation which is widely used in remote sensing literature is visual assessment of the segmented images. This approach has the advantage of not requiring any implementation but is subjective and time consuming.

3. Unsupervised Evaluation

In order to overcome the difficulties of supervised segmentation evaluation, we propose to perform evaluation in an unsupervised manner. In unsupervised evaluation a measure of uniformity of intra-class features and/or a measure of separation of inter-class features is used to measure the quality of segmentation (Rosenberger, Chabrier et al. 2006). Although this approach has received must attention, most methods in the area are based on the assumption that each individual object is of uniform intensity properties. In cases where images contain areas of uniform texture such as remotely sensed images, these approaches will fail.

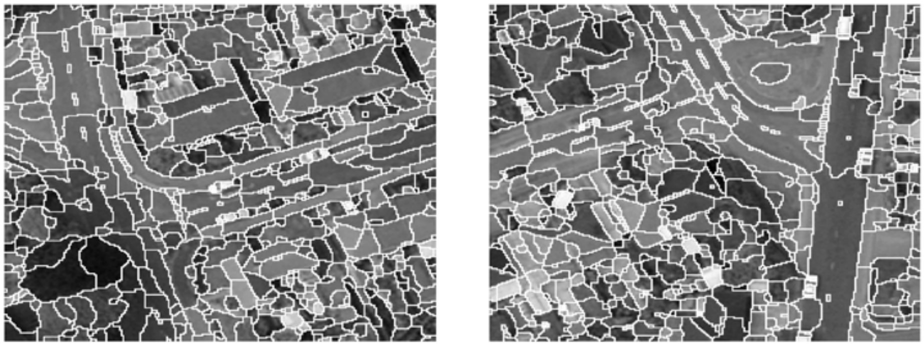
Our unsupervised evaluation technique builds on the work of (Chabrier, Emile et al. 2006) and (Rosenberger, Chabrier et al. 2006). For unsupervised evaluation Chabrier (Chabrier, Emile et al. 2006) defined a set of texture and intensity features which cannot complement but actually competed against each other. In this approach each region is defined as being either predominately uniform intensity or texture, and only the corresponding subset of features is used in segmentation evaluation. Most objects will have unique average intensity and texture values so failing to use both feature sets leads to reduced discrimination strength. In this paper we propose a set of texture and intensity features for segmentation and unsupervised evaluation that actually complement each other, thus giving greater discrimination power. These features consist of the average intensity and texture features for each land-cover, for further details see (Corcoran and Winstanley 2006) and (Corcoran and Winstanley 2007). Given a feature set and segmentation result derived using these features, we must then define the cost function of the features which measures the accuracy of segmentation. We use a novel measure of the ratio between inter and intra object features as such a function.

An important issue with unsupervised evaluation approaches, is how best to evaluate if we are using the correct feature set, segmentation algorithm and optimizing the correct segmentation evaluation cost function. One approach is to treat a supervised evaluation method as the optimal solution and attempt to generate an unsupervised method which has high correlation with the supervised method (Chabrier, Emile et al. 2006). Generation of the ground truths for aerial images for use in supervised evaluation presents a number of issues which we discussed previously. Another option is to use synthetic images where ground is known (Rosenberger, Chabrier et al. 2006). Unless synthetic images of similar complexity, containing areas of uniform properties and shapes similar to aerial images are used, then this form of evaluating unsupervised methods is not accurate. To create images of this complexity would require an understanding of the underlying processes generating aerial images which is unknown. This view is also shared in (Usamentiaga, Garcia et al. 2006). Therefore visual assessment is used to evaluate the accuracy of our unsupervised evaluation.

That is, the goal of this work is to produce a feature set, segmentation algorithm and evaluation cost function which targets segmentation where individual objects of uniform visual properties are accurately represented. Visual assessment of the optimal segmentation in terms of the given cost function will evaluate this. The need to perform visual assessment of the unsupervised evaluation procedure begs the question of why do we not simply perform visual assessment of the segmentation algorithm and abandon unsupervised evaluation. The motivation for having an unsupervised evaluation procedure is that it will generalize to allow the evaluation of different segmentation algorithms on different data sets therefore removing the need for future visual assessment work.

4. Results & Conclusions

Figure 2 show some examples of the optimal segmentation result in terms of the segmentation cost function for the given feature set. We can see from these images that our unsupervised evaluation strategy favours a scale of segmentation much smaller then that produced by human subjects. It returned a mean of 799 objects with standard deviation of 20 objects when applied to our dataset. On the same dataset the human interpreters returned an average of 48 objects with standard deviation of 6 objects. This optimal segmentation in terms of the unsupervised criteria is quiet close to the segmentation result we desire where individual areas of uniform visual properties are represented as single objects. Since this evaluation method targets the desired segmentation result, it may be used to aid the choice of segmentation algorithm or algorithm parameterization for the given feature set extracted from different data. Close inspection of segmentation results reveals some errors; some of objects are over-segmented and in some cases the boundary localization is not exact. Future work will aim to reduce these errors and improve segmentation performance.



(a) (b)

Figure 2: Some examples of the optimal segmentation result in terms of evaluation cost function for the given feature set are shown in (a) and (b).
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Biography

Padraig Corcoran of the National Centre for Geocomputation (NCG), is in his Third year of PhD study. He has presented at GISRUK on three previous occasions.

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Automatic computation of river channel bifurcation angles

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KEYWORDS: Channel bifurcation, line thinning,

1. Introduction

Bifurcations are important river channel features that exert a major control over downstream morphological change. The importance of the geometry of a channel bifurcation has become widely recognised (e.g. Pittaluga et al., 2003), with the bifurcation angle determining the division of sediment and water downstream and, hence, the stability of the bifurcation (Bridge, 1993). Bifurcation angles of between 40° and 60° are reported as stable (Burge, 2006), with wider angles indicating instability and a high probability of channel abandonment (Federici and Paola, 2003). See figure: 1 for a schematic diagram of angles of deviation at a bifurcation.

Bifurcation angles can be quantified from remotely sensed imagery (EGIS, 2002; Burge, 2006) across a wide range of river settings and scales and at numerous points in time. Hence, they offer a parameter which can be easily applied in studies attempting to predict river channel stability in varied environments. Indeed, EGIS (2002) developed a predictive tool for the Jamuna River that enables the probability of a bifurcation becoming unstable to be made up to 12 months in advance. However, this model relies on the manual definition of channel centrelines from binary (inundated / not inundated) channel images and the manual measurement of angles of deviation of these centrelines at bifurcations. The result is an enormously time-consuming process that limits the application of the EGIS model to relatively small areas of channel or relatively short periods of time.

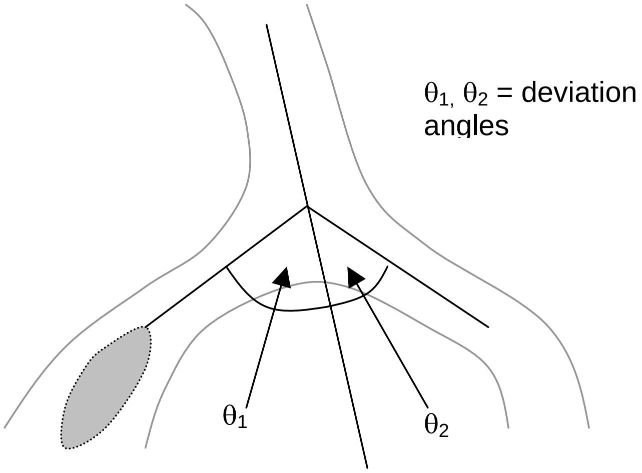

Figure 1. Measurement of angles of deviation at a bifurcating channel

The solution to improving the applicability of the EGIS model lies in the automatic extraction of the channel centreline (through approaches such as raster thinning) and then the automated measurement of bifurcation angles from this skeleton. This paper outlines a new regression-based bifurcation angle measurement algorithm and demonstrates its application to skeletons derived from the highly complex data of the Jamuna River, Bangladesh.

2. Generating the Skeleton

Thinning algorithms reduce binary images to their skeletons via an iterative shrinking process, where contour pixels are analysed and deleted if certain removal criteria are satisfied. To generate the unit thick skeleton (representative of the complete river network's centreline) required for this research, a modification of the well-known, iterative parallel thinning algorithm of Arcelli et al (1975) was used. In this, masks were iteratively applied to the binary river raster and where pixel configurations matched, pixels were deleted. The additional masks of Hilditch (1983) (see figure: 2), were also applied to address the pixel redundancy issues that would otherwise occur (see figure: 2).

0	0	0
	1	
1	1	

	0	
1	1	1
	1	

0	0	0
	1	
	1	1

0	0	
	1	1
	`1	

0		
0	1	1
	1	

Figure: 2 The Masks (with their 90° rotations) used in Hilditch (1983)'s Thinning Algorithm (Hilditch 1983)

Of note is the fact the applied thinning algorithm was selected (from the several hundred papers published on the subject since the late 1960's (Lam et al., 2002)) on the grounds it had the potential to cope with the highly irregular, noisy binary data of the Jamuna, and preserve both channel topology and geometry to an acceptable degree. However like all iterative algorithms the resulting skeletons were subject to artefacts such as noise spurs, loops and necking (see figure: 3). While the former two artefacts may be removed by post-processing, the latter's impact on topology is more difficult to remove.

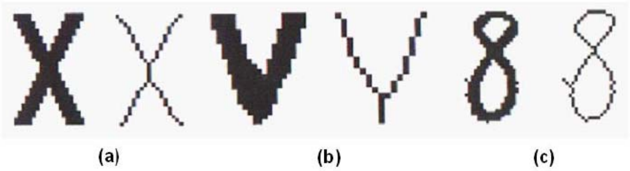

Figure: 3 Classic Thinning Artefacts: a) Necking b) Tailing c) Spurious Projection (Parker 1997)

3. Automating Bifurcation Angle Measurement

Bifurcation angles are measured relative to the upstream channel orientation and accordingly, which of the three skeletal segments at a node, represents it, must be identified. Although the actual node can be easily identified according to both the number of black pixels (N(b)) and transitions from white pixels (0) to black (1) (T(b)) in a cyclical traversal of *N(p)* (see figure: 4), the identification of the upstream segment is problematic where no flow direction/elevation data is available. To solve this problem a node ordering routine was developed that tracked along all skeletal segments (i.e. examine *N(p)* for each cell, find the next cell in the segment and step into it), established which node was upstream of which, and marked the nodes with hierarchical values.

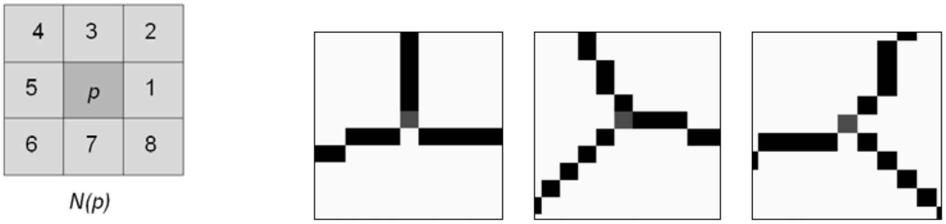

Figure 4 Possible *N(p)* Node Configurations - N(b) > 2 AND T(b) > 2)

Starting from the most upstream node (e.g. marked 1) all stream segments were tracked along in turn until a new node was reached. Where this new node was 'downstream' in terms of a user defined bearing and distance, it was then labelled with the next hierarchical order (e.g. 2). For each node, the order and coordinates were stored in an array, and after its three segments were analysed, the process was repeated for the next stored node. Where segments were tracked along in both directions (starting from either end node), the initial assigned value was retained. Ideally the algorithm would result in all nodes upstream of another, being assigned a lower value (enabling the upstream segment to be automatically identified) (see figure: 5).

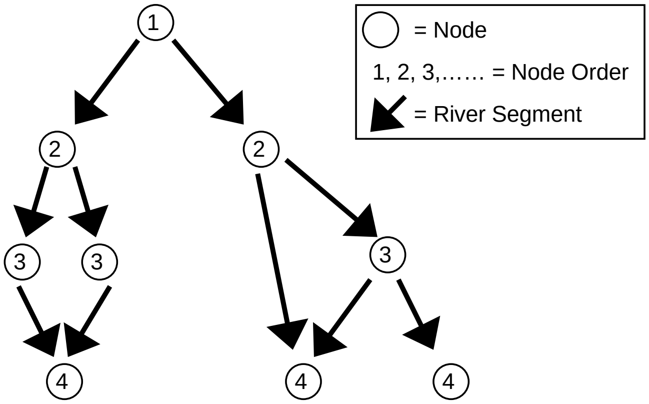

Figure: 5 Schematic Diagram of the Node Ordering Hierarchy

Bifurcation angles were then calculated directly from the node ordered skeleton. The node values enabled bifurcations to be automatically identified as nodes with one upstream, and two downstream, segments. For each bifurcation identified, all river segments were again tracked along and for a specified length; each one had its row/column coordinates stored in an array. These coordinates were then used to generate a regression line (coming closest to passing through all coordinates and having the minimum sum of distance^2 to them) that approximated each channel centreline and as such reduced the influence of noise on the data.

To ensure that each regression line was representative of its equivalent channel centreline, the length of the sampled segment (starting from the node) was adjusted in accordance to the scale and character of the Jamuna data. For sections unaffected by thinning artefacts (and over 1 km), the first 1/3 of the segment was proven to be representative of the channel centreline in the majority of cases. From the regression line, slope (as a function of X) could be calculated and converted to a bearing (in degrees) using $\tan^{-1}$. From the three bearings (one for each segment) relative angles were then calculated and the bifurcation angle derived.

4. Algorithm Application

In applying the algorithm to a data set as complex as the Jamuna river, some examples of failure were expected, and indeed this was the case. However, from a mathematical perspective the algorithm successfully calculated bifurcation angles based on the information it collected (i.e. the sampled coordinates for each line segment). Furthermore in general the generated skeleton proved suitable for the purpose of calculating angles of deviation, with good results being achieved (see figure: 6(a)). In validating the results through comparison with 45 manually derived results, errors ranged from 0.13 to 50.4°, with an average of 12.80°. Where larger inaccuracies were experienced, this was a result of the regression line generated being unrepresentative of the river channel and there were two major causes for this:

i) The skeleton contained thinning artefacts that resulted in sections of arbitrary centreline (mainly at intersections), and as such some derived measurements were meaningless.

ii) The length of segment from which samples (coordinates) were taken was unrepresentative of the channel centreline. This was a particular problem where the sampled section was acute and the generated line was essentially an averaged misrepresentation (see figure: 6(a)).

Another issue was the fact that the node ordering procedure did not always succeed. Failures occurred in situations where thinning artefacts produced additional arbitrary nodes at skeletal junctions (disrupting the node ordering process) or where flow direction was highly ambiguous. This resulted in the incorrect identification of the upstream segment and therefore the bifurcation also. Accordingly angles calculated in these circumstances were again unrepresentative.

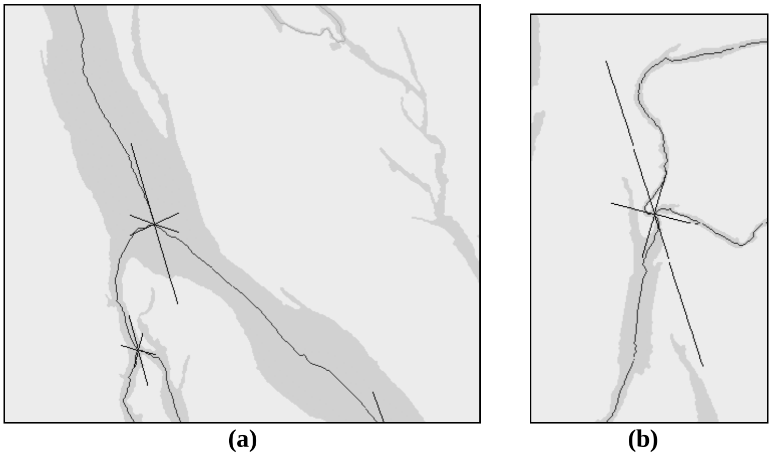
(a) (b)

Figure: 6 Raster lines (black) illustrating a) Successfully calculated line orientations at two nodes b) A failure at an acute section of channel

5. Discussion

The aim of this research was to develop an algorithm that could measure bifurcation angles with the highest level of automation possible. Although full automation was not achieved, the algorithm worked well, and the average error of 12.80° was in fact low when considering the approximate nature of manual centreline extraction (calculations being based on channel shape only, with no consideration of water depth or the location of dominant flow), as well as the limitations of an average value. The research also succeeded in clearly identifying the issues that at present prevent full automation being achieved.

In the case of thinning artefacts; such errors were inevitable as a result of the local focus and simplicity of the thinning algorithm used, and considering this, and the complexity of the Jamuna River data, results were better than expected. Further, in some cases it was possible to skip over unrepresentative sections and still extract meaningful results. However the main problem was that artefacts prevented the algorithm from being robust and as such human intervention/checking remained a requirement (a major barrier to automation).

The issues resulting from measuring accurate, but un-representative, sections of centreline resulted from the use of parameters (i.e. specifying the proportion of segment to be sampled). Although parameters were applied to prevent this problem, their relative rigidity in contrast to the irregularity of the Jamuna data, meant that they were not suitable in all situations. Conversely a parameter based approach provided the algorithm with the flexibility to be applied to braided river data sets of all scales.

Finally the problems arising from the failures of the node ordering algorithm were expected, as it was a rather basic attempt to achieve a greater level of automation, in the absence of flow direction information. To a certain extent it achieved its purpose and when applied to simple or localised data examples it worked well. However, again skeletal artefacts and complex channel configurations degraded the results.

6. Conclusion

This novel research successfully outlines a new regression-based bifurcation angle measurement algorithm and demonstrates its successes and failures when applied to skeletons derived from the highly complex data of the Jamuna River. Although the issues identified may be difficult (if not impossible) to overcome, there remains much scope for improvement. Indeed it is hoped that the study has laid down good foundations and will stimulate further research to see full automation achieved.

Future research should focus on i) the development of thinning algorithms with the capability to better preserve river channel centrelines/junctions, ii) investigation into the potential of more complex/numerous (e.g. rule based) parameters to ensure that the algorithm is more robust, iii) further development of the node ordering algorithm to attempt to overcome the current causes of failure.

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Geographically weighted visualization – interactive graphics for scale-varying exploratory analysis

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1 Introduction

A popular approach to investigation of geographical patterns in a spatially referenced data set is the concept of *local statistics* (Getis and Ord, 1992; Unwin and Unwin, 1998), perhaps arising from Openshaw's stated dissatisfaction with 'whole map statistics' – (Openshaw *et al*, 1987). A point location $\boldsymbol{u}$ in the study area is selected, and some statistical technique is applied only to the data within some radius h centred around $\boldsymbol{u}$. Applying this procedure to a number of locations spanning the study area gives a view of spatial variability in the distribution of the data values. For the 'geographically weighted' (GW-) approaches, h is either fixed for all $\boldsymbol{u}$, or chosen to equal the distance from each $\boldsymbol{u}$ to its kth nearest neighbour - see for example Brunsdon *et al* (1996). Mapping the results for each location for some given h is an effective way of showing local changes in distribution of one or more attribute variables. However, a number of spatial processes operate at several scales simultaneously. While static mapping is useful for exploring spatial variation for a fixed k or h (Brunsdon *et al.*, 2002), visualising variability of the spatial patterns with h, is arguably too complex a task for a static map. Interactive graphics provide opportunities for exploring complex structured data sets (Thomas and Cook, 2005). The intention here is to provide an interactive tool for varying h through a process of visualization to help gain insight into spatial data and characterise spatial processes.

Here we propose a series of graphics and interactions that meet this aim and present an interactive visualisation tool that allows analysts to investigate the properties of spatial data at a range of scales, through a number of *views*.

2. Context : Challenges for Multivariable Spatial Analysis - Guerry's Moral Statistics of France

We focus on a particular multivariate geographic data set – that collated and graphically represented by André-Michel Guerry in his '*Essai sur la statistique morale de la France*' (Whitt and Reinking, 2002). He identified geographic outliers and some regional trends and used such visual inspections to hypothesize about relationships between variables. Friendly (2006; in press) uses statistical and graphical methods to revisit the data set. Regression analysis shows that some of Guerry's postulated associations do not hold and that others omitted by Guerry exist. Friendly (2006; in press) uses multivariate graphics and conditioned choropleths (Carr et al., 2005) to augment Guerry's univariate maps.

3. Geographically Weighted Graphics

Graphical representations of geographically weighted summary statistics (Brunsdon et al, 2002) are the basis of our geographically weighted interactive graphics, or '**geowigs**'

3.1 Summary Statistics

A number of summary statistics are proposed in Brunsdon *et al* (2002) – for example, a geographically weighted mean taken at a point ***u*** with a bandwidth *h* is defined by

$$M(\mathbf{u},h) = \frac{\sum w_i(\mathbf{u},h)x_i}{\sum w_i(\mathbf{u},h)} \qquad (1)$$

where $w_i(\mathbf{u},h)$ is the weight associated with the observed variable x at location i. If location i is represented by the vector $\mathbf{u}_i$ then

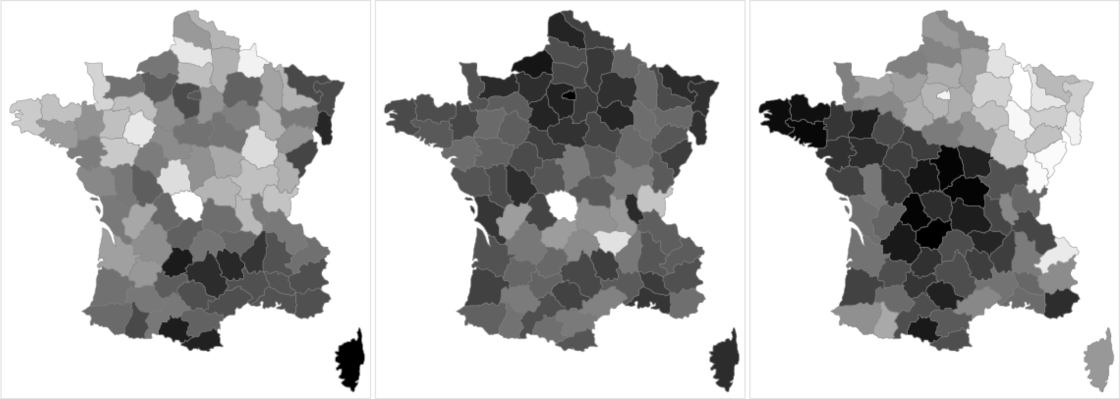
$$w_i(\mathbf{u},h) = \left(1 - \frac{\|\mathbf{u}_i - \mathbf{u}\|^2}{h^2}\right)^2 \qquad (2)$$

is one possible weighting scheme. In a similar manner other geographically weighted statistics – such as a geographically weighted median, or other geographically weighted quantiles, can be defined – see Brunsdon *et al* (2002) for further details. Note that we often choose **u** to be the centroid of the *i*th department here. In this case, we use the notation *M*(*i,h*) to refer to the gw-mean at the centroid of department *i* with bandwidth *h*.

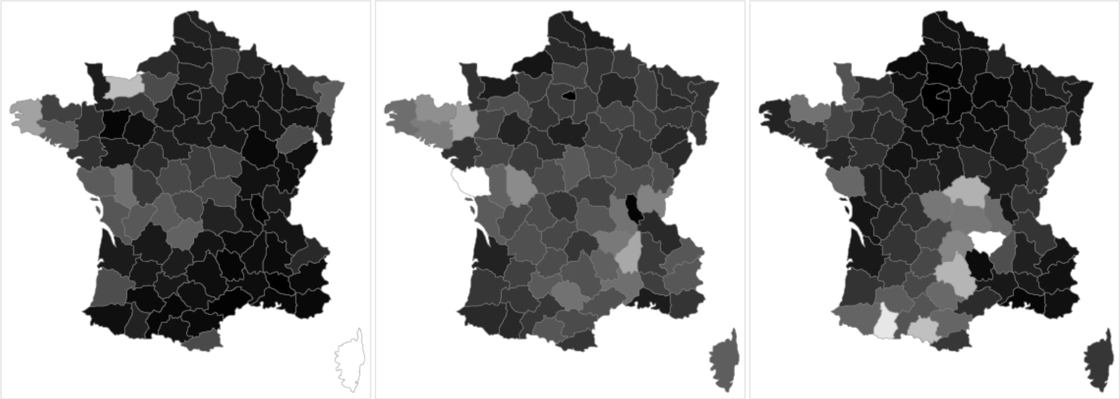
3.2 Graphic Types

The Guerry data set contains six key quantitative variables for each of the 86 departments of France in 1830. Here we use the index *i* to refer to the departments, which are mapped by Friendly and Guerry and shaded according to rank (Figure 1).

Guerry regarded high values are being indicative of moral character and so in accordance with Guerry and Friendly's maps low values are represented by darker shades to reveal 'la France obscure and la France éclairée'.



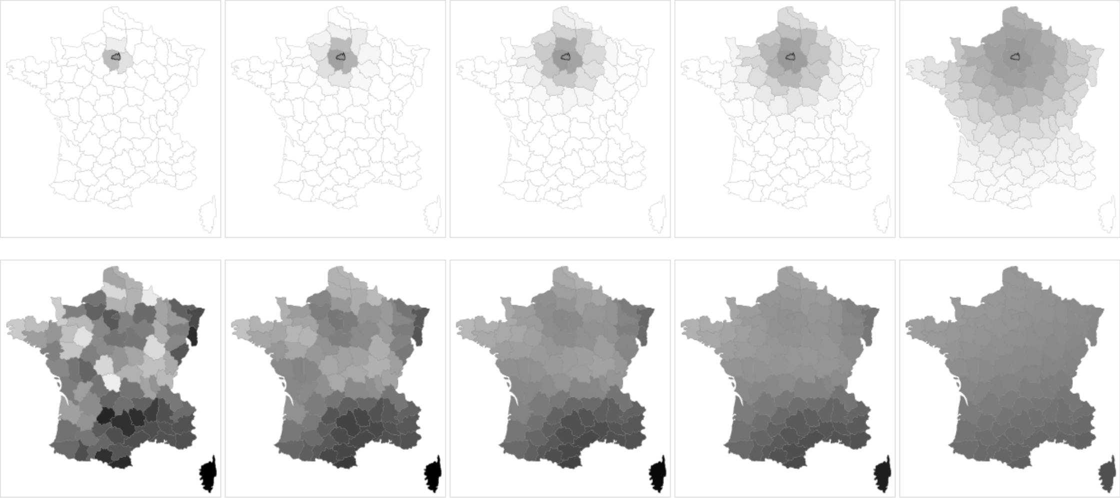
x1: population per 'crime against persons' *x2*: population per 'crime against property' *x3*: percentage who can read and write



x4: donations to the poor *x5*: population per illegitimate birth *x6*: population per suicide

Figure 1. Unclassified choropleth maps of Guerry's six key variables.

Spatial variation in any single variable can be depicted at a range of scales by displaying geographically weighted means . In Figure 2 we show maps of *gw-means* for variable 1.

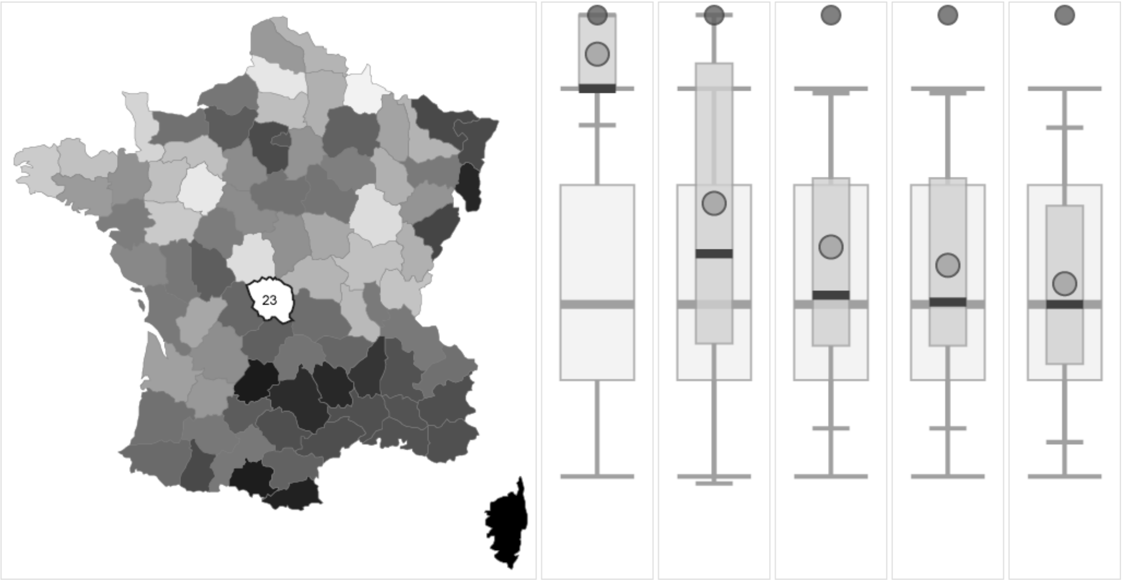


h=0.025 h=0.050 h=0.075 h=0.100 h=0.200

Figure 2. Geographically weighted maps for variable 1.

Weighting maps (Figure 2, top) show the relative contributions of local departments w_{ij} – ie the weighting applied to department j in the calculation of $M(i,h)$ for a single unit with five increasing values of h. Using consistent symbolism in *gw-maps* (Figure 2, bottom) shows the effects of increasing h on the local weighted value of a single statistic.

The univariate *gw-maps* reveal some trends at particular scales, but it can be useful to compare local variation at a range of scales. We achieve this by generating *gw-boxplots* at a range of scales from gw-percentiles (Figure 3). The lighter boxplots represent the national figures (consistent across all values of h). Darker *gw-boxplots* show local variation for any combination of $\boldsymbol{u}$ and h, which tend towards the national values as h increases. The smaller darker circle shows the local value $z(\boldsymbol{u})$, the larger lighter circle represents the *gw-mean* – $M(\boldsymbol{u},h)$



original values *x1*
i=23 highlighted - Creuse

i=23 *h*=0.025

i=23 *h*=0.050

i=23 *h*=0.075

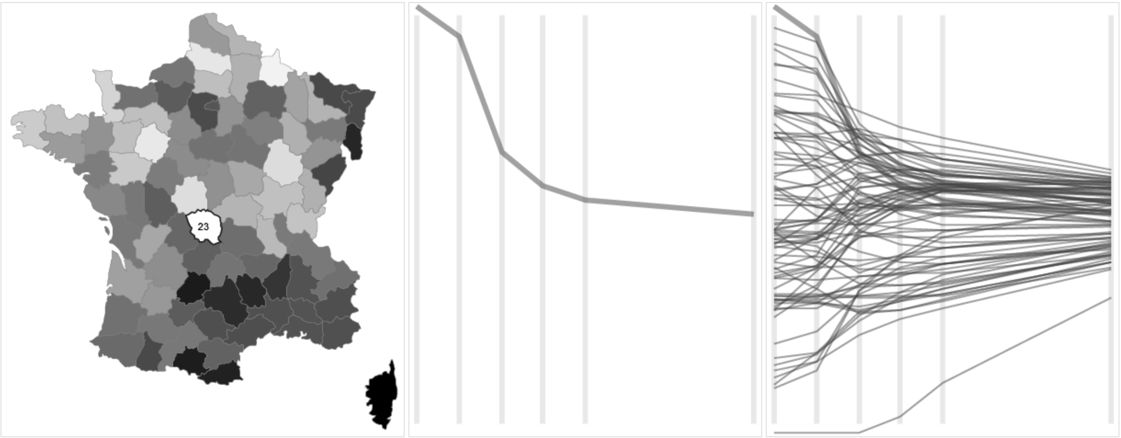
i=23 *h*=0.100

i=23 *h*=0.200

Figure 3. *gw-boxplots* for a single department – variable 1 shown at five different scales.

In Figure 3, Creuse (i=23), is evidently a local high at h=0.025 – as suggested clearly by the map and identified by Guerry, though not an outlier. Also note that 'local' variation at scale h=0.050 in 'crime against persons' exceeds that observed in the national data set – a trend that is more subtle than the identification of a local high, the regional analysis of Friendly or the national 'obscure / éclairée' classification.

A *scalogram* uses the x-axis to represent h and the y-axis for $M(i,h)$. Lines linking $M(\boldsymbol{u},h)$ for all h for every $\boldsymbol{u}$ enable us to consider variation in multiple zones at a range of scales for any variable (Figure 4).



original values $x1$, i=23 highlighted

scalogram $x1$, i=23.
$x_i h$, where h=0, 0.025, 0.050, 0.075, 0.100, 0.200

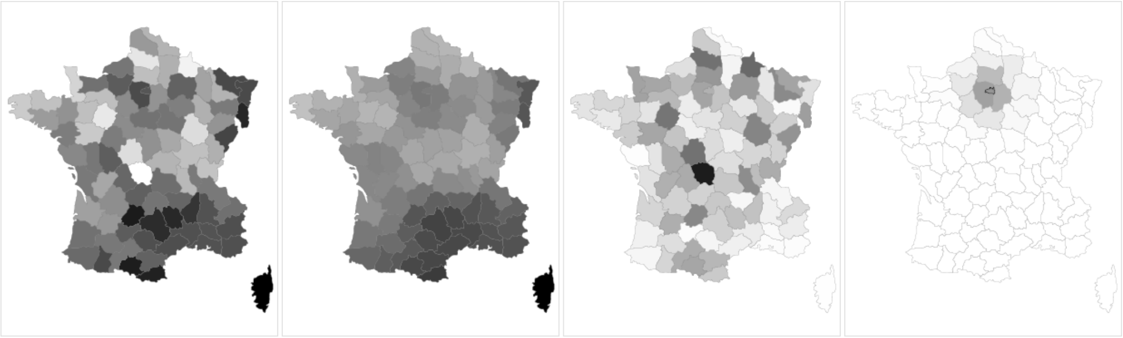
scalogram $x1$, for all i.
$x_i h$, where h=0, 0.025, 0.050, 0.075, 0.100, 0.200

Figure 4. S*calograms* for variable 1 - a single department and all departments.

The three views in Figure 4 show the mapped data (left), the *scalogram* for Creuse (center), which is an outlier in the original data and the complete *scalogram* for all 86 departments (right). The vertical lines show values of *h* for which *M*(*i*,*h*) has been calculated. A number of other effects are also identifiable.

3.3 Interactions – Software Implementation

Our demonstrator software uses maps, *gw-boxplots* and *scalograms*. A series of interactions and alternative symbolism that enable users to rapidly move between these and other views to interrogate the spatial structure of data sets. Clicking the maps cycles through the variables available (Figure 1) the computed values of *h* (Figure 2) and the four spatial views (Figure 5).



choropleth map
original values
$x1$

gw-map
geographically weighted mean
$M(\boldsymbol{i},h)$ (h=0.05)

gw-residual map
map of absolute differences
$|\boldsymbol{i}-M(\boldsymbol{i},h)|$ (h=0.05)

weighting map
weights for a single department
w_{ij} (i=75, h=0.05)

Figure 5. Map Views – Choropleth Map, gw-map, gw-residual map and weighting map.

The four spatial views available are: the data view – *choropleth map* showing original values (see Figure 1); the *gw-map* – *gw-mean* values for a particular *h* (see Figure 2); the *gw-residual map* - shows local effects of the geographic weighting at a particular scale for all zones; the *weighting maps* – shades relate directly to the effect of each department on the value of M($\boldsymbol{u}$,h) (see Figure 2). The *gw-effect map* uses a diverging scheme as advocated by Harrower and Brewer (2002). When reproduced in greyscale darker shades represent greater variation between original values and local means.

All of the views are linked so that any interaction results in updates to all views and selecting a location on the map causes the *gw-boxplots* to be centred on that location (Figure 6).

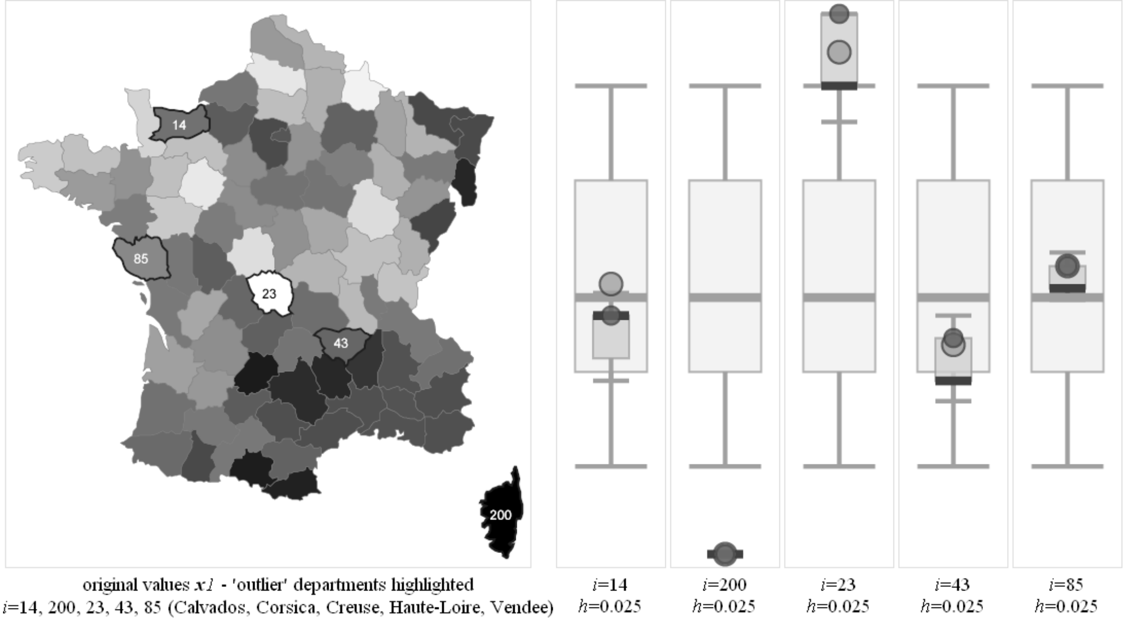


Figure 6. *gw-boxplots* for a single variable at a single scale – five different departments.

The *gw-boxplots* are dynamically updated as the map is brushed, supporting rapid comparison and exploration. The departments shown here are the 'outliers' identified in Friendly's paper.

Our software shows *gw-boxplots* for all selected variables and so these interactions occur for multiple variables concurrently. Figure 7 shows the effects of interactively varying the mapped variable the scale (h), the department of interest and the map view whilst undertaking exploratory analysis.

The examples in Figure 7 map variables 1 and 2 respectively and show the effects of highlighting departments 23 (Creuse) and 43 (Haute Loire). Each shows a choropleth of the original values, and then pairs of multivariate *gw-boxplots* and *weighting maps* for h=0.025 (top) and h=0.100 (bottom).

We also display the *scalogram* at all times and this is also updated dynamically to correspond with any changes in variable or scale (Figure 8). The links are graphically and geographically weighted so that whenever an item in a view is selected through interaction symbolism is changed to emphasize other local items according to their degree of locality (Dykes and Mountain, 2003).

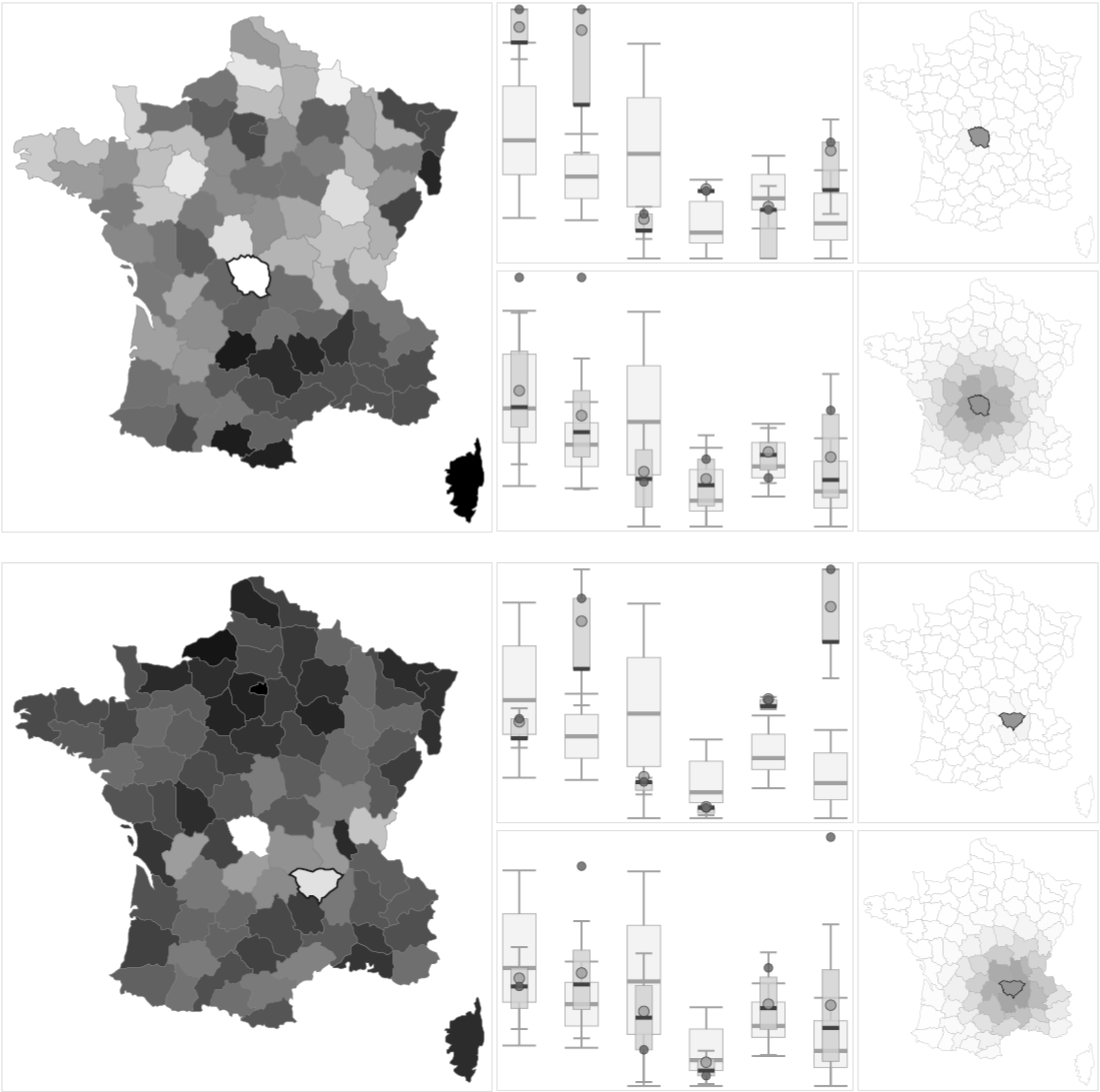


Figure 7. *gw-boxplots* for two departments for six variables.

Figure 8 shows maps and *scalograms* for two different combinations of department and variable: v=1, i=23 (top) and v=2, i=43 (bottom). In each case the first *scalogram* is shaded according to the original statistical value recorded for each department. The second *scalogram* uses geographically weighted shading in which the opacity of the line is varied such that departments that are closest to that which has been brushed with the cursor are visually emphasized. The currently selected value of *h* is shown by emboldening the appropriate horizontal line and through a *weighting map* focused on the brushed spatial unit.

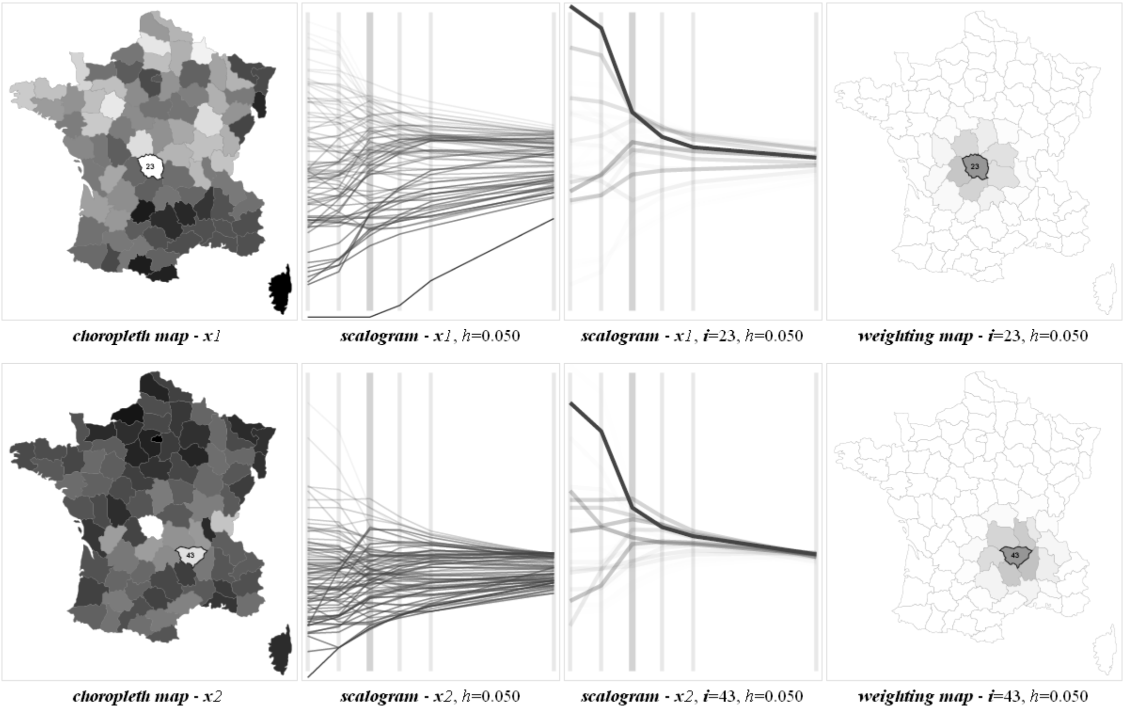


Figure 8. *scalograms* with statistical and geographically weighted shading (z and w_{ij}).

4. Summary and Conclusions

Here we use geographically weighted interactive graphics, or ***geowigs***, to hypothesize about the geographic variation in the data set. We introduce the *gw-boxplot*, the *scalogram*, and geographical highlighting, symbolism and interactions. These approaches build upon existing methods and technologies (Dykes, 1998; Brunsdon, 1998; Brunsdon et al., 2006) and are implemented in demonstrator software that permits further analysis. Our consideration of the geographic and scale-based variation in the Guerry data responds to Friendly's invitation to rise to Guerry's visualization challenge. Whilst our focus is predominantly on the six key quantitative variables used in Friendly's work (Friendly 2006; Friendly in press) our techniques are extensible to consider higher numbers of variables. These methods address the need for graphical displays of multivariate local variation that consider of 'neighbourhoods' in a flexible manner (Unwin and Unwin, 1998).

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Understanding geovisualization users and their requirements – a user-centred approach

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1. Introduction

Despite offering promising techniques and interactions, uptake of geovisualization applications has been slow and problems have been reported by researchers when users have attempted to engage with the software. We offer a small scale, detailed case study (Gerring, 2004) in the design, development and evaluation of tools to support geovisualization through user-centred approaches. User-centred techniques are employed and evaluated in the context of geovisualization to guide those involved in the use and development of tools that support this process. We determine which aspects may usefully inform designers in addressing the particular difficulties experienced in building usable geovisualization software, and report upon our experiences in understanding users and their tasks, and in establishing requirements.

Slocum et al. (2001) consider that "evidence for the successful adoption of geovisualisation techniques has been limited"; Andrienko and Andrienko (2006) state that "the use of visualization tools by people different from the tool designers seems to be quite limited", and Fuhrmann et al. (2005) ask if "novel tool designs are actually usable and useful for knowledge discovery and decision making?" Some researchers have employed user-centred techniques for geovisualization (Slocum et al., 2003; Robinson et al., 2005) with varying degrees of success. Andrienko et al. (2006) have documented broader user understanding difficulties. Generally visualization researchers appear to engage only seldomly with users - in an analysis of 65 papers describing new visualizations, Ellis and Dix (2006) discovered fewer than 20% reported employing user evaluations. With this background, it is timely to consider what the methods of human-computer interaction (HCI) can contribute, their limitations, and how they might be modified for the particular characteristics of geovisualization (Dykes, 2005).

Those who argue that geovisualization is beneficial consider it a *process*. This process involves ideation and knowledge discovery and is supported by interactive software tools (MacEachren and Kraak, 2001). A *user-centred* approach would consider this process as beginning well before software design and involving fully understanding users, their needs and their requirements to meet particular tasks, as well as software design, development, use and evaluation.

2. Approach

Our approach to the deployment of geovisualization is fully situated in an organisational context rather than being predominantly technology driven. User-centred techniques are employed at the outset to understand users and their requirements in relation to a proposed application of geovisualization for the analysis of spatial data and we evaluate the appropriateness of these methods. This is achieved by identifying candidate methods from the HCI literature at each stage of the process, selecting the most appropriate methods for specific circumstances, reflecting upon their effectiveness and any limitations and making modifications to address these. Our provisional findings suggest that some of these methods are appropriate, but that some specific enhancements are required.

The study was conducted among a team of research officers working in crime and disorder reduction who operate within a wider group of analysts in Leicestershire County Council (LCC). Team members represent potential users likely to benefit from and adopt geovisualization as they undertake exploratory work with multivariate spatio-temporal data, use graphics for communication and analysis, have experience of a geovisualization prototype (Attilakou, 2005) and consider that geovisualization may help them with their work.

In order to understand these potential users, a two-week data collection exercise took place. Preece, Rogers and Sharp (2002) describe four methods for finding out about users and their tasks: ethnography, Coherence, contextual inquiry and participatory design, each of which has strengths and weaknesses. In practice, a combination of ethnography and contextual inquiry (Beyer and Holtzblatt, 1998) was used, combining ethnography's depth and the systematic and well-structured approach offered by contextual inquiry. Reference material (publications, metadata on datasets) was collected and open-ended interviews conducted (structured with the contextual inquiry methodology in mind), recorded in audio and transcribed. The lengthy transcription process gave a good insight into the major aspects of the LCC research officers' work and allowed key themes to be identified. Email communications between the LCC research officers and us relating to supplementary enquiries or questions of clarification constituted another data source. The transcripts (with our own words edited out) and supplementary emails formed a corpus of written material suitable for Content Analysis (Krippendorff, 2003) and were formally evaluated using concordance software (Hüning, 2003), calculating word frequencies and showing keywords-in-context (KWIC) (Luhn, 1960). The results assisted the categorisation process and illuminated relative priorities among items raised by users. The robustness of our understanding of the research officers' work was confirmed when we iterated the key themes identified back to the primary research officer for comment.

Having achieved an understanding of potential users, requirements can be established. A number of different user-centred methods exist for this process (Nikula and Sajaniemi, 2002). Robertson (2001) suggests techniques to 'trawl' for requirements and a template for guidance in the form of the Volere system (Robertson and Robertson, 2006). Individual team members were interviewed for an hour each using this template. The material was audio recorded, transcribed and analysed in a similar way to the earlier material.

Once requirements are established, developers need task descriptions. A range of formal (hierarchical task analysis, GOMS) and somewhat overlapping informal methods (scenarios, use cases, essential use cases) exist, and for a small scale development, informal tools are more suitable (Preece, Rogers and Sharp, 2002). An appropriate approach is to create a "scenario" based on a part of the work of LCC research officers. Scenarios are 'stories about people and their activities…[that] support reasoning about situations of use' (Carroll, 2002).

Task descriptions lead to conceptual designs and on to prototyping. Prototypes of the application will be iterated with the potential users, firstly using paper prototyping (Snyder, 2005), where we will explore the extent to which the technique can provide useful insights for an interactive application, before committing to writing code for high level prototypes.

Figure 1 shows how various human-computer interaction (HCI) techniques mediate between users and developers, compared to the technology driven model that has been used in much geovisualization development.

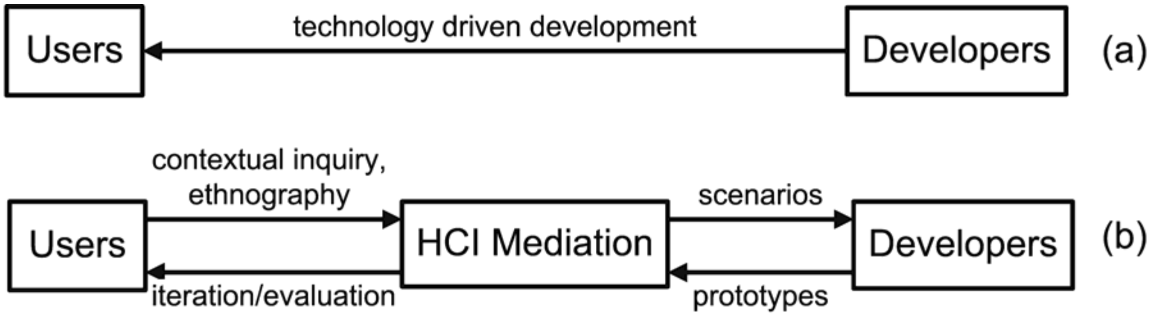

Figure 1: Two models of user interaction as part of developing geo-visualization applications. (a) technology driven, (b) HCI techniques mediating users and developers offer a user-centred approach.

3. Results

3.1 Understanding users

The 'user understanding' analysis resulted in a clustering of information into a number of headings – inputs (dealing with data sources and suppliers); outputs (customers and presentation) and characteristics of the potential users – their roles, goals, work, tools, expertise and skills. Some critical issues are unlikely to have emerged using a technology driven implementation model (see Figure 1). Among these were the variety in work undertaken from routine (for example, monthly crime reporting using "dashboards" - Few, 2006) to highly exploratory; the range of current tools employed and how loosely coupled they are; the emphasis the research officers placed on adding value (and how they managed to achieve that); their skill sets and expertise levels; the varied nature of their customers; and the spatial and temporal constraints on data availability.

3.2 Establishing user requirements

The strength of the Volere template is in its wide-ranging focus, exposing issues that would be unlikely to occur to a novice interviewer. It succeeded in eliciting a number of specific application requirements, including establishing a limit on the number of attribute datasets that would need to be considered in an analysis ("tens of datasets only"); the speed of screen refresh considered acceptable (indicating a low level programming language was not required); the preference for continuous zooming rather than selecting fixed areas from a menu; the desirability of, but not the necessity for, a background map layer to toggle on/off for orientation; the need for hands-on training (rather than documentation) to be able to use the application; and the importance of simplicity in the overall design and need to avoid unnecessary complexities.

However, the technique failed to provide an adequate bridge between the users and the developers to establish clearly the kind of tools, or interactions between tools, that might be required in the future application and this is where some modification is required to generate sufficient information to inform geovisualization design and designers. As it stands, the resolution of the Volere system is not fine enough for the complexities of geovisualization applications, or it cannot establish "undreamed of" requirements (Robertson, 2001). When prompted, the LCC research officers were able to indicate only two other applications that featured the kind of tools and interactions they believed might be useful - both websites. This is not unexpected given the complexity and specialized nature of geovisualization as a discipline and the techniques that it encompasses and may explain some of the difficulties reported by geovisualization researchers when testing their tools 'in the wild'.

In order to overcome this problem, a scenario developed to mediate between users and developers will additionally be used to mediate users to geovisualization experts - informing experts in geovisualization about the context of the research officers' work in LCC so that their expertise can be brought to bear on the interactive conceptual design of the application (see Figure 2). This technique will be evaluated using our reflective and adaptive technique.

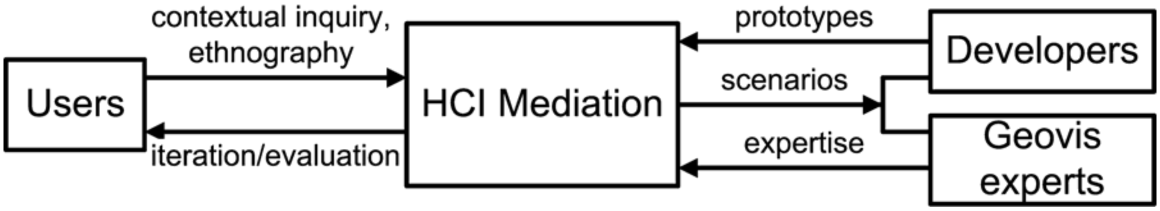

Figure 2: HCI techniques mediating users, developers and geovisualization experts.

4. Summary and Conclusions

In summary, we have had some success with HCI techniques, particularly those employed to understand users in detail, and these have informed the user-centred application creation process beneficially. Establishing requirements has been less satisfactory with the method employed unable to specify the complex tools and interactions that characterise geovisualization applications. However, another HCI technique, that of using ‘scenarios’, can be employed as a mediation bridge between users and geovisualization experts and has some promise. Our planned process of iterative prototype development with continual user involvement and reflection upon the quality of the results will enable us to evaluate both the geovisualization approach itself and the HCI techniques used to advance and evaluate it as we continue the user-centred application creation process.

5. Acknowledgements

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Biographies

David Lloyd is studying for a PhD on the use of human-centred techniques in geovisualization at City in collaboration with Leicestershire County Council. He completed his Masters in Geographic Information at City University London with distinction.

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Robert Radburn is a Senior Research Officer at Leicestershire County Council working with a variety of partners and agencies to support evidence-based policy. He is a champion of the use of information visualization and geovisualisation techniques to inform service delivery within regional and local authorities.

Towards a Comprehensive Multilayer Hybrid Display for GIS Data

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1. Introduction

As we naturally relate to our world in three or more dimensions, some data may be more readily visualized in 3D. However, direct 3D analogues to 2D GIS are not always ideal because they can suffer from several shortcomings. These issues include: hilly terrain occluding data, the self-occlusion of data and the simultaneous visualization of different types of data in 3D.

Studies have shown that 2D views are often used to establish precise relationships, while 3D views help in the acquisition of qualitative understanding (Springmeyer et al., 1992). It would be ideal if the benefits of both 2D and 3D could be incorporated into the same GIS. Our hybrid 2D/3D system attempts this by seamlessly integrating 2D and 3D views within the same window. Our system visualizes multiple layers of information that can be continuously transformed between 2D and 3D over the base-terrain. In the current work, we present a set of expanded capabilities for our GIS which include: hybrid landmark and chart layers, 3D point layers, the aggregate grouping of multiple hybrid layers, layer painting and unified controls for layer groups.

2. Related Work

In recent years, GIS has gradually moved into the third dimension such systems include ArcGIS (ESRI, 2006), Terrafly (Rishe et al., 1999) and GeoZui3D (Ware et al., 2001). However, a recent review (Stota and Zlatanova, 2003) of the status of 3D GIS postulated that 3D GIS is merely at a point where 2D GIS was several years ago. Often 3D is simply used for illustration or fly-bys and we argue that further research is needed to fully explore the possibilities and constraints of 3D GIS. Our work is also somewhat related to a small number of prototype systems proposed in the area of medical visualization that incorporate aspects of 2D and 3D in some fashion (Tory and Swindells, 2003).

3. Review of the Hybrid 2D/3D GIS

Our first prototype (Brooks and Whalley, 2005) allowed multiple layers of information to be continuously raised or lowered by the user, using control balls, directly over the base-terrain. During elevation, the layers maintain their geographical position relative to the base terrain and flatten (figure 1a-d). It is important that the user is able to mentally map a flattened 2D layer to the 3D terrain that it is residing over. To aid this, a ground level shadow of the layer system is provided which indicates the correlation between the data in the 2D/3D layers and the 3D base terrain.

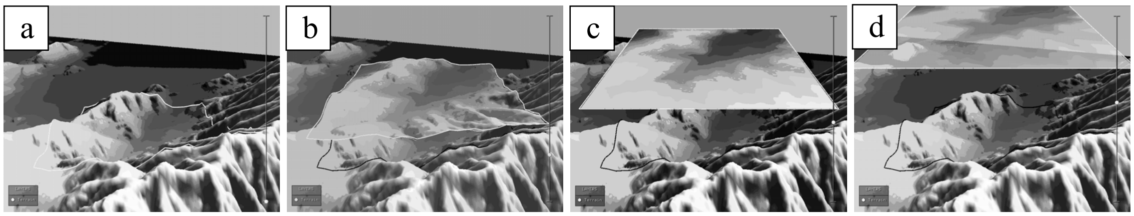

Figure 1: A layer is shown gradually rising from image *a* to image *d*.

4. New Hybrid GIS Facilities

This section discusses the new expanded capabilities of our hybrid GIS. In particular, we expand the range of possible hybrid layers that our system now offers and provide new interactive facilities for controlling how layers are visualized.

4.1 Layer Grouping

Our layering system offers a convenient means of handling multiple heterogeneous sets of aspatial data by separating the data content into layers, with each layer's height controllable via its own associated control ball. We now add the ability to group two or more layers into a single entity. The user can form a layer group simply by raising (or lowering) layer A's control ball onto the control ball of layer B. Layers can also be added to an existing group in the same fashion. An example of three grouped layers is shown in figure 2, left. The layers are: atlas, railroads and hypsography.

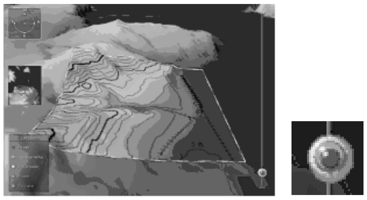

Figure 2: Left: Multiple thematic layers grouped into a single unit. Right: close-up of multiple control balls in an *onioned* state.

When multiple layers are grouped it is important to provide a visual indication of the grouping and of the individual member layers. We achieve this by modifying the edge trim that surrounds each layer in the grouped state. Each of the representative colors for each of the layers is incorporated into the new edge trim in an alternating dash pattern (figure 2, left). Secondly, (figure 2, right) we display the combined control balls as if they are each a layer of an onion that has been sliced in half. This onioning offers a further visual cue to the user and is also a practical means of control.

We also need to clarify exactly how layers are shown with respect to other layers in the same group. The case that poses difficulties is when using multiple raster layers in a single group, as they completely occlude each other. To overcome this issue, we introduce the notion of direct layer painting which allows the user to reveal the data contained in one raster layer at the expense of all other raster layers in the same group. This effect is localized to wherever the user 'paints'.

Let us consider an example layer group that contains 3 raster layers added in this order: A, B and C. Initially, the raster layer that is completely visible is the first layer, A, that was added to the group. Layers B and C are not initially visible. This default arrangement may not be sufficient as the user may wish to see certain portions of all three layers, A, B, and C, at the same time. To tailor visibility within the group, the user can perform layer painting. The user first clicks on the name of the layer (within the layer legend) that he or she wishes to reveal portions of. We will assume this is layer B. The user then paints with the mouse directly onto the rendered area of the layer group. The areas that the user paints over will then only show information contained within layer B, thereby hiding data from layers A and C. The user can therefore adjust the visibility of all layers in a given group in this fashion. Figure 3 shows an example of this where 3 disjoint regions are painted for 3 raster layers within the group. Note that the regions have been colour coded in this figure illustrate the concept; normally, the corresponding raster data from the 3 layers would be shown.

Figure 3: Disjoint regions shown painted for 3 separate raster layers in a layer group.

4.2 Point Layers

Point layers can be represented by a 3D sphere (figure 4) in our system. The size of the sphere can represent one aspatial aspect of the data points. Each sphere is embedded in a layer and as the layer flattens, the spheres also flatten to form a 2D view (figure 4, right). The spheres also become transparent with the layer if the layer is raised sufficiently high. Also, it is possible to form multiple point-layers for different data content where each point-layer is assigned its own color and meta-data legend entry.

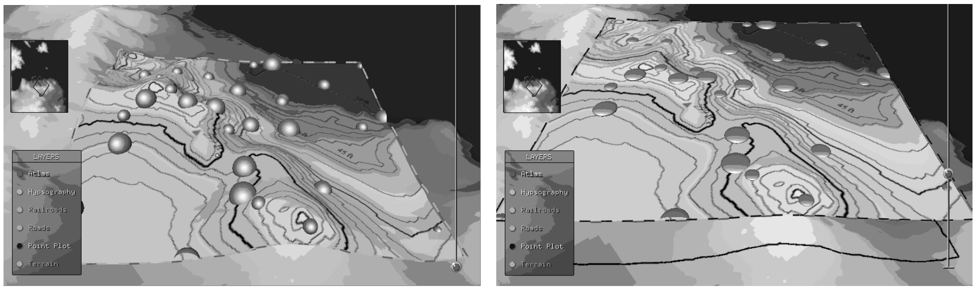

Figure 4: A partially transitioned point layer using sphere and disk symbols.

4.3 Landmark Layers

Our system now includes representations of major landmarks such as buildings in a cityscape (figure 5, left). As a cityscape is raised using the associated control ball, the buildings flatten gradually becoming 2D polygons.

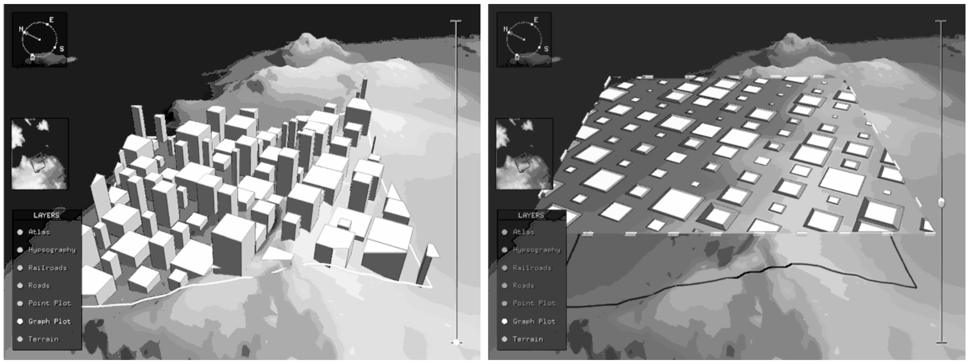

Figure 5: A landmark layer a ground-level (left) and at the flattening level (right).

During this flattening, the spatial information provided by the 3D view with respect to the building heights is lost. To overcome this a 2D scaled edge trim is implemented by scaling the top of the 3D building inwardly, proportional to the height of the building(figure 5, right). The taller the building, the more of an 'edge' there is around the building when flat. Additionally we shade a building as if it is 3D providing a further visual cue.

4.4 Chart Layers

Chart layers provide a way of visualizing aspatial data attributes using classifications. Our chart layers are also subject to 3D to 2D transitioning (see figure 6). Classifications include both pie-size and color. The semantics of the classifications are available in an auxiliary attribute-classification legend (figure 6 (right)). One might argue that when the chart layer is viewed in 3D, it offers an immediate impression of the overall data with respect to the 3D spatial terrain data. In the 2D mode it is more visually precise and eliminates potential occlusions.

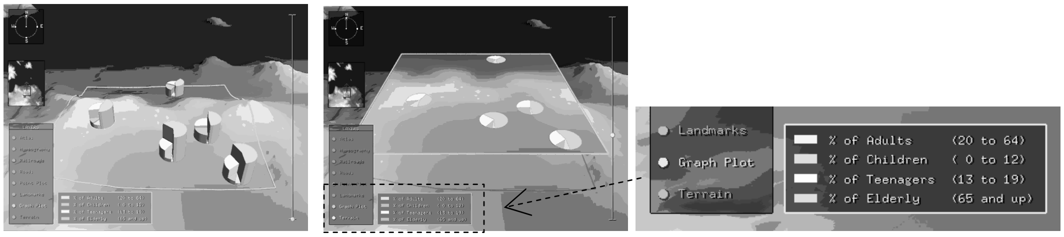

Figure 6: A transitioned chart layer employing a pie chart view. Right: Auxiliary legend for pie chart classifications.

5. Conclusions and Future Work

Our 2D/3D transitional layers can overcome both the self-occlusion and terrain-occlusion issues in 3D GIS. Our layering system also offers a convenient means of handling multiple heterogeneous sets of aspatial data and allows the user to temporally set aside data not in use. In the current work, we presented expanded capabilities for our system including: landmark layers, chart layers, 3D point layers, layer groupings and layer painting. There remain many opportunities for extending the system beyond its current form. One extension would involve the addition of advanced query facilities that could construct new query layers interactively. A user study would also provide insight into the practicality of the system.

6. Acknowledgements

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Marine GIS: 3D Graphics Applied to Maritime Safety

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1. Introduction

Maritime safety is growing in importance with the constant growth of the sea shipping as well as pleasure boats and other boats segments. A gradually growing number of cargo ships that carry hazardous loads make possible collisions and groundings of sea vessels poise serious treat to the environment, as well as the life and health of the people and animals inhabiting coastal zones. Growing number of pleasure boats makes collisions between big ships and small crafts more and more likely to happen, with often fatal consequences to the lives of the crews of the second. The disaster and damage caused in the event of major sea collision can be very difficult and costly to deal with. Maritime safety has also a huge impact on the world economy where the cost of shipping, clearly related to the level of safety, is an important factor.

In order to decrease the number of accidents the world sea authorities introduced many standards and new technologies like ECDIS and AIS (IMO, 2004). However these did not solve all of the issues and there are many points of the marine safety management process where improvements can be introduced. These include bathymetry data collection and processing, nautical charts production, providing navigation aid software on-board the boats, vessel traffic planning, analysis and monitoring, as well as improving the level of training accessible for mariners.

One particular aspect of maritime safety involves the visualization of the situation close to any particular ship, so that appropriate action may be taken. While many features may be seen directly from the bridge in good conditions, bad lighting and weather may obscure them, and much of the necessary information concerns maritime control, and is only available on charts or in pilot books.

It seems clear that an integration of all these components within a single simple view would improve maritime safety. A sufficiently-good integrated computer display, if it could mimic the real view from the bridge, could be developed at moderate cost and should be sufficiently straightforward to match with the real world while adding those extra features necessary for navigation. Modern PC-laptops are powerful enough to run such system, and so it would make cheap but superior alternative to chart plotters used by boats owners nowadays.

Based on this observation we proposed a new type of special GIS software, based on kinetic 2- or 3-dimensional data structures, a sophisticated 3D visualization engine, and intelligent navigation rules. The Marine GIS as a navigation aid is meant for use on board of marine vessels using a PC-laptop integrated with on-board equipment (GPS, AIS, ARPA) through the standard NMEA interface.

2. Creation of the Marine GIS

Ford (2002) demonstrated the idea of 3D navigational charts and concluded that 3D visualization of chart data had the potential to be an information decision support tool for reducing vessel navigational risks. Our intention was to adapt IHO S-57 Standard Electronic Navigation Charts (IHO 2001) for 3D visualization.

Several components are required for such a system. Firstly, an appropriate 3D graphics view of the surrounding land- and sea-scape is needed. Secondly, we needed to populate this engine with the terrain, landscape, buildings and ships appropriate to the geographic location. Thirdly, bathymetry was modeled directly from samples of survey soundings, giving a triangulated terrain model of the sea floor. Fourthly we needed to create models of specific navigational (ships, buoys and lighthouses). Fifthly, chart information was obtained from ENC data, and new techniques were needed to view this 2D information in 3D. The steps described above were implemented in prototype form in the work of Gold et al. (2004), although extensive revisions are being performed. Sixthly, to provide real-time data of ships a preliminary interface between the Marine GIS and the AIS has been developed by Stroch and Schuldt (2006).

2.1 The 3D Graphics Engine

The development of our graphics system is based on Graphic Object Tree that manages the spatial relationships between graphic objects. These objects may be drawable (such as houses, boats and triangulated surfaces) or non-drawable (cameras and lights). The basis of the tree is that objects can be arranged in a hierarchy, with geometric transformations expressing the position and orientation of an object with respect to its parent – for example the position of a light in a lighthouse, or a camera on a boat. This was described in (Gold et al., 2004). Our recent work was to take the tools already developed, and add features specific to marine navigation.

2.2 Terrain, buildings, objects

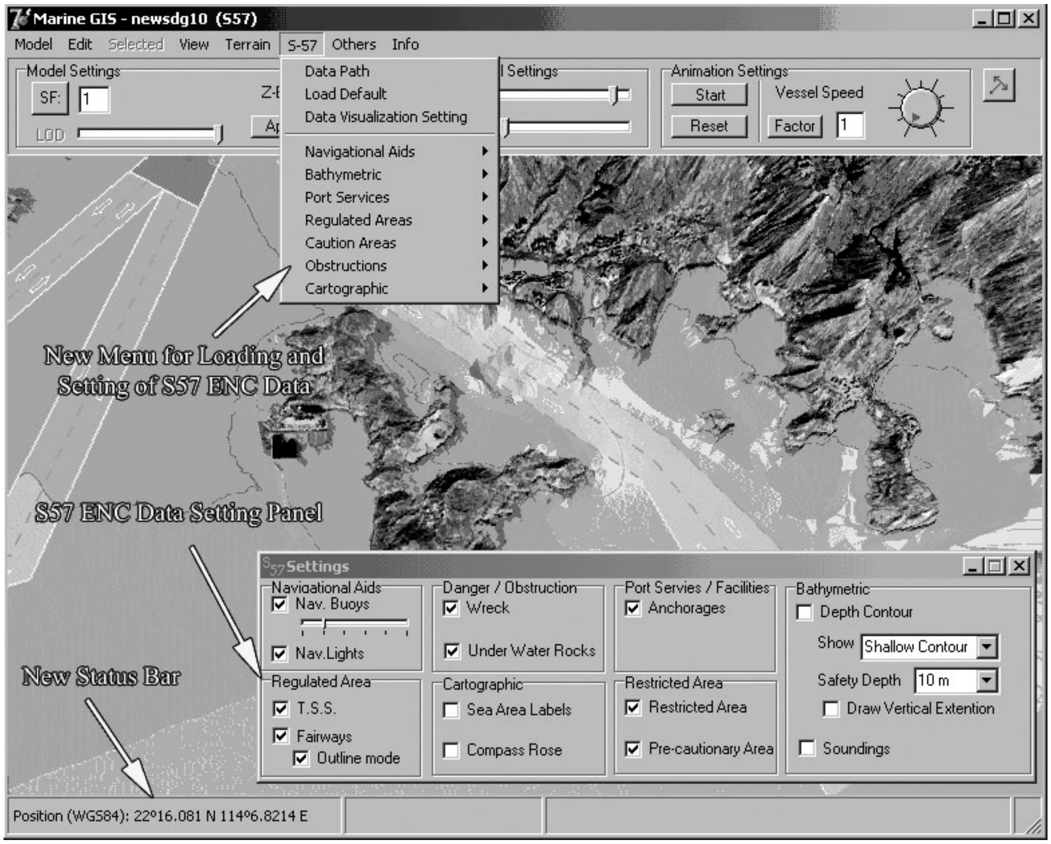
After the development of GOT we had to develop a landscape model close to the coast, in order to permit reasonable coastline silhouettes (Dakowicz and Gold, 2003), and in step three we added the bathymetry based on samples of the survey soundings. Shoreline points were calculated from the intersection of the triangulated terrain model with the sea surface, which may be changed at any time to simulate tides.

These shoreline points were incorporated within a kinetic Voronoi diagram layer, expressing the neighbourhood relations on the sea surface, and this was used for collision detection by adding the real-time ship locations.

2.3 IHO data display

Marine features identified in the IHO S57 standards were incorporated. Figure 1 shows the selection of particular S57 data items for display. These included navigational buoys, lights, soundings, depth contours, anchorage areas, and others.

Selecting a ship permits the viewpoint to be changed to that ship, permitting an evaluation of the point of view of the oncoming traffic. Other selected objects may be queried for their attributes.



New Menu for Loading and Setting of S57 ENC Data

S57 ENC Data Setting Panel

New Status Bar

SF: 1

Vessel Speed Factor: 1

Navigational Aids
☑ Nav. Buoys
☑ Nav.Lights

Danger / Obstruction
☑ Wreck
☑ Under Water Rocks

Port Servies / Facilities
☑ Anchorages

Bathymetric
☐ Depth Contour
Show: Shallow Contour
Safety Depth: 10 m
☐ Draw Vertical Extention
☐ Soundings

Regulated Area
☑ T.S.S.
☑ Fairways
☑ Outline mode

Cartographic
☐ Sea Area Labels
☐ Compass Rose

Restricted Area
☑ Restricted Area
☑ Pre-cautionary Area

Position (WGS84): 22°16.081 N 114°6.8214 E

Figure 1. S-57 data menu and S-57 settings dialogue

2.4 Overview of the system

Different features of the Marine GIS are shown on Figures 2-5.

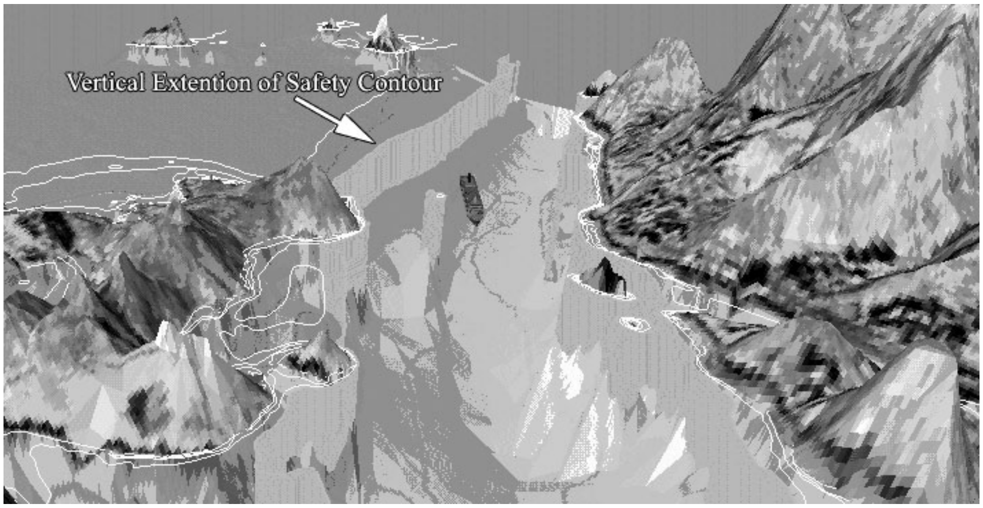
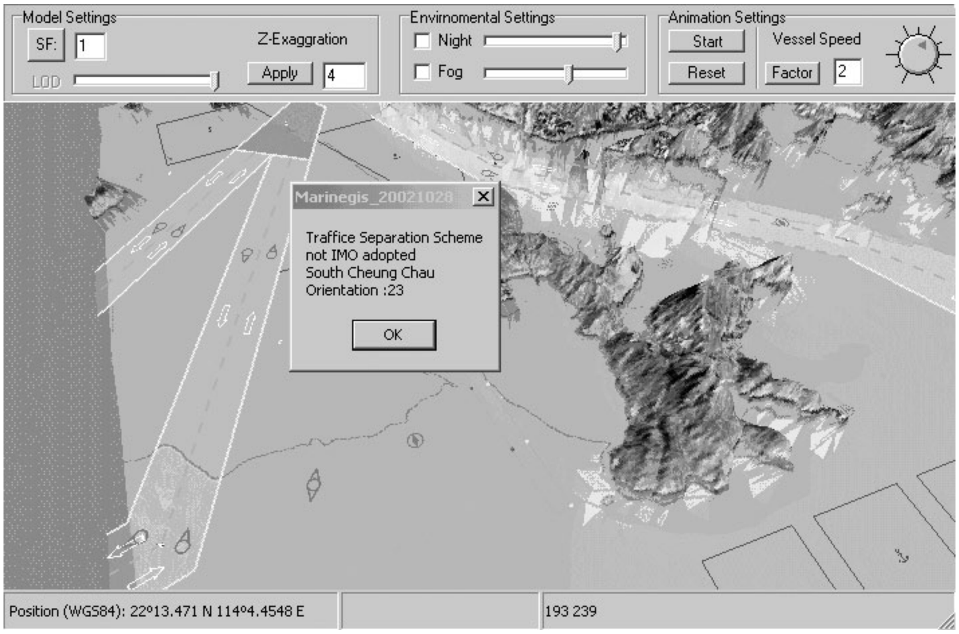


Figure 2. Visualization of safety contour with vertical extension

Safety contours may be displayed along the fairways, and a 3D curtain display emphasizes the safe channel. Fog and night settings may be specified, to indicate the visibility of various lights and buoys under those conditions. Safety contours and control markers may appear illuminated if desired, to aid in the navigation. The result is a functional 3D chart capable of giving a realistic view of the navigation hazards and regulations.



SF: 1

Z-Exaggration 4

☐ Night

☐ Fog

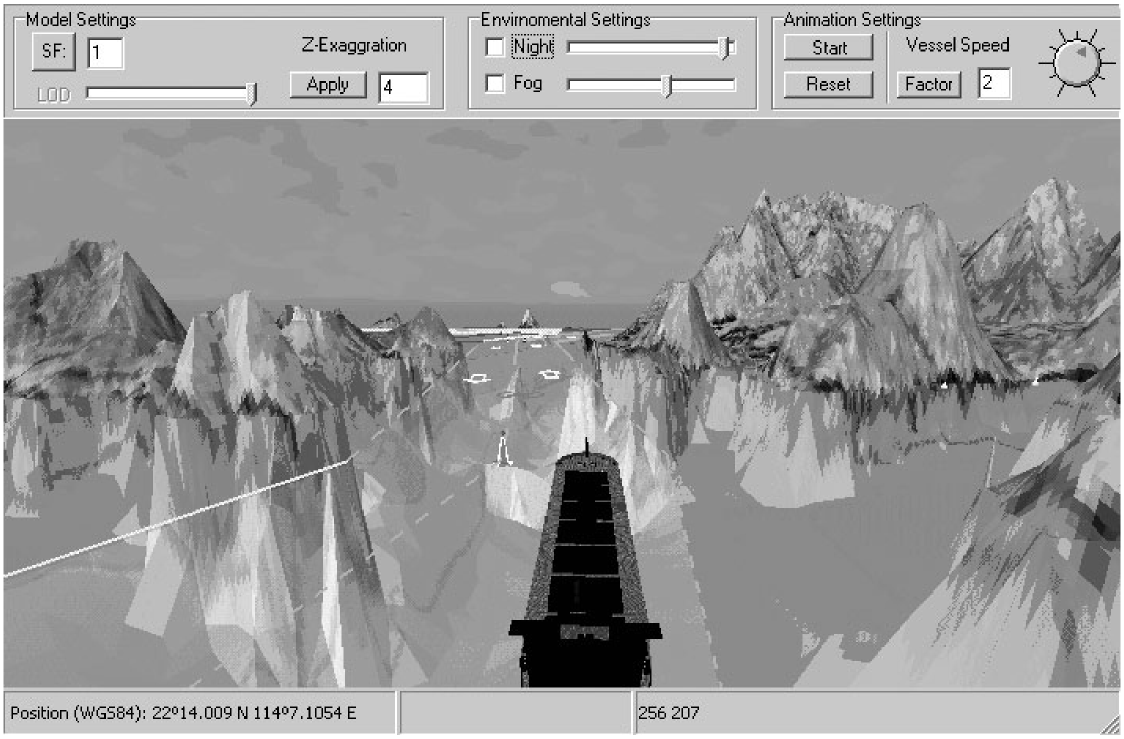
Vessel Speed Factor 2

Traffice Separation Scheme
not IMO adopted
South Cheung Chau
Orientation :23

Position (WGS84): 22º13.471 N 114º4.4548 E

193 239

Figure 3. Scene showing the terrain, traffic separation scheme, anchorage area, and other S57 features with the result of query: attributes of traffic separation scheme are displayed



SF: 1

Z-Exaggration 4

☐ Night

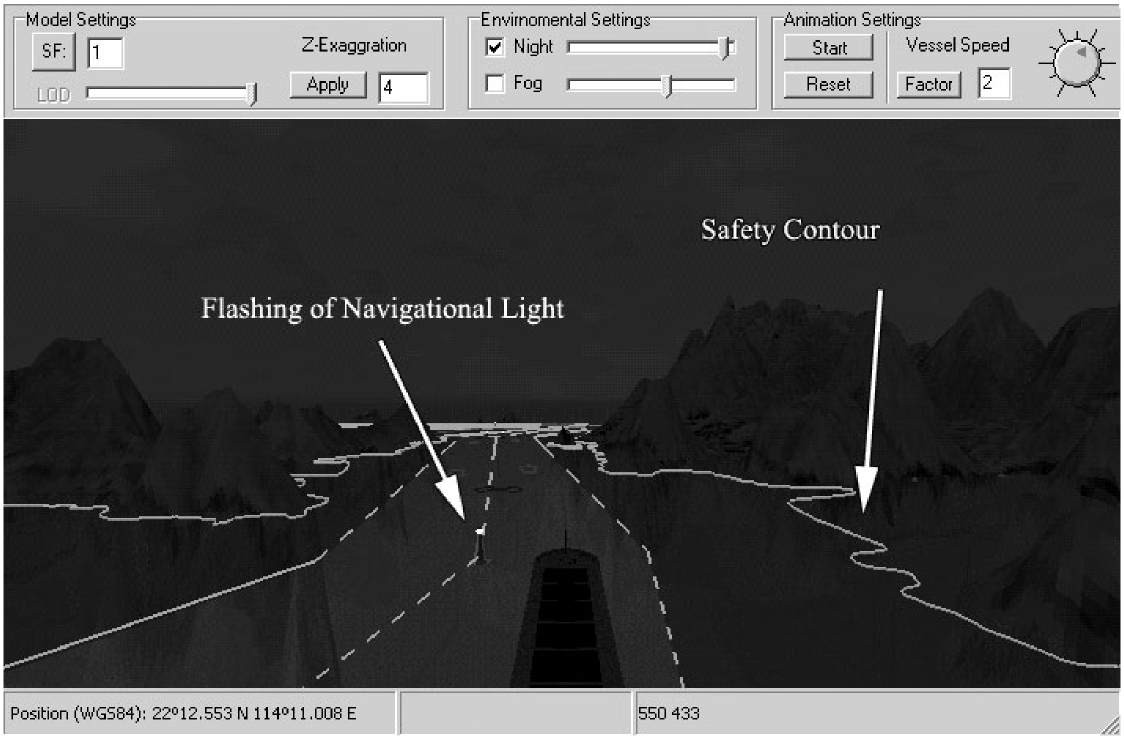
☐ Fog

Vessel Speed Factor 2

Position (WGS84): 22º14.009 N 114º7.1054 E

256 207

Figure 4. Scene in navigational mode. When animation mode is activated, the viewpoint will follow the movement of the ship model



SF: 1

Z-Exaggration 4

☑ Night

☐ Fog

Vessel Speed Factor 2

Position (WGS84): 22º12.553 N 114º11.008 E

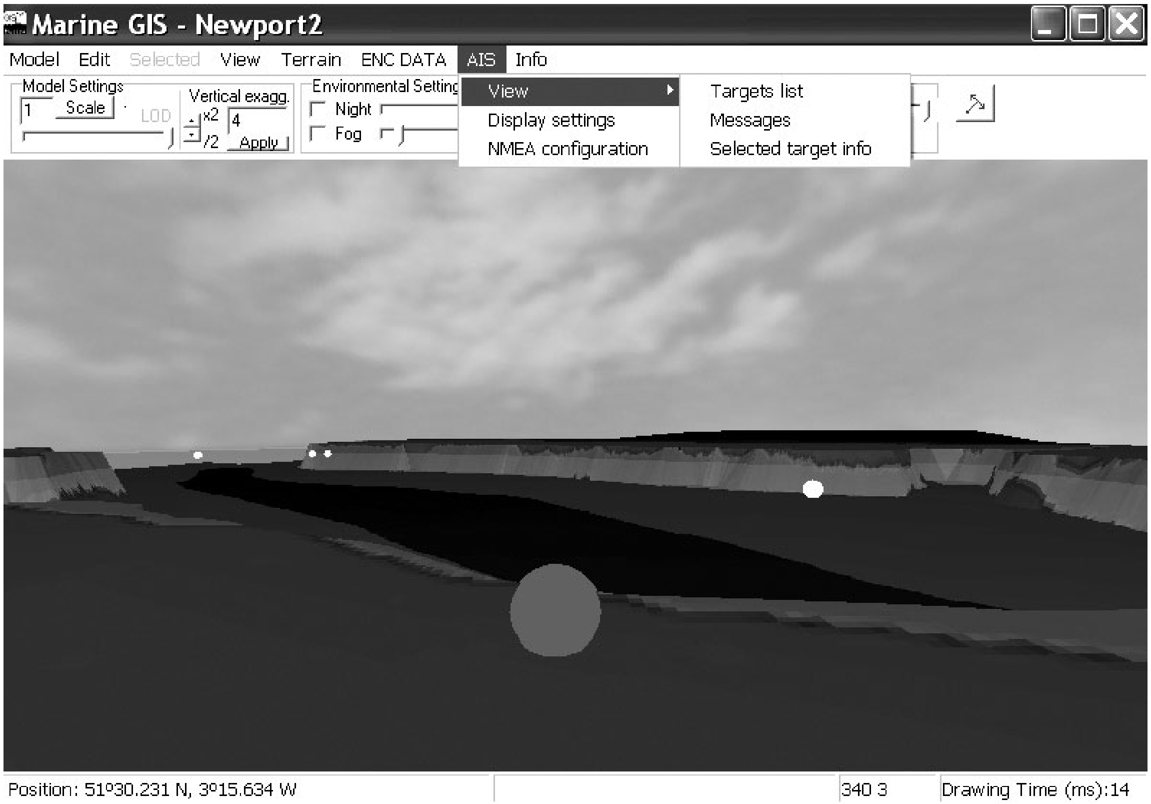
550 433

Figure 5. Night scene with navigational lights, safety contour and traffic separation scheme

3. Integration of AIS

Integration of AIS transponder into the Marine GIS was performed in two steps. First an external specialized library for reading AIS messages was designed and implemented using UML modeling tools and the best object-oriented programming practices. Then the library was incorporated into the Marine GIS 3D interface.

The software created allows for real-time tracking and recording of the AIS data, as well as for its later playback for test and simulation purposes. Several safety features related to the AIS specificity were implemented and tested. The integration with the NMEA multiplexer allowed for incorporation of the GPS data of the observer's own position. Figure 6 shows a view of AIS targets moving in the Bristol Channel recorded during field tests in Newport.



Position: 51°30.231 N, 3°15.634 W | 340 3 | Drawing Time (ms):14

Figure 6. AIS targets on Bristol Channel (distant white spheres) seen from the observer's point of view (the gray sphere in the forefront). The targets sizes are exaggerated as the distance is about 10 NM

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Biography

Rafal Goralski was one of the creators of Marine GIS at the Hong Kong Polytechnic University. For several years he was an industry software development specialist, programmers’ team leader and project manager. Currently he is studying for his PhD at the University of Glamorgan under supervision of Professor Christopher Gold.

Urban Location Based Services using Mobile Clients: The ICiNG Approach

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1 Introduction

The ICING project is conducting research into eGovernment and Location Based Services and also into two-way interaction with the physical environment. The research focuses on the areas of embedded intelligence, tighter integration of operator platforms and city infrastructure to enable novel services, empowerment of citizens to evolve systems of interaction with the city via social software, input from citizens and sensors for management systems and decision modelling, and a combination of city systems and multi-modal, multi-device communications to provide enhanced services. The technology platforms are gathering indicators from the City, processing the information, proposing actions to be taken with human intervention and supervision and connecting the City with its constituency. Services and information are delivered on a range of commodity devices, providing greater reach and accessibility to local government and communities.

Solutions are being tested in ‘City Laboratories’ in strategic city regeneration districts, 22@ in Barcelona, the Grangegorman area of Dublin and Arabianranta in Helsinki, where users will trial and evaluate technologies and services.

2 Icing Mobile Client (IMC)

There are many Location Based Services (LBS) identified in the ICiNG project. These range from providing a location tracking sensor network to retrieving data based on a mobile devices location. While these services are heterogeneous in nature they all require a method of determining the location of a device or sensor. There are many systems available to provide this location information, many using cell services provided by mobile operators or using satellite location technology such as GPS.

However, each of these technologies and services have advantages and disadvantages.[1-4]. Some services operate well in urban areas and in areas of high cellular radio density while others perform well where line of sight to satellites in the GPS system is easily established. Furthermore beyond the purely technical or technological considerations to be taken into account in location determination are issues of privacy and safety which location technologies raise [5].

The issue of which of these technologies to use is however being somewhat obviated by the increasing trend in mobile devices to incorporate multiple access technologies in the same platform [6]. The availability of GSM, WiFi, Bluetooth and GPS on the same device offers the possibility of using all these technologies in combination to improve location availability and accuracy.

The proposed IMC system will perform this positioning task, allowing other software components to query for device and user location. It will provide this location service through a simple software interface on the mobile device which allows the component to be reused by other mobile device applications (MDA).

3 IMC Architecture

The *Icing Mobile Client (IMC)* refers to the complete set of application components on a mobile device. The IMC is comprised of,

- The *ICING Location Client (ILC)* which purpose is to calculate and make available the device location based on wireless beacon information.[1]
- A number of *Mobile Device Applications (MDA)*. An example of an MDA is an accessibility application that enables users of the icing system to report problems and issues to city authorities using a mobile device Jabber (XMPP) client extension.

The *ILC* is designed as a provider network independent, privacy sensitive and low cost (in terms of network resource usage) software component to allow mobile devices (especially mobile phones) to determine by a 'best guess' method the device's current location. The prototype ILC software uses a variety of location determination methods. These include (in order of increased location accuracy (see figure 1);

- Using GSM cell phone masts to triangulate position
- Using Global Positioning Satellite (GPS) location (where the device supports this method)
- Using WiFi access point triangulation (where supported)
- Using Bluetooth beacon proximity (where supported)
- Using Semacode (2D bar code) tags

The phone also requires a RMS mapper database to be stored on the phone; this file provides cell phone mast, wi-fi AP and Bluetooth beacon co-ordinates which allows the application to determine position. The application then stores location information, together with time and method information. The application provides a local interface to other applications running on the mobile device to access this information. DIT and Telefonica (Spain) are developing a demonstrator Mobile Device Applications to showcase the technology. This consists of an accessibility issue reporter application whereby a user can report an issue by taking a photo of it and uploading it to Dublin City Council office for accessibility [2].

This prototype will be a Symbian Series 60 (3rd Edition) application. The Symbian mobile device Operating System defines a Server Application Framework (SAF) that allows applications to communicate through client/server inter-process communications (IPC). A client application will launch and connect to a server application. The server application can carry out functions for the client application, with user interaction. The server application may provide new variants of functionality that the client already uses. The server application can also provide functionality that cannot be performed by the client application due to capabilities restrictions, as the server application runs in a separate process [8]. Clients and servers also need to know how to communicate. The Server Application Framework allows them to use well defined services, which encapsulate the IPC messages and provide easy-to-use APIs.

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[1] The ILC owes this approach to the Placelabs project. URL:http://www.placelab.org/

[2] Under the Irish Disability Act, 2005, Dublin City Council are required to make Dublin City accessible for all citizens. The following public domains must be audited to ensure they are accessible for people with disabilities; all buildings to which the public has access, public parks, amenities, open spaces and streets.

In the case of Icing, MIDlets are used in the development of the ILC and MDA's. A MIDlet is a Java program for embedded devices, more specifically the Java ME virtual machine. A MIDlet requires a device that implements Java Mobile Edition, MIDP [7].

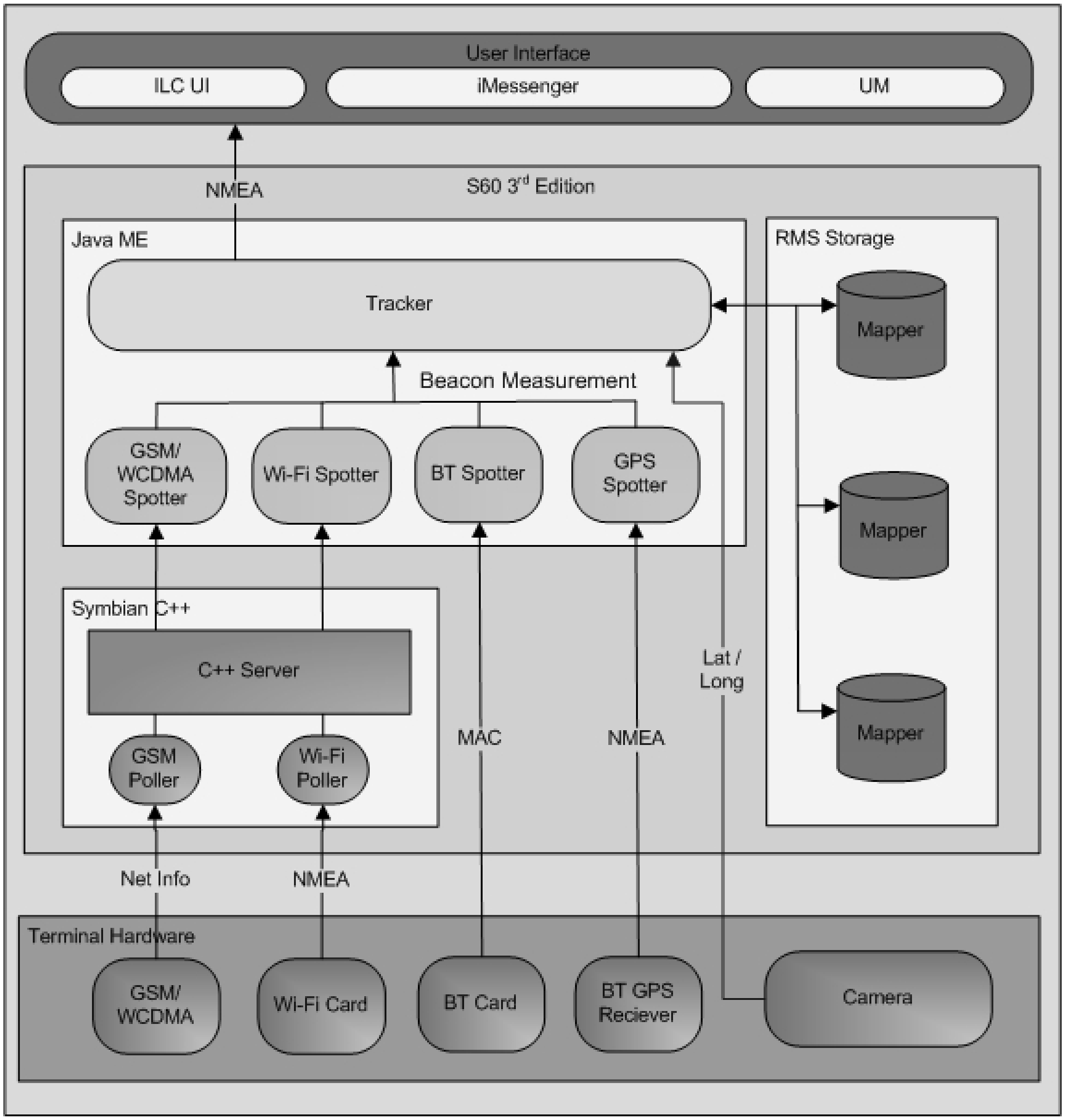

Figure 1: IMC Architecture

The messenger platform consists of a client-server architecture based on existing Open Source solutions. For the communication between parties we use the Extensible Messaging and Presence Protocol (XMPP) which is an open protocol for instant messaging, also called Jabber.

For the server side we will use the XMPP-based solution Wildfire. Wildfire Server is an instant messaging server platform, based on XMPP/Jabber protocol and written in Java that has been released dual-licensed under both a commercial and the GPL license. However we will adapt/enhance the standard functionality, by using some already available plug-ins and by developing our own to support some functionalities required for the ICING project (such as terminal location).

For the client-side application we are using Smack, which is an Open Source XMPP (Jabber) client library for instant messaging and presence. A pure Java library, it can be embedded into applications to extend the XMPP client to report location.

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Innovative Cities for the Next Generation (ICiNG) is a 30 month IST 6th Framework supported) project which is carrying out research into a multi-modal, multi-access concept of e-Government. The ICiNG partners are;

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- Institut Municipal d’Informatica
- Telefónica Investigación y Desarrollo, S.A.U.
- Agència d’Ecologia Urbana de Barcelona
- 22 Arroba BCN S.A.

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Ask the expert: The potential for location-based support in the fire service

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1. Introduction

Nottinghamshire Fire & Rescue services are a progressive division of the fire service and use a variety of location-based technology to respond to incidents. Mobile Data Terminals (MDT) are installed in fire-engine cabs, directing fire-service personnel to incidents and delivering other contextual information. Examples of this information include hydrant location, building plans, and the location of hazards on industrial estates.

This research elicits knowledge from an expert to establish the scope for incorporation of location-based services (LBS) into incident response. These services could be delivered on a hand-held computer or head-up display. Previous research includes examining spatial information in centralised control (Jiang et al., 2004) and transferring knowledge about building configuration using virtual reality (Bliss et al., 1997). The present study views current and future positioning technologies together with interoperable data sources capable of delivering the kinds of contextually relevant information that would generate useful, location-based support in this application domain.

The purpose of the research is to direct investigation into human factors aspects of representing spatial information. Representations should generate the best possible understanding of the information whilst maximising performance during response to an incident.

2. Method

The critical decision method or CDM (Klein et al., 1989) was adapted as a framework to elicit the ways in which spatial and geographical knowledge could influence decisions and actions on the fire-ground. The CDM technique is effective in eliciting knowledge about professions that cannot be observed directly for example the air force, or indeed, the fire service. The procedure involves interviewing an expert to develop a detailed description of an incident together with an incident time-line. Decision making and actions taken are then probed using the time-line as a framework. The expert is then encouraged to identify and expand on areas where critical decisions or actions are taken. What-if questions and different scenarios are presented to the expert on the basis of the timeline. In this way critical points where decisions are taken and information used to make those decisions can be identified.

Klein et al. (1997) use the CDM technique to elicit knowledge about decision making to inform the design of interfaces which improve decision making of military personnel. In the same way, this interview was used to explore the ways in which location-based, spatial information could be used to improve decision making on the fire ground. The timeline was developed around decision points where spatial information was used to inform a decision. Possible LBS applications were suggested at decision points and the expert was asked to comment on how these services might change or improve decision making.

The expert selected is an incident commander with over twenty-five years experience in the fire-service. The expert has wide ranging experience including operational and management. One author (JN) spent two days at the fire-service headquarters in Nottinghamshire to develop knowledge of the domain and the terminology employed by the fire service prior to the main interview.

The main interview lasted for two hours and forty-five minutes, during which time a scenario of an incident attended by the expert was developed and the potential for location-based support was explored.

3. Results

3.1 Incident

The incident described was a large fire at a warehouse under development in Beeston, Nottinghamshire. The fire took place at night, near to midnight, and took over seven hours to bring under control. The premises were in the process of being redeveloped into flats having previously been industrial premises built in the 19th Century. Original features had been retained and the building was five-storeys high. The fire had started on the fourth floor and was rapidly spreading to the fifth floor and the roof. The local area was surrounded by shops and homes.

The immediate consequences of these circumstances are:

- The layout of the building was unpredictable and unfamiliar since redevelopment was taking place.
- The building was once used for industrial purposes; many lift shafts and voids were still present.
- The building had many points of entry and access given its location near the town centre and its previous use as a factory.
- The building was close to shops and main roads in the area.

3.2 Analysis

The approach to assessing the potential for LBS is adapted from Klein et al. (1997). Decisions and actions taken, described in the interview, which have location as a critical element are listed. In addition, the reasons why those decision and actions are difficult are included. Current methods are described and finally, a hypothetical LBS is suggested in response to the action. Results are shown in Table 1.

4. Discussion

The CDM analysis has revealed a number of useful location-based services that could be developed to assist the fire service in responding to incidents. Some services identified would require improved positioning technologies (see Grejner-Brzezinsks, 2004, for review). General improvements in positioning technologies that allow seamless indoor and outdoor positioning, together with inertial technologies, could generate the reliability needed for such critical applications. Already ‘smart buildings’ are being developed where the use of ultra wideband or RFID technologies can locate individuals with high precision. Tapping these technologies could provide the data required to locate the individual and deliver appropriate location-based support.

Other applications are feasible with current technology; the data is present but not in a usable or intuitive form. Delivering building plan or site data from a database, directly to the individual is a possibility using wireless technology and hand-held devices or ruggedised laptops. Conflating this data with , for example, current wind-speed or thermal imaging provides further possibilities for support. Currently, much data is gathered on the fire ground itself. Thermal imaging data is delivered to the in-cab data system and the incident commander makes inferences concerning wind speed and fire spread. Truly interoperable data sources and structures would allow this data to be processed and then delivered to a handheld device. In the same way, an algorithm that dynamically computed routes out of a building could be developed and the information delivered directly to the appropriate individual. Interoperable data sources are the key to developing these services.

Understanding the human factors requirements when delivering this kind of information are critical if LBS are to be used in this context. Users must be able to understand and act on information quickly if the services are to be used and not discarded for more traditional methods of working. The CDM technique is a valuable tool for rapid elicitation of user knowledge or user requirements, in this instance the fire-service and location-based support. The detailed understanding of user requirements developed by using the CDM technique can then drive system design. Interface design or interaction with a device are two examples in which understanding user requirements are critical.

Table 1

Abstraction of decisions and actions with suggested LBS applications

Action	**Why Difficult?**	**How decisions are made**	**LBS**
Fight Fire	Dynamic situation that requires continuous updating. Requires dynamic assessment of risk with many variables. Choices dictate whether to commit crews into building.	Risk to crew is the key variable. Relies on prior experience of situation and location. Relies on spatially distributed data sources: reports, data gathering crews, MDT information, thermal imaging, knowledge of building structure and type.	Display all information in one place. Predicted movement of fire through building, access points and location of any known hazards or casualties within structure.
Fight Fire – Positioning of jets	The need to co-ordinate many resources in the correct locations. Access to and knowledge about fire ground and appropriate water supplies is key.	Prior knowledge about local water mains and fire ground. Walking around fire ground. Taking into account future movement of fire within structure.	Represent fire ground and jets. Ability to create what-if scenarios. Visualising spread of water jets or cooling effects on spread of fire. Show location and size of water mains. Infer resource requirements.
Find safe routes into and out of building	High risk operational environment. Dynamic environment. Limited time due to physical demands and oxygen requirements of crews.	Overall impression of fire. Type of structure. Location of hazards or casualties. Sometimes, static 3D CAD models available. Guidelines laid on way into building.	Interactive model of building layout with data representing distance and time. LBS directing firefighter to specific points in the building.
Protect Public	Balancing risk with the need to keep roads, shops etc open. Knowledge of peripheral hazards required which may not be obvious.	Prior knowledge of environment. Macro view of area showing key access routes or hazards, e.g. petrol stations. Places where many people congregate – pubs, halls, shops. Appraisal of fire behaviour leads decisions.	Macro level view of area indicating specific public risks given particular movement of fire. Conflation of weather and thermal data to predict movement of fires.
Protect surrounding structures	Requires prediction of fire spread and knowledge of the structure and contents of nearby buildings.	Visual search and local knowledge. Walk – around. MDT data if available. Some integration of thermal data if available.	Representation of surrounding structures and distance to seat of fire. Data about fire loadings of surrounding buildings
Search & Rescue	High risk operational environment. Sometimes risk to crew outweighs the benefit of rescue. Limited time due to oxygen requirements.	Dependent on state of fire. Size of building is critical. Potential knowledge from MDT data.	Planning aid to direct search attempts or segment building into areas. Fastest search route planning. Fastest exit if necessary. Device to direct individual crew members to a location.

Future research in this area will examine the human sciences aspects of understanding and acting on spatial data in this application. The research will focus on delivering simplified map information to firefighters using handheld computers in order to navigate around an incident. For example different representations may generate differences in memory, performance or mental workload. Understanding these factors will lead to services that are both useful to, and usable by the individual.

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6. Acknowledgements

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7. Biography

Jim Nixon

Jim Nixon is a research student examining human factors issues surrounding the perception and communication of different geospatial representations over mobile communications. Jim holds an undergraduate degree in psychology and a masters degree in human factors. He is a graduate member of both the Ergonomics Society and the British Psychological Society and is working towards professional registration.

A Synchronised Virtual Environment for Developing Location-Aware Mobile Applications

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KEYWORDS: Virtual Environments, Mobile Devices, GPS, Visualisation, Augmented Reality

1. Introduction

The increasing power and robustness of mobile devices coupled with positioning capabilities is allowing a wide range of location-aware applications to be developed. Some of these applications focus on navigation and the design of geographic representations which offer a more egocentric approach to mapping (Meng, 2005). Other applications concentrate on augmenting the user's view of the world with supplementary information such as the display of the horizon annotated with features of interest as in the recreational package Viewranger (Augmentra, 2007). Whatever the focus of the application there is usually a requirement to associate the information on the device with the real world around the user. This reconciliation of 2D representation with the 3D world around the user is one tangible element of spatial literacy, the formal ability to think spatially (Golledge, 2003).

This paper describes the use of a virtual environment for testing location-aware mobile applications during development and presents one such application in detail. The virtual environment features a visualisation theatre with large screen stereo projection of 3D virtual worlds, the user location in these models being synchronised with any mobile devices in the room through a simulated GPS signal (as a text-based NMEA string) transmitted from the ceiling. The mobile application currently under development is an example of what could be termed 'Mobile Geospatial Augmented Reality' where supplementary information of various types is presented to the user relevant to their spatial context, not only their position but the area visible from that location. The application is designed for use in the context of a geography fieldtrip to allow students to directly compare computer generated landscape visualisations to their real world counterparts, as well as offering the same scene draped with geology or with a model of retreating glacial ice.

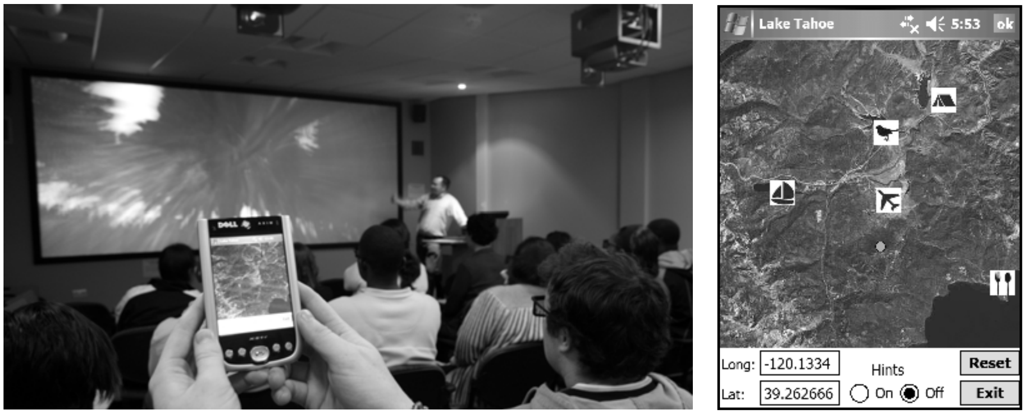
2. Background

Rather than focus on the effectiveness of interactive virtual environments as with the related research of Whitelock and Jelfs (2005) the approach was to develop techniques to be used in the context of real fieldwork. The development of these techniques began with field-based exercises designed to engage students in the issue of the representational fidelity of Digital Surface Models through the use of landscape visualisation in fieldwork (Priestnall, 2004). Students render and print views from known points within a 3D model of the field site and take these out into the field to undertake direct comparison from these points in the field. These techniques are now being extended through the use of mobile computing devices supported by ongoing developments in SPLINT (SPatial Literacy IN Teaching), a Centre for Excellence in Teaching and Learning funded by the Higher Education Funding Council of England (HEFCE). Involving the University of Leicester (lead), the University of Nottingham, and University College London, SPLINT aims to advance the pedagogy of geospatial technologies, and to explore and enhance spatial literacy in a range of disciplines across Higher Education.

The focus of activity for the Nottingham arm of SPLINT is on the development of mobile applications in support of fieldwork and in the wider use of virtual models and visualisation. Virtual models of the University Park campus, Nottingham and the Newlands Valley fieldtrip site in Cumbria are the first models under construction. Location-aware mobile applications have been developed for both sites and in order to allow the operation of these to be tested and developed further the lab-based visualisation has been synchronised with mobile devices operating in the same room.

3. Synchronised Virtual Environment

The visualisation theatre (Figure 1) features two pairs of data projectors creating a 5m x 2.5m image, viewable in stereo through the use of ‘passive’ eyewear. The real-time rendering software used is Vega Prime and models are currently being built in the Blueberry, Creator and 3D Studio MAX software packages. The user’s position within the virtual model is transmitted every second as a GPS NMEA string via a Bluetooth transmitter in the ceiling of the lab. Any mobile device equipped with Bluetooth reception can therefore pair with the transmitter in exactly the same way as it would with a Bluetooth GPS in an outdoor environment. Location-aware applications which use GPS positional information to trigger actions based on user movement can therefore be tested within this environment before actual field testing is undertaken. Ongoing developments with the use of the transmitted position will include the simulation of variable positional accuracies of GPS including the influence of urban canyons and heavy forest cover. Such a configuration clearly offers potential to explore the way people use instructional media to assist wayfinding as demonstrated by Li and Longley (2006) in an unsynchronised virtual environment.



Long: -120.1334

Lat: 39.262666

Hints ○ On ● Off

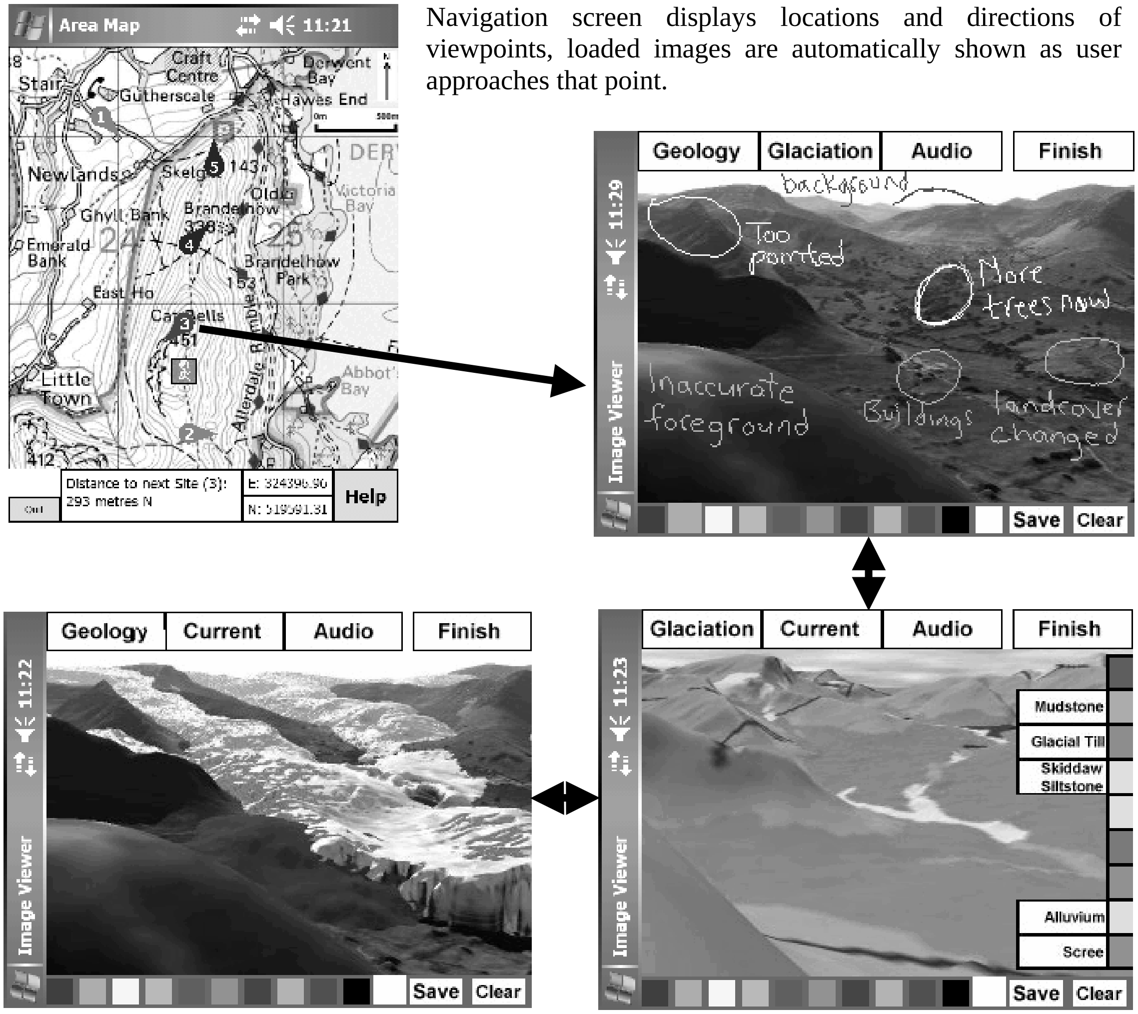
Figure 1. Synchronising a lab-based Virtual Environment with a mobile device.

To test the synchronisation procedure a ‘proof-of-concept’ application has been created in the Visual Basic.NET Compact Framework on a Personal Digital Assistant (PDA) using a demonstration terrain dataset of Lake Tahoe, USA. The Tahoe Tourist Trail featured in Figure 1 represents a simple ‘orienteering’ exercise was developed whereby users had to visit a series of way points in the fastest time possible.

4. Mobile Geospatial Augmented Reality

A series of location-aware mobile applications are being developed building on the Tahoe Trail application and focusing on techniques for augmenting real scenes with various computer-generated imagery relevant to the user’s position. These applications are being developed for PDAs and tablet PCs where the screen is held up towards the real scene to offer additional information about that scene, ‘augmenting’ reality for the user. This technique could be considered to fall within the domain of ‘Mobile Geospatial Augmented Reality (MGAR)’ although not true Augmented Reality as described by Piekarski (2006). The handheld MGAR technique currently adopted (Priestnall and Polmear, 2006) is being further developed within the synchronised virtual environment. A PDA-based application has been created to allow students to take computer-generated landscape visualisations out into the field to develop a schema for assessing such images against reality. A 5m resolution Digital Surface Model (DSM) derived from airborne radar draped with colour aerial photography forms the model of the 'current' landscape, with solid and drift geology data giving a 'hidden' landscape, and a reconstruction of the retreating glacial ice a 'past' landscape. Five viewpoints are chosen and for each of these three 3D views are created (current, past, and hidden), and then copied to the PDA using a purpose written data loader.

Once in the field the GPS-enabled PDA displays a navigation screen as shown in Figure 2. The locations and directions of the loaded views are shown on the map along with a moving icon representing the user. Upon reaching the first viewpoint the 3D view representing the radar model is displayed automatically. Students are encouraged to critically assess the degree to which such visualisations offer faithful representations of the real scenes and a sketch facility has been developed to allow annotations to be made to these images in the field (Figure 2, upper right image). The equivalent view with geology drape and also the glaciated model can be viewed, as shown by the lower two images in Figure 2. Students are encouraged to observe physical evidence to support or refute the glacial scenario represented and for evidence of the influence of subsurface geology on the observable landscape.



Distance to next Site (3): 293 metres N

E: 324396.90

N: 519091.31

Navigation screen displays locations and directions of viewpoints, loaded images are automatically shown as user approaches that point.

Figure 2. Mobile Geospatial Augmented Reality Application

An additional feature of the current application is the use of pre-determined visibility maps which record whether certain key landscape features should be visible from any given location. Grid-based binary viewsheds were created within ArcGIS by digitising areas of interest using evenly distributed observer points within these areas. To improve computational efficiency when querying on the mobile device various encoding techniques are being explored. Currently the binary viewsheds representing a series of landscape features of interest are re-coded following a geometric sequence beginning with 1 and having a scale factor of 2, ie: 1, 2, 4, 8, 16, 32, etc. In this way the viewshed grids can be added together giving cell values which represent unique combinations of the original inputs, in a similar way as multiple water flow directions are often encoded. For example in Figure 3 the landscape areas 1, 2, 4, and 16 are visible from location X so the cell at X would receive the value 23, being the sum of the individual codings. The 'audio' button on the mobile application interface triggers a query of the visibility map and interprets the local cell value as a series of individual inputs, knowing the geometric sequence used to create it. This series of input values in turn triggers a sequence of sound files to be played, each of which describes the evolution of a landscape feature which should be visible from that location. This technique is similar to the way audio was used in the city tourist guide developed by Mackaness and Bartie (2005).

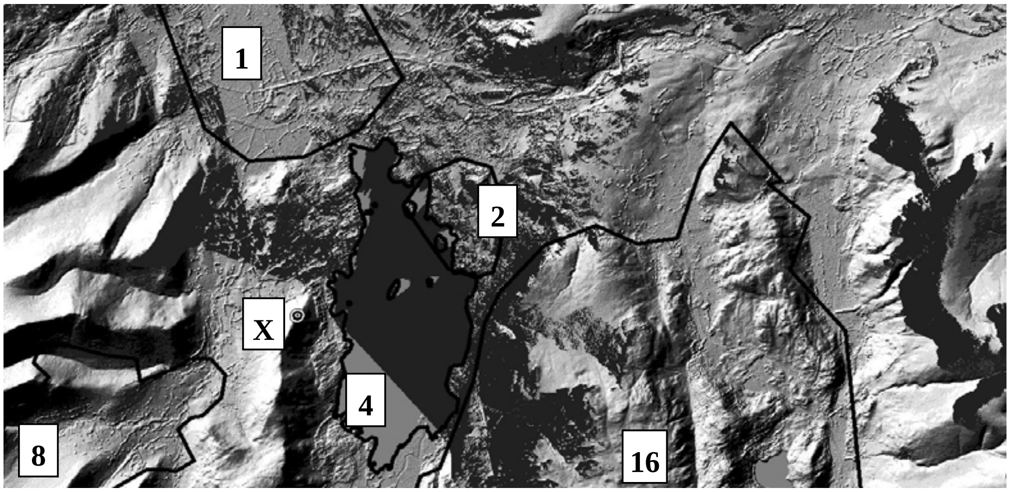


Figure 3. Visual context: The use of composite visibility maps

The usability of the mobile applications under development is critical and the synchronisation with the lab-based 3D visualisation offers a controlled development environment for testing and refining the basic operation of the applications. The second phase of testing relates to field-based operation and addresses usability issues of the devices themselves. Initial testing reveals that in full sunlight the trans-reflective screens generally perform well apart from when the view direction is directly into the sun. The simplicity of design proved critical and many such issues can be tested in the lab but it will only be after several field tests with large numbers of students when the effectiveness of the application will become clear. The intention is to evaluate usability issues of the mobile application alongside the original technique which used printouts in the field to ensure that the mobile technology is not interfering with the learning objectives. This will be reported on in future research output.

5. Ongoing developments

In addition to the use of the virtual environment as a test bed for location-aware mobile applications several aspects of what may be termed spatial literacy are being investigated including:

- The ability for users to associate various portrayals of terrain on a mobile device (smart phone, PDA, tablet PC) with realistically rendered 3D landscape visualisation. One study of this type is being undertaken in collaboration with the Visual Learning Lab, a HEFCE-funded Centre for Excellence in Teaching and Learning led by Education, University of Nottingham.
- The effectiveness of various portrayals of urban environments for way finding, using a virtual model of the University of Nottingham campus under construction. In addition to testing

applications designed to assist outdoor navigation the use of the same application in both lab and field offers the opportunity to study the differences in way finding behaviour between virtual and real environments.

- Further investigation into the use of 'visual context', investigating more thoroughly the creation and use of visibility maps in mobile applications.

6. Conclusions

A test bed environment linking lab-based 3D visualisation with location-aware mobile applications has been presented and an example of a 'Mobile Geospatial Augmented Reality' application is described. There is great potential for the further use of this environment for exploring certain aspects of spatial literacy in addition to exploring certain design and usability aspects of mobile applications.

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Many thanks to Chris Strusselis of Antycip SA for coding within the Vega environment to establish the Bluetooth output from the virtual model. Digital data for the development of the Cumbria mobile application was obtained from Intermap (the DSM), Getmapping (aerial photography) and the British Geological Survey (solid and drift geology). Thanks also to colleagues associated with the SPLINT CETL including Andy Burton, Martin Smith, Claire Jarvis, and Nick Tate.

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Biography

Gary Priestnall is an Associate Professor (Senior Lecturer) whose research interests lie in geographic representation, landscape visualisation, spatially-aware mobile applications for geography fieldwork. Gemma Polmear is a Research Associate working on the HEFCE-funded Centre for Excellence in Teaching and Learning - SPLINT (Spatial Literacy IN Teaching), developing mobile geospatial augmented reality applications.

A Dual-frequency GPS survey to test medium-scale DTM data quality and to generate precise DTM data for sea-level rise prediction in protected habitat areas.

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1. Introduction

Global average temperatures have increased by about 0.6°C (± 0.2°C) during the 20th century, and are projected to increase by between 1.4°C and 5.8°C by 2100 (IPCC, 2001a). This is predicted to lead to worldwide sea-level rise (SLR) of up to 1m by 2100 (IPCC, 2001b), which will have an impact on coastal environments protected under the Natura 2000 Habitats and Birds Directives (EU, 1992 & 1979).

Estuaries are predominantly sedimentary environments, and are characterised by shallow slope gradients, which make them particularly sensitive to changes in sea-level. The Shannon estuary is the largest river estuary in Ireland and it is designated as a Special Area of Conservation (SAC) under the Habitats Directive providing protection for coastal salt marsh habitats within the estuary.

Sea-level rise (SLR) predictions will be carried out for a portion of the estuary, based on Intergovernmental Panel on Climate Change (IPCC) predictions for best case, median case and worst case SLR up to 2100. IPCC predictions range from a best case minimum of 0.1m, to a median case prediction of 0.48m, through to a worst case of 0.88m.

Regional geological phenomena can add significantly to these trends. A north-south gradient of post-glacial land-surface rebound has been observed in Ireland on a geological timescale, with greater rebound in the north relative to the south resulting in land-surface submergence in the south of Ireland (Devoy, 2000), adding an additional trend to climate-induced SLR.

Historical trends in tidal records provide a useful indicator of changing sea-level. Data provided The Shannon Foynes Port Company (SFPC) for periods from 1877 – 1902, 1949 – 1965, 1970 – 2000 & 2002 – 2004 suggested an average upward trend of 4-4.5mm/yr for the period from 1877 - 2004. Continuation of this trend (in the absence of any acceleration for SLR) suggests local SLR of between 40cm to 45cm by 2100.

2. DTM data and sea-level rise

The generation of meaningful SLR prediction maps in a Geographic Information System (GIS) presupposes the existence of reliable Digital Terrain Model (DTM) data. Ordnance Survey Ireland (OSi) 1:50,000-scale data is the best national coverage dataset that is currently available in Ireland. Vertical errors in this dataset are quoted at ±5m. Highly precise DTM data can be derived from LIDAR (LIght Detection And Ranging) survey data, with height errors of ±15cm typically quoted for LIDAR DTM data. LIDAR-derived DTM data is starting to become available for major urban areas in Ireland, but there are as yet no immediate plans to extend this to non-urban areas. The lack of accurate DTM data for the Shannon estuary has created a need for the generation of DTM data from first principles.

Rasterised DTM data is often classified according to its spatial resolution. While this is often valid as a general indicator of the spatial resolution of the measured data from which a raster is derived, it cannot be relied upon as such. The density of the spot heights on the OSi 1:50,000-scale spot heights for the area around Shannon averages one per 30 hectares. In addition, these spot heights are not all from field measurements, but are more typically derived from photogrammetric interpretation. Contours interpolated from the spot heights are issued by OSi as part of the overall base DTM dataset, and these are typically used as base data for the generation of a raster DTM. The coastline at a scale of 1:10,000 is often used to extend the DTM model to the coast. The use of a relatively sparse set of data, most of which are interpolated values suggests that vertical accuracies will indeed be subject to significant errors.

SLR prediction modelling in a GIS typically involves a simple reclassification of a DTM by subtracting a given SLR height value from every cell in the DTM raster dataset. This creates a new model of terrain height. While error ranges of ±5m are acceptable for mapping purposes, they are beyond the level of accuracy needed for SLR prediction. However, vertical errors can be expected to be largest in mountainous regions, where vertical gradients are greatest. The range of possible error in the coastal region was assessed to determine whether the elevation data was of sufficient quality for SLR modelling, and to provide a high-quality dataset for the generation of a local DTM.

3. Methods

Dual-frequency (survey-grade) GPS (Global Positioning Systems) survey equipment is capable of measuring elevation to a precision range of 1 – 2cm relative to the local geoid. A Dual-frequency GPS survey was carried out in an area to the south of Shannon town, where habitat mapping from the National Parks and Wildlife Service (NPWS) confirmed the presence of protected salt marsh habitat within the Shannon estuary SAC. The results of the GPS survey were compared with the national coverage DTM to quantify the error ranges encountered within the OSi 1:50,000 dataset, and to provide the basis of a high-quality local DTM for use in SLR predictions in GIS.

The spatial extent of the GPS survey area was chosen to cover a range of spot height and contour elevation values (table 3) in order to facilitate accuracy testing. A raster

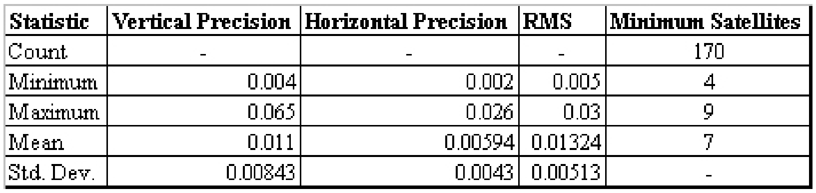
DTM grid was derived from the 1:50,000-scale spot height and contour data to provide the basis for a simple SLR inundation model, which could be used to guide the GPS point survey. This area was sub-divided into an initial network of twenty six 500x500m blocks and 310 sub-blocks measuring 100x100m providing a sampling framework for the GPS survey.

The first GPS survey was carried out over a 7-day period in September 2006. A Trimble R8 dual-frequency differential GPS receiver was used to capture 170 x,y,z points at an average spacing of 80m. GPS points were recorded in WGS84 / ERTS89 coordinates relative to the Irish OSGM02 GEOID model.

4 Analysis and Discussion

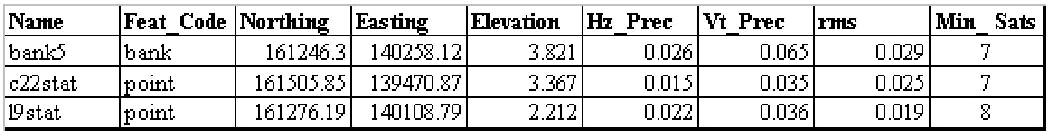
The density of the survey points is roughly 45 times that of the OSi 1:50,000-scale spot heights for the area. The GPS point data was recorded in fast-static mode, which measures position over a period of at least 8 minutes for each point. Elevation values derivable from this method are currently more accurate than Real Time Kinematic (RTK) in Ireland, which defines position over a much shorter time-span by reference to a national network of 13 OSi GPS correction stations.

Trimble Geomatics Office (TGO) software v.1.62 was used to post-process the 170 points captured. The data was post-processed against RINEX data from the OSi GPS reference station at Limerick University. The baseline to this station from the centre of the survey area is well within the recommended range of 30km, being located at approximately 22km from the survey site. The locations of these OSi GPS reference stations are updated daily, and are known in the x,y, & z planes to an accuracy of <1mm (OSi Geodetic site: http://www.osi.ie/gps/index.asp). The TGO software enabled each point in the survey network to be referenced against the known location of the station at Limerick, returning an estimate of the accuracy of each surveyed point in the x,y, & z planes. The average vertical error in the 170 points captured after post-processing was 11mm, with a maximum vertical error of 6.5cm, and a minimum error of 4mm (table 1). The point that returned the worst accuracy (6.5cm) turned out to be in a location where it was not needed, and was excluded from subsequent analysis (table 2). The next two low accuracy results were within the region of 3cm, and were deemed more than acceptable for the purposes required.



Statistic	Vertical Precision	Horizontal Precision	RMS	Minimum Satellites
Count	-	-	-	170
Minimum	0.004	0.002	0.005	4
Maximum	0.065	0.026	0.03	9
Mean	0.011	0.00594	0.01324	7
Std. Dev.	0.00843	0.0043	0.00513	-

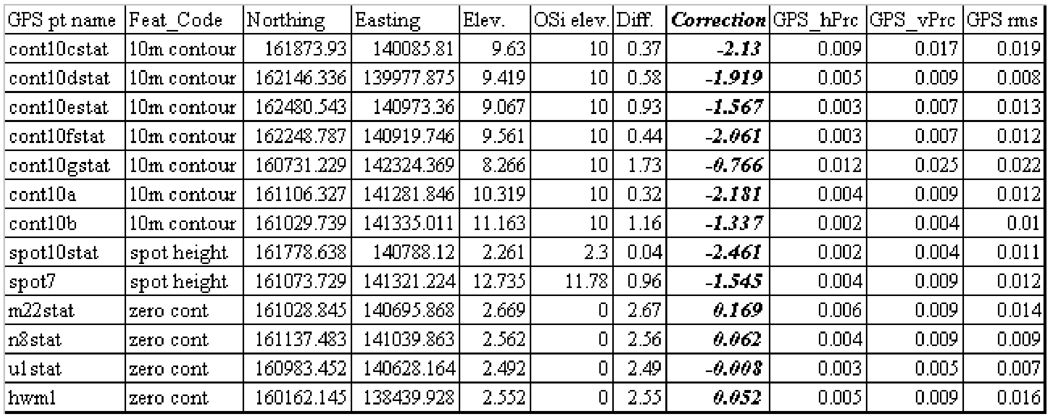
Table 1: Minimum, maximum and mean vertical RMS errors in the 170 points surveyed.



Name	Feat_Code	Northing	Easting	Elevation	Hz_Prec	Vt_Prec	rms	Min_ Sats
bank5	bank	161246.3	140258.12	3.821	0.026	0.065	0.029	7
c22stat	point	161505.85	139470.87	3.367	0.015	0.035	0.025	7
19stat	point	161276.19	140108.79	2.212	0.022	0.036	0.019	8

Table 2: The three low-accuracy, maximum and mean vertical RMS errors in the 170 points surveyed.

The results observed suggest that the errors observed in the OSI base data were smallest at the coastline itself (table 3) and were greater inland. Locations that corresponded with points and contours on the OSi spot height and contour data were identified and surveyed with the Trimble R8. Only two spot heights (out of a planned 4) could be located in the field. One was no longer in existence, due to construction activity, and the other was inaccessible and was set aside for capture in a next planned survey. The difference between the elevations as defined by the OSi spot height data and the GPS suggested an OSi underestimation error of 1.545m and .461m respectively (table 3). Seven points on OSi 10m contours were identified, visited and surveyed by GPS, revealing vertical errors of between -2.181m and -0.766m. Four points on the OSi 1:10,000-scale zero contour were identified, visited and surveyed by GPS, indicating vertical errors of between -0.008m and 0.169m (table 3). These results suggested that zero contour data may be the most accurately defined in the OSi base DTM data. All these results will be compared to extended analysis from a contiguous survey planned for March 2007.



GPS pt name	Feat_Code	Northing	Easting	Elev.	OSi elev.	Diff.	***Correction***	GPS_hPrc	GPS_vPrc	GPS rms
cont10cstat	10m contour	161873.93	140085.81	9.63	10	0.37	***-2.13***	0.009	0.017	0.019
cont10dstat	10m contour	162146.336	139977.875	9.419	10	0.58	***-1.919***	0.005	0.009	0.008
cont10estat	10m contour	162480.543	140973.36	9.067	10	0.93	***-1.567***	0.003	0.007	0.013
cont10fstat	10m contour	162248.787	140919.746	9.561	10	0.44	***-2.061***	0.003	0.007	0.012
cont10gstat	10m contour	160731.229	142324.369	8.266	10	1.73	***-0.766***	0.012	0.025	0.022
cont10a	10m contour	161106.327	141281.846	10.319	10	0.32	***-2.181***	0.004	0.009	0.012
cont10b	10m contour	161029.739	141335.011	11.163	10	1.16	***-1.337***	0.002	0.004	0.01
spot10stat	spot height	161778.638	140788.12	2.261	2.3	0.04	***-2.461***	0.002	0.004	0.011
spot7	spot height	161073.729	141321.224	12.735	11.78	0.96	***-1.545***	0.004	0.009	0.012
m22stat	zero cont	161028.845	140695.868	2.669	0	2.67	***0.169***	0.006	0.009	0.014
n8stat	zero cont	161137.483	141039.863	2.562	0	2.56	***0.062***	0.004	0.009	0.009
u1stat	zero cont	160983.452	140628.164	2.492	0	2.49	***-0.008***	0.003	0.005	0.007
hwm1	zero cont	160162.145	138439.928	2.552	0	2.55	***0.052***	0.005	0.009	0.016

Table 3: The three low-accuracy, maximum and mean vertical RMS errors in the 170 points surveyed.

5. Initial conclusions

Based on the trend observed in the historical tidal data for Limerick Docks, the minimum IPCC SLR prediction for 2100 appears to be very unlikely in the Shannon estuary. SLR of 0.4 – 0.45m can be expected in the absence of any acceleration in the trend observed between 1877 and 2004.

The vertical accuracies achieved across the entire GPS survey area suggests that dual-frequency GPS is a reliable source of base data for generation of a DTM of sufficient quality for use in SLR prediction mapping.

The error ranges encountered in the initial survey suggest that errors in the OSi base data are within the published ranges, with the smallest errors occurring at the coastline. The classification of error in the OSi data as discussed here will be subject to revision as further GPS surveys are carried out in adjoining areas long the coast.

The impact of sedimentation is also being assessed, and appraisal of various interpolation methods will be assessed in addition to modelling salt marsh change based on DTM-derived variables and local coastal energy gradients.

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Accuracy Assessment of Digital Elevation Models Based on Approximation Theory

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1. Introduction

Digital elevation models (DEM) are essential to various applications such as terrain modeling and watershed delineation. Since the 1980s, error propagation theory has been the dominant framework to assess DEM accuracy, which leads to the current practice on using error variance or Root Mean Squared Error (RMSE) to describe DEM quality. However, error propagation theory is found incapable to explain some empirical observations such as the correlation between DEM error and terrain complexity (e.g. (Wise 2000; Oksanen and Sarjakoski 2006). This paper presents approximation theory in computational science as an alternative framework. Specifically, the paper clarifies the nature and composition of DEM error; discusses the challenges facing the error propagation theory; and illustrates how approximation theory can be applied to assess a DEM generated from linear polynomial interpolation such as linear interpolation in 1D, Triangulated Irregular Network (TIN) interpolation, and bilinear interpolation in a rectangle.

2. Errors in a DEM

To assess DEM error, an understanding of its nature and composition is necessary. In the literature, some scholars have made explicit assumption that DEM error is randomly distributed (Li 1993; Huang 2000; Weng 2002). Others expressed reservations because of findings from empirical analysis (Oksanen and Sarjakoski 2006). Suppose T is a DEM point whose true elevation is Z_T. Given an interpolation method, the interpolated elevation using source data with and without error are denoted by $Z_T^{'}$ and H_T respectively. It can be seen that

$$Z_T^{'} = H_T \pm \delta_T \qquad (1)$$

where δ_T the impact of the errors in the source data on point T. The total error of T, denoted by ΔZ_T is:

$$\Delta Z_T = Z_T - Z_T^{'} = Z_T - (H_T \pm \delta_T) = (Z_T - H_T) \pm \delta_T = R_T \pm \delta_T \qquad (2)$$

where $R_T = Z_T - H_T$ is the interpolation error and can be shown to be systematic error. Under the assumption that systematic error and gross error in the source data are removed, δ_T can be shown random error. Equation 1 shows that the total error in a DEM point is not random but a mixture of random and systematic error.

3. Error propagation theory

3.1. Error propagation theory in its general form

Since 1980, error propagation theory has been used to assess DEM accuracy. The general form of error propagation theory is as follows. Suppose error ε is the sum of two errors x and y, i.e.

$$\varepsilon = x + y \qquad (3)$$

if ε is observed repeatedly for n times, there is:

$$\varepsilon_i = x_i \pm y_i, \quad i = 1, ..., n$$

or equivalently

$$\varepsilon_i^2 = x_i^2 + y_i^2 \pm 2x_i y_i$$

The average of these observations is:

$$\frac{\varepsilon_i^2}{n} = \frac{x_i^2}{n} + \frac{y_i^2}{n} \pm \frac{2x_i y_i}{n}$$

Under the assumption that x and y are random errors which typically have normal distribution with mean of 0, the above equation can be rewritten as

$$\sigma_\varepsilon^2 = \sigma_x^2 + \sigma_y^2 \pm 2\sigma_{xy}^2 \qquad (4)$$

where $\sigma_\varepsilon^2 = \sum \varepsilon_i^2 / n$, $\sigma_x^2 = \sum x_i^2 / n$, $\sigma_y^2 = \sum y_i^2 / n$, and $\sigma_{xy}^2 = \sum x_i y_i / n$. Furthermore, if x and y are independent of each other, equation 4 can be simplified to

$$\sigma_\varepsilon^2 = \sigma_x^2 + \sigma_y^2 \qquad (5)$$

3.2. Application of Error propagation theory in DEM

As shown in equation 1, the total error of a DEM point can be written as

$$\Delta Z_T = R_T \pm \delta_T$$

which is in the same form as equation 2, therefore error propagation theory has been applied to study DEM accuracy. Per equation 4,

$$\sigma_{\Delta Z_T}^2 = \sigma_{R_T}^2 + \sigma_{\delta_T}^2 \pm 2\sigma_{R_T \delta_T}^2 \qquad (6)$$

In the literature, the covariance term is typically omitted to result in (Tempfli 1980; Li 1993; Aguilar *et al.* 2006):

$$\sigma_{\Delta Z_T}^2 = \sigma_{R_T}^2 + \sigma_{\delta_T}^2 \qquad (7)$$

While the error propagation theory in equation 6 and 7 provide an elegant framework to study DEM, a few challenges exist: (1) error propagation theory assumes both errors are random error. However, the interpolation error R_T is not random error but systematic error. Whether error propagation theory is applicable in the context of DEM error is thus worth of consideration. Furthermore, the application of equation 7 requires that R_T and δ_T are independent of each other. In reality, R_T and δ_T both dependant on the interpolation function. Their independence is thus difficult to determine. Considering these challenges, error propagation theory which is the root of using error variance and RMSE to describe DEM accuracy seem to deserve a second thought.

4. Accuracy assessment based on approximation theory

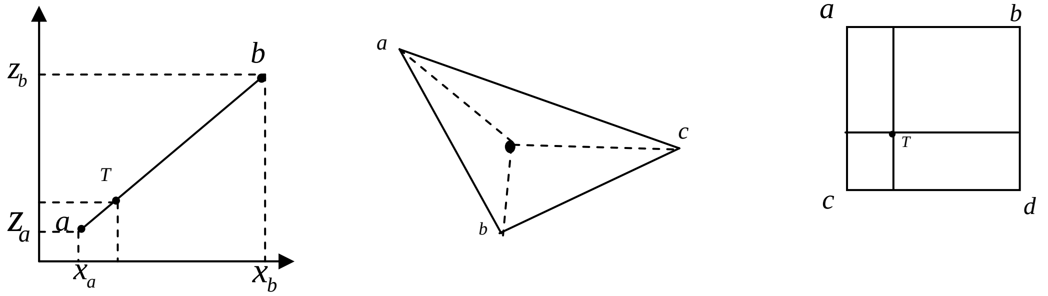
An alternative framework is approximation theory which concerns how to approximate an actual complex function $f(x, y)$ using simpler functions $F(x, y)$ and quantitatively characterize the errors introduced thereby. In the context of DEM research, $f(x, y)$ is the terrain, $F(x, y)$ is a DEM. According to approximation theory, the goodness of approximation is measured by truncation error which is the largest difference between the two functions, i.e. $\max\left|f(x, y) - F(x, y)\right|$. Let $T(x_T, y_T)$ a DEM point. Its error is

$$\Delta z_T = f(x_T, y_T) - F_1(x_T, y_T) = R_T \pm \delta_T$$

The truncation error of the DEM is $\max\{\left|\Delta z_T\right|\}$, i.e.

$$\max\left|\Delta z_T\right| = \max\left|R_T \pm \delta_T\right| \le \max\left|R_T\right| + \max\left|\delta_T\right| \tag{8}$$

In the following, we derive $\max\left|R_T\right|$ and $\max\left|\delta_T\right|$ for the three linear polynomial interpolation methods in Figure 1.



(a) (b) (c)

Figure 1: Three linear polynomial interpolation methods to generate a DEM: (a) linear interpolation, (b) TIN interpolation, and (c) bilinear interpolation in a rectangle.

It can be shown that the functions of the three interpolation methods are as follows:
Linear interpolation:

$$Z_T^{'} = \omega_1 Z_b + \omega_2 Z_a, \omega_1 + \omega_2 = 1, \omega_1, \omega_2 > 0 \tag{8}$$

TIN interpolation:

$$Z_T^{'} = \omega_1 Z_a + \omega_2 Z_b + \omega_3 Z_c, \omega_1 + \omega_2 + \omega_3 = 1, \omega_1, \omega_2, \omega_3 > 0 \tag{9}$$

Bilinear interpolation in a rectangle:

$$Z_T^{'} = \omega_1 Z_a + \omega_2 Z_b + \omega_3 Z_c + \omega_4 Z_d \;, \omega_1 + \omega_2 + \omega_3 + \omega_4 = 1,\; \omega_1, \omega_2, \omega_3, \omega_4 > 0 \qquad (10)$$

where Z_a, Z_b, Z_c, Z_d are the elevations of the corresponding vertices as shown in Figure 1.

4.1. Impact of source-data error

The impact of the errors in the source data on a DEM point *T* is as follows:

Linear interpolation: $\delta_T = \omega_1 \delta_b + \omega_2 \delta_a$

TIN interpolation: $\delta_T = \omega_1 \delta_a + \omega_2 \delta_b + \omega_3 \delta_c$

Bilinear interpolation in a rectangle: $\delta_T = \omega_1 \delta_a + \omega_2 \delta_b + \omega_3 \delta_c + \omega_4 \delta_d$

The bound of the impact can be shown to be

$$\max |\delta_T| \le |\delta|$$

where $|\delta|$ is the largest error in the source points.

4.2. Impact of interpolation error

All of the three interpolation methods are piecewise polynomial interpolation, i.e. dividing the terrain into patches and conduct DEM interpolation patch by patch. For each patch, the corresponding terrain $f(x, y)$ is assumed to be twice or more continuously differentiable. It can be derived that the interpolation error bounds are

Linear interpolation in 1D: $|R_T| \le \frac{1}{8} M_2 h^2$

TIN interpolation: $|R_{TIN}| \le \frac{3}{8} M_2 h^2$

Bilinear interpolation in a rectangle: $|R_T| \le \frac{1}{4} M_2 h^2 + \frac{1}{64} M_4 h^4$

where M_2, M_4 are the second and fourth order maximum norm over the entire terrain, h is the largest distance between two source points. M_2, M_4 are essentially indicators of terrain complexity, and h is the sampling density.

Combing the bounds of the interpolation error and the impact of the source-data error, the total error of a DEM point generated by each of the three linear polynomial interpolation methods is summarized in Table 1.

Table 1. DEM error of three linear polynomial interpolation methods.

	δ_T *: random error*	R_T *:* interpolation error
Linear interpolation in 1D	$\lvert\delta_T\rvert \le \lvert\delta\rvert$	$\lvert R_T\rvert \le \frac{1}{8}M_2h^2$
TIN interpolation	$\lvert\delta_T\rvert \le \lvert\delta\rvert$	$\lvert R_T\rvert \le \frac{3}{8}M_2h^2$
Bilinear interpolation in a rectangle	$\lvert\delta_T\rvert \le \lvert\delta\rvert$	$\lvert R_T\rvert \le \frac{1}{4}M_2h^2 + \frac{1}{64}M_2h^4$
Total error bound	$\max\lvert R_T\rvert + \lvert\delta_T\rvert \le \max\lvert R_T\rvert + \max\lvert\delta_T\rvert$	

5. Discussion and Conclusion

Many research on DEM accuracy observed that DEM accuracy is related to terrain complexity and sampling density (Wood 1994; Aguilar *et al.* 2006). The research in this paper based on approximation theory offers a theoretical explanation for this observation. It can be seen that DEM error is a mixture of the interpolation error and random error. In the case that terrain is very complex and source point density is low, M_2h^2 will be large which may render all three interpolation methods ineffective. Increasing sample density will decrease the interpolation error. In the case that very high density of source data is available and the source data is highly accurate, as in the case of LiDAR, high accuracy DEM is almost guaranteed regardless of the interpolation method used.

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Biography

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A tool for assessing error in digital elevation models from a user's perspective

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1. Introduction

A Digital Elevation Model (DEM) is a representation of geographic reality. The elevations recorded within DEMs have been shown to contain errors pertaining to sampling, measurement and interpolation (Fisher, 1998). Even a small amount of elevation error can greatly affect derivative products (Holmes et al., 2000). This can potentially have a significant impact on the application of DEMs in Geographical Information Systems (GIS) where first and second order derivatives are considered.

DEM vendors generally provide users with a measure of vertical accuracy in the form of the Root Mean Squared Error (RMSE) statistic only. However many papers have reported on the limitations of a single value of accuracy, stressing that DEM error is spatially autocorrelated (e.g. Kyriakidis *et al.,* 1999). Arguably, the best method for error modelling is based on conditional stochastic simulation (Fisher, 1998). Conditioning the simulation model includes sample observations of error and thus allows consideration of spatial autocorrelation. Unfortunately computation is complex.

The main aim of this research was to simplify existing procedures to enable the 'average' DEM user to perform his/ her assessment on the implications of choosing a particular dataset for their work. User requirements were identified and a methodology was designed to adhere to the essential requirements, whilst maintaining the option of modifying defaults (Table 1). As an application the use of a DEM for landslide susceptibility modelling was considered to add context to discussion and demonstrate the relevance of the propagation of error consideration.

2. Methods

The study area occupies approximately 25km^2 of north-western Slovenia and focuses on the tectonically active intersection of the Alps and Dinaride mountain ranges. Previous research in the study area had revealed that only slopes of 14 degrees or greater showed correlation with landslide occurrence that was significantly different from the random occurrence of landslides (Komac, 2006; pers. comm). This figure was taken as a critical angle for slope susceptibility to landslide in the study area, and was the simplistic landslide model applied.

Requirement type	***Description***	***Necessity***
Data:	Test DEM(s)	Essential
	Higher accuracy data for reference surface	Essential
Variables:	Sample size and point locations	Essential
	Grid resolution for display of results	Optional (default)
	Number of simulations (*N*)	Optional (default)
Knowledge/ skills:	Variogram interpretation	Essential basic
	Interpretation of results	Essential
External Software:	Manipulation of data (e.g. MS Excel)	Essential
	Further visualisation (e.g. Surfer, Golden Software)	Optional

Table 1 User requirements in the error assessment methodology

Two independent test DEMs were provided by the Environmental Agency of the Republic of Slovenia at 12.5m and 25m grid spacing. A Light Detection and Ranging (LiDAR) dataset was used as a surrogate for the 'true' elevation, from which 100 sample points were randomly selected to be representative of the reference elevation surface. Error is defined here as the disparity in the elevation value projected by a DEM and its true value, and is given by subtracting the DEM value from the reference surface (after Heuvelink, 1998). The geostatistical modelling and simulation was performed with the GSTAT package used in the R software environment (Pebesma, 1999). This is freely accessible software copyrighted under the General Public Licence (GPL). Prior to evaluation an algorithm was written in R that would automatically set up grid nodes for calculation, dependent on the bounds set by the minimum and maximum coordinate sample values (grid resolution defaults to 100m^2). There were four main stages to represent the uncertainty and demonstrate the propagation of error to the landslide model.

1) *Modelling spatial dependence*
   A variogram was used to show the spatial autocorrelation of error. A model was achieved in GSTAT by a two-step procedure of first calculating the sample variogram from raw data and then fitting a model. Interpretation was required to select an appropriate model (Table 1).

2) *Stochastic simulation*
   The variogram model determined above was preserved and used with Inverse Distance Weighted (IDW) interpolation and sequential Gaussian simulation to generate *N* error map realisations. Each error realisation was added to the original test DEM (re-gridded to error nodes) to generate *N* equally probable DEMs. *N* defaults to 100.

3) *Propagation through to surface derivatives*
   The overall average slope was calculated according to the third-order finite difference method (Aguilar et al, 2006). This resulted in the generation of *N* equally probable slope maps.

4) *Propagation to landslide susceptibility modelling*

The landslide susceptibility model defined areas of slope angle greater than 14 degrees as susceptible to the hazard of landslide. Discrete valued categories (such as 'susceptible' and 'non-susceptible') can contain errors due to misclassification (Zhang and Goodchild, 2002). To examine the probable and possible uncertainties in classifying the landslide hazard, two frameworks were adopted: probabilistic and fuzzy.

   i. Probability of susceptibility classification: A nominal value of *true* was given to the simulated cell if its slope value exceeded the critical angle and *false* if it did not. Counting up the true and false declarations for each cell and dividing by *N* gave the probability of that cell being susceptible to landslide.

   ii. Fuzziness in susceptibility: For the *N* simulations the minimum and maximum simulated values of slope (for each grid cell) were recorded. Each value was then tested against the critical angle as before and the cell attribute was set to *true* if it was greater than 14 degrees and *false* if it was equal to or less than. A three-tier classification system was used to define each cell. For each cell if both minimum and maximum values were *true* then that cell was given a value of 1 and was susceptible to landslide. If either minimum or maximum was *true* then the node was given a value of 0.5 and classified undecided. If neither was *true*, the cell was not susceptible and given a value of 0.

3. Results and analysis

The spatial distribution of error was similar for the DEMs of differing resolution, although the magnitude was slightly higher for the 25m DEM. The relative spatial variation of mean error for the 12.5m DEM is shown in Figure 1a. Graphics were created using the Lattice package in GSTAT and (optionally) projected onto a topographic map. The mode of formation was different for each DEM so a similar spatial distribution may imply a terrain-dependent error causal factor (e.g. Liu and Jezek, 1999). To demonstrate the propagation of error, slope values directly derived from each DEM (no consideration of uncertainty) were compared to the mean values of the slope realisations (Figure 1b). This provided an indication of how slope estimation would vary were it derived directly from the DEM or from the multiple equally likely realisations. The main region of slope discrepancy was adjacent to the peak in mean elevation error, thus supporting the hypothesis of error propagation and the previous work of authors such as Murillo and Hunter (1997).

The test DEMs showed similar spatial probability distributions. The alternative method resulted in a fuzzy three-tier classification system of susceptible, not susceptible and undecided. There were significant differences in the allocation of susceptibility areas from the two DEMs (Figure 2). In particular the variation was evident in the valley section.

Figure 3 summarises the consequences of landslide classification based exclusively on either the 12.5m DEM or the 25m DEM. The coarser resolution DEM would be more uncertain about classifying a cell as susceptible or non-susceptible to landslide. In a comparison with the 25m DEM, the 12.5m DEM classifies a greater number of cells as ‘susceptible’ or ‘non susceptible’.

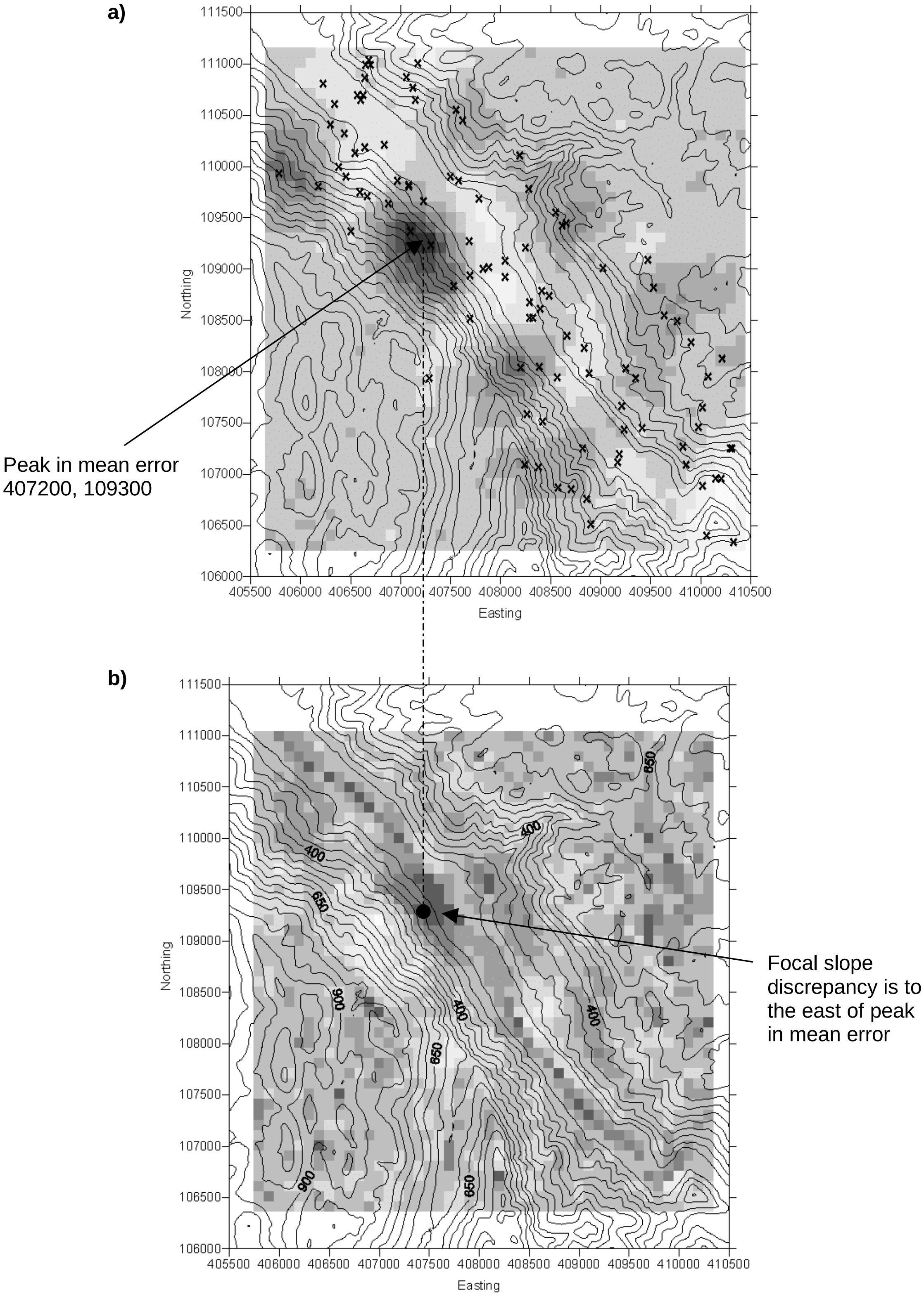
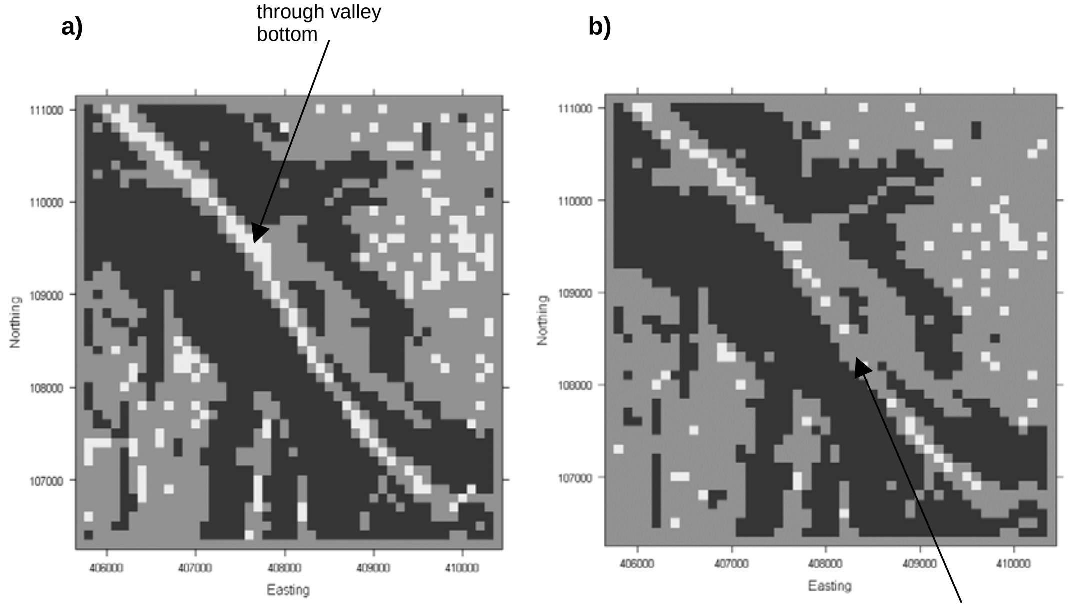


Figure 1 Maps from GSTAT showing the location of a) mean error in elevation and b) propagation of error to slope (for 12.5m DEM). Crosses mark sample site locations and elevations on contours are in metres.



Almost continuous non-susceptible area through valley bottom

Broken line of non-susceptibility though valley bottom

Figure 2 Fuzziness in defining cells as susceptible; darkest cells = 1 susceptible, lightest cells = 0 not susceptible, other = 0.5 undecided; a) 12.5m DEM; b) 25m DEM

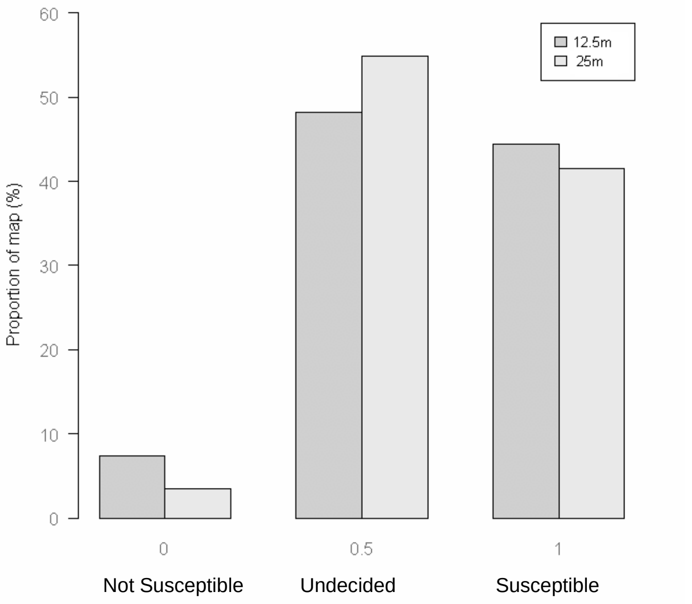


Figure 3 Barplot produced in GSTAT showing the percentage of cells in each of the three classes

4. Conclusion

The methodology developed here provides an instrument for error quantification, demonstration of propagation, and visualisation that is a simplification on existing techniques. Publicly available software has been used to facilitate a universally distributable and pliable tool. On the basis of this study a fuzzy framework proved to be the most useful approach for highlighting the consequences of using different DEMs for landslide hazard assessment. The existing code for stages 1 to 3 of the methodology could be used for any application. Following minor modifications, the work could be integrated into fitness for use assessment, risk management studies and cost benefit analyses etc. The necessity of user expertise was successfully minimised but it is obligatory for the user to have a general understanding of uncertainty analysis and variogram modelling. Uninformed interpretation of these aspects could add a further dimension to error propagation.

5. Acknowledgements

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Commuting in Northern Ireland: Exploring Spatial Variations through Spatial Interaction Modelling

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1. Introduction

This paper is concerned with spatial variation in commuting flows and their relations with other variables across Northern Ireland (NI). Knowledge about such patterns is of interest in setting the context for employment policy (Blumenberg and Shiki, 2004) as well as in understanding more about the spatiality of everyday life. The analysis is based on a spatial interaction model used to relate flows between wards to a variety of potentially important explanatory variables. Spatial variations in residuals from the model are explored, and potential ways of developing the model and alternative approaches are suggested.

Previous research has explored spatial variations in commuting in NI using data (reported in wards) from the 1991 Census of Population. This research assessed the relations between mean commuting distance per ward and other variables including the degree of deprivation (using the Robson Index of Multiple Deprivation), the percentage of households with no car, the number of people in SOC (Standard Occupational Classification) groups 1 to 3 and the percentage of residents who were Catholic, among other variables (Shuttleworth and Lloyd, 2005; Lloyd and Shuttleworth, 2005). The relations between these variables were assessed using global regression, moving window regression (MWR) and geographically weighted regression (GWR). The present analysis employs a different methodological framework to explore other aspects of ward-to-ward travel-to-work patterns in NI. It also makes use of spatial interaction data (flow data), rather than area based counts used previously. Firstly, flows are explored using the FlowMapper routine of Waldo Tobler[1], although the results are not presented here. Secondly, a Poisson gravity model, defined below, is used to explore the relations between the number of people commuting between wards and a set of other variables.

2. Data and methods

The main component of the analysis is a gravity (spatial interaction) model, used to model movement of workers between wards. Both data and the model applied are detailed below.

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[1] http://www.csiss.org/clearinghouse/FlowMapper/

2.1 Data

The analysis makes use of flow data provided as an output from the 2001 NI Census of Population. The variables used are (i) flow between wards, (ii) the number of workers resident per origin ward, (iii) the number of jobs per destination ward and (iv) the road distance between wards. In addition, a religion variable specified as the absolute difference between the percentage residents in the sending and the receiving wards who are Catholic (by community background, i.e., religion or religion brought up in) is generated. Note that the Protestant case is almost the inverse as the numbers of people who list their community background as either another religion or 'no religion' is proportionately small.

2.2 Spatial interaction modelling: the Poisson gravity model

A widely-used approach to spatial interaction modelling is to calibrate the model using log-linear regression (Haynes and Fotheringham, 1984; Fotheringham and O'Kelly, 1989). Flowerdew and Aitkin (1982) demonstrate several limitations of such an approach, and propose the use of Poisson regression to help overcome some of the problems they identify. Given that the number of people moving from one place (*i*) to another (*j*) must be a nonnegative integer, the Poisson distribution is appropriate. For a Poisson distribution with a mean λ_{ij}, then the probability that *k* people moved is given by:

$$\Pr(n_{ij} = k) = \frac{e^{-\lambda_{ij}} \lambda_{ij}^{k}}{k!} \tag{1}$$

It is assumed that λ_{ij} is logarithmically linked to a linear combination of the logged independent variables:

$$\lambda_{ij} = \exp(\beta_0 + \beta_1 \ln P_i + \beta_2 \ln P_j + \beta_3 \ln d_{ij}) \tag{2}$$

where P_i and P_j are the populations of zones i and j. The logarithmic link function means that it is unnecessary to log the number of the number of individuals who have moved (Lovett and Flowerdew, 1989). The model was implemented using S-PLUS® software.

3. Results

Two models were specified. Firstly, a model with the dependent variable flow between wards and independent variables number of workers resident per ward (RESTO), number of jobs per ward (WRKTO) and distance between wards (DIST). The second model comprised, in addition to the independent variables described above, the religion variable (REFDF) described in Section 2.1. The models have null deviance 4254829 on 338723 degrees of freedom. The coefficients for model 1 are given in Table 1, and those for model 2 are given in Table 2. Model 1 has residual deviance 1,206,890 on 338,720 degrees of freedom and model 2 has residual deviance 1,110,044 on 338,719 degrees of freedom.

	Value	Std. Error	t value
Intercept	-1.517	0.020237	-74.981
LOG DIST	-1.331	0.000807	-1648.130
LOG RESTO	0.143	0.002820	50.838
LOG WRKTO	0.769	0.000991	776.667

Table 1. Model 1 coefficients.

	Value	Std. Error	t value
Intercept	-2.830	0.020970	-134.943
LOG DIST	-1.123	0.001048	-1071.620
LOG RESTO	0.233	0.002861	81.525
LOG WRKTO	0.815	0.001005	810.584
LOG RELDF	-0.107	0.000340	-313.758

Table 2. Model 2 coefficients.

The signs of model 1 (Table 1) are as may be expected. That is, the coefficient for distance is negative, indicating that flows become smaller as the distance between wards increases. The sign of the coefficient for the number of workers resident per ward (RESTO) is slightly positive, as the number of flows increases with an increase in the number of workers resident per ward. The coefficient for number of jobs per ward (WRKTO) has a larger positive value, indicating that large flows correspond to more jobs per destination ward. The coefficients for the common variables in model 1 and 2 have the same signs. The coefficient for the religion variable (RELDF) in model 2 is negative, indicating that as differences between sending and receiving wards by community background decrease, worker flows increase, other factors in the model being equal. This is interesting given the extensive literature on the possible effects of the religious ‘chill factor’ in NI (see, for example, Smith and Chambers, 1991), and will be explored further in future work.

	Flows	Model 1 pred.	Model 2 pred.	Model 1 error	Model 2 error
Min.:	0	0.0124	0.0141	-1678.6950	-1576.9550
1st Qu.:	0	0.1861	0.2219	0.1374	0.1652
Mean:	1.9836	1.9836	1.9836	0.0000	0.0000
Median:	0	0.3641	0.4224	0.2761	0.3227
3rd Qu.:	0	0.8354	0.9248	0.5806	0.6556
Max.:	1727	2652.2470	5896.9090	2068.2470	5312.9090
Std. Dev.:	15.7124	15.6687	21.8352	14.3274	18.7486
Skewness:	23.6236	50.1388	102.2684	6.7590	97.3740
Kurtosis:	1028.659	4995.6630	19847.7100	3012.9370	23096.6700

Table 3. Summary of flows, predicted flows and prediction errors. Pred. is prediction, Qu. is quartile.

Table 3 summarises the residuals from models 1 and 2. The addition of the religion variable increases the size of the errors and this is perhaps counter-intuitive. One possible explanation is that, while religion may have an important influence on work flows overall, the relationship is not straightforward, and it may not be an important factor for all places, workers, or employment sectors. Figures 1 and 2 show, respectively, the residuals from estimates made by each model of total flow into each ward. In both cases, the marked over-estimation of total flows in urban areas is apparent. There are some instances of marked under-estimation of total flows, including the Aldergrove ward (the location of Belfast International Airport), to the east of Lough Neagh. An obvious next step is to account for urban/rural differences, and various approaches are being explored.

Shuttleworth and Lloyd (2005) and Lloyd and Shuttleworth (2005) demonstrated the marked spatial variation in relations between average commuting distances and a range of other variables in 1991 in NI. The inadequacy of a global regression model was highlighted, and the value of local regression approaches such as GWR was stressed. In the present research, the global model clearly fails to explain much of the variation in commuting flows. While the addition of further explanatory variables may improve the explanatory power of the global model, it is likely that significant spatial variations in the residuals from such an expanded model will remain, and that such variations are due to more than simply model misspecification. The paper will therefore assess spatial variations in flows by applying origin and destination specific gravity models. Nevertheless, the preliminary analysis presented here has enabled some initial ideas to be developed about the factors influencing ward-to-ward flows of workers in NI. It seems clear that there is much room for increasing the explanatory power of the model and the spatial patterns revealed by the residuals suggest some possible approaches.

4. Conclusions and future work

The analyses of interactions between wards presented in this paper are limited to the use of an unconstrained Poisson gravity model. Additional work will extend to other models. These will include various origin and destination specific models to allow the assessment of locational variations of commuting flows. More specifically, the potential benefits of applying variants of such models, as detailed by Nakaya (2001), will be explored as part of future work.

5. Acknowledgements

The Northern Ireland Statistics and Research Agency (NISRA) are thanked for the provision of 2001 Northern Ireland Census of Population data. The ward-to-ward road distances were calculated using data provided by NISRA.

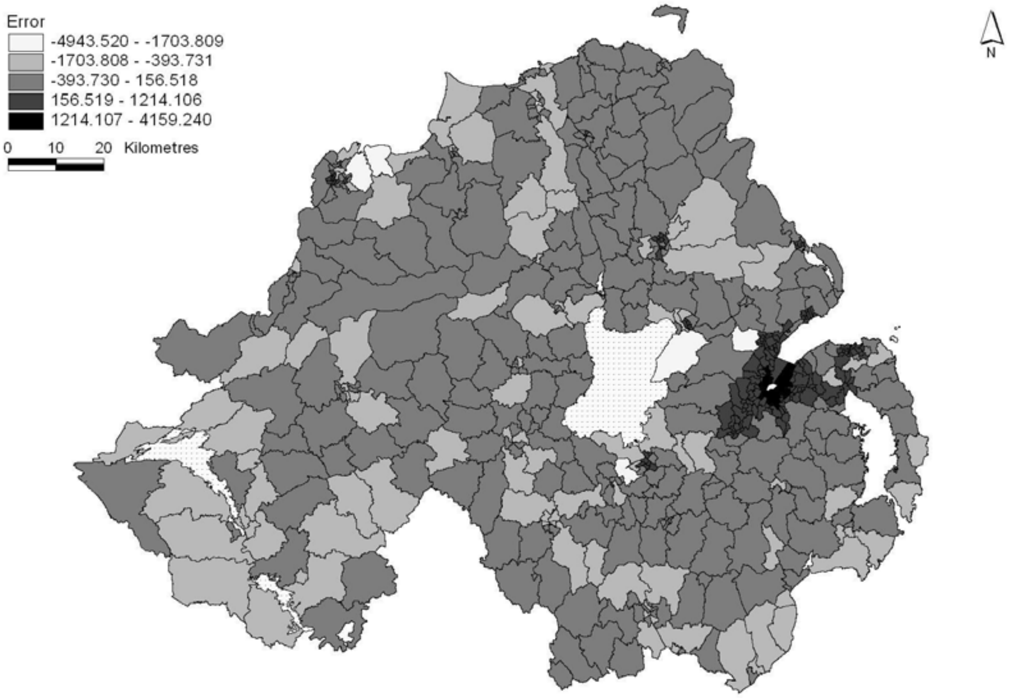

Figure 1. Model 1: estimated total flow into wards minus observed total flow into wards. NI Census of Population data — © Crown Copyright. Reproduced under the terms of the Click-Use Licence.

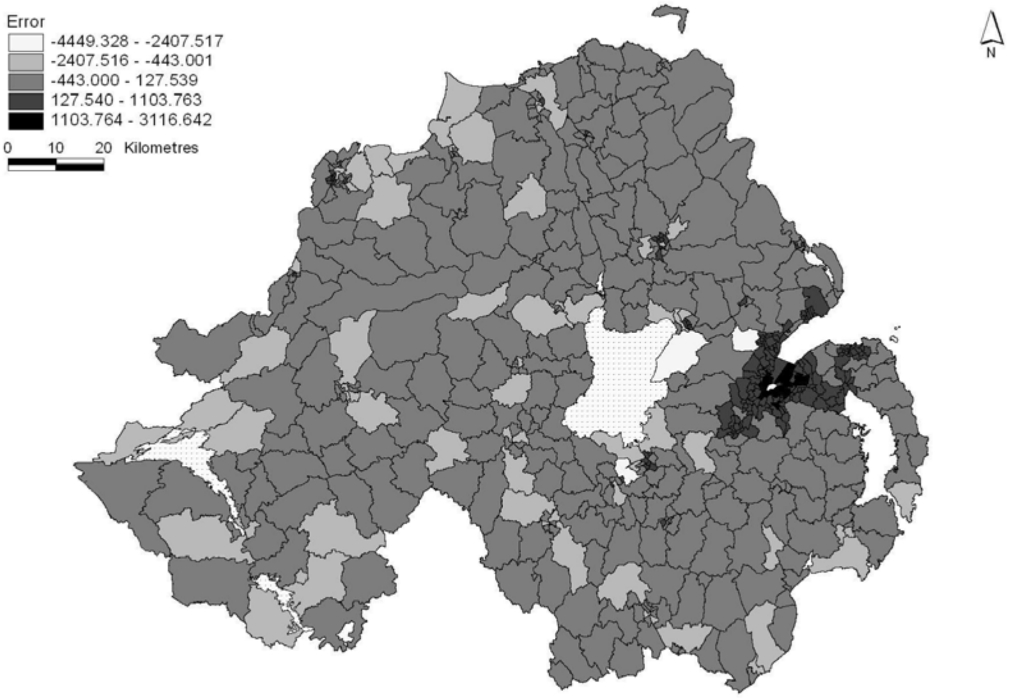

Figure 2. Model 2: estimated total flow into wards minus observed total flow into wards. NI Census of Population data — © Crown Copyright. Reproduced under the terms of the Click-Use Licence.

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Biography

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Measuring Pedestrian Accessibility

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1. Introduction

Accessibility analysis has an increasing role in policy making and evaluation, particularly for policies targeted towards social exclusion. In the UK, local transport authorities are required to undertake accessibility planning and to develop accessibility strategies as part of the Local Transport Plan (LTP) process. Accessibility measures are useful in helping to identify groups of people and locations with poor levels of access to services and facilities, for policy formulation and for monitoring progress.

This paper describes work, currently being undertaken as part of a programme of research looking at Accessibility and User Needs in Sustainable Urban Environments (AUNT-SUE), to develop a GIS-based tool (AMELIA) for assessing the extent to which transport policies address the needs of the socially-excluded. AMELIA includes the availability of the mode of travel, trip purpose, socio economic differentiation, travel time and travel cost. As part of the design process for AMELIA, methods of accessibility measures are being explored and this paper discusses pedestrian accessibility measures along with their data requirements.

2. Accessibility measures

There are many different measures of accessibility that vary in terms of detail, parameters and perspectives. These measures have been reviewed elsewhere (Geurs and Eck, 2001; Geurs and Wee, 2004; Halden et al, 2005). Opportunity measures describing the level of accessibility to spatially distributed activities, such as the number of people within 30 minutes travel time of a destination or the number of jobs within 30 minutes travel time from an origin, are widely used in practice in the UK (Department for Transport, 2004). There are several reasons for this: the measures rely on available data or data that could be easily collected; they can be easily implemented in a GIS, and hence the measures and results can be better visualized and hence easily understood and interpreted by planners and policy makers. Such tools are available (Mackett and Titheridge, 2004), many based on GIS, in particular Accession (2006), which is the software commissioned by UK's Department for Transport to help planners carry out such measures.

However, the tools and methods have been applied at a macro-level and tend to be focused on motorized transport modes such as cars and public transport from transport access points rather than the complete journey. Where attempts have been made to include the whole journey, pedestrian access and egress tends to be dealt with rather crudely, using either a crow-fly buffer around the transport access point, or by representing the pedestrian network using road centre line data. Road centreline data are currently available from Ordinance Survey probably the most common being the Landline plus data and the new Mastermap product – ITN (Integrated Transport Network). The ITN road centreline data includes pedestrian only tracks and paths, but does not differentiate footways on each side of the carriageway. Hence pedestrian accessibility measurements to transport access points and destinations are simplified and may not be suitable when measuring for certain groups of people such as the elderly and wheel-chair dependent. The main reason for this is the lack of availability of pedestrian network data of footways and crossings. A database has been set up for the city of St Albans in the UK, as part of AMELIA work, as explained in Section 3 with methods for measuring pedestrian accessibility discussed in Section 4.

3. Data

Detailed micro-level data that influence pedestrian accessibility has been collected on the street. Data were collected on the following: buildings, characteristics of the footway, road crossings, bus stops and car parks. The aim is to collect data on all the physical barriers to walking for reaching a destination. Data collected on footways include obstacles to movement, width, the material, and its condition, and the gradient where it was steep enough to pose a possible problem. Data collected on road crossings include the location, the width of crossing, the width of the island, if there is one, the type of crossing, and dropped kerb gradients. Such micro-level data were also collected for transport access points such as bus stops and car parks and for destinations.

Based on the above data a GIS database was compiled for St Albans using the digital data from the Ordnance Survey Land-Line Plus data as the base. Using the footways and crossing data collected, a detailed pedestrian network layer of link-node structure was created by manually digitizing the pavements and crossings using the Land-line data as a backdrop. The links representing footways and crossings were used to store the respective attribute information collected, which could be modelled for network analysis purposes such as the cost of traversing a particular link or as a barrier.

4. Methods

The simplest way of performing a location based or opportunity measure in GIS would be to generate a buffer based on crow-fly distance and find the number of either people or destinations contained within it. This has been used as an approximate measure mainly for walking when pedestrian network data are not available. With the setting up of the St Albans database consisting of a detailed pedestrian network, more accurate network based measures that reflect the actual distance and factors representing travel impedances or barriers could be analysed. Three different methods to measure opportunities based on network distance have been considered:

a) Service area method

b) Network buffer method

c) Network method

Method (a) typically generates a polygon indicating bands of travel time or distances. (Figure 1). These bands are generated using the pedestrian network distance, with the edges of band representing lower and upper limits of distance specified by user. The procedures and options for constructing such areas varies between GIS software packages, and may or may not allow zone construction procedures to be defined (Smith et al.,2006). Similar polygon bands representing travel time contours called as 'isochrones' are used in many accessibility planning tools (London Transport, 1999; Robins 1999; Accession, 2006). This type of polygon generation are more suitable for macro accessibility analysis such as by car, wherein assumption of walking distance off-road or minor roads have been made. However, for measuring pedestrian accessibility particularly along networks of footways and crossing with attributes to consider physical barriers, this method may not be suitable. Note that Figure 1 includes destinations along footways that are not accessible. Since all the pedestrian walkways are included in the data, there is no other way those building could be accessed. Hence this method may result in over-estimating the destinations accessible by pedestrians.

Figure 1. Service area method

Method (b), instead of generating polygons, just uses the network that could be accessed and buffers them to measure the destinations that are accessible (Figure 2). While this method is better in terms of not including areas or destinations where there are no accessible footways, the width to be buffered proved sensitive. The reason being that the widths of footways and streets vary and hence the buffer could not be applied uniformly. If the width of buffer is chosen very small say 5m, destinations with bigger offsets from the footways are not measured. Also, in some wide pedestrian-only streets, modelled as a single footway, the destinations, though accessible, may not be included in the buffer. If it is increased to compensate, say to 7 or 8 m, destinations on the opposite side of the footway may be included in the buffer for narrower streets. This factor becomes critical when measuring for users who use wheel chairs or elderly. Hence this method may result in over or under-estimates of the number of destinations which are accessible depending on the street characteristics of the area such as layout, width.

Figure 2. Network buffer method

Method (c) does not rely on overlaying techniques to measure the destinations accessible. Instead of generating service area polygons or buffer, it just uses the network directly. This is achieved by generating dummy links from each destination to the pedestrian network modeled (Figure 3). The centroid of each building is connected to the nearest footway. This eliminates the issue of under or over estimating the number of destinations accessible as each individual destination can be reached through the network. Hence this methods measures the exact number of destinations along footways that are accessible by pedestrians, when compared with the above two methods. However, this method would require programming to automate the generation of dummy links as it may be time consuming to do it manually. Still, the links could only connect the centroid of the building to the nearest footway spatially. Hence manual editing of some links may be required considering the building entry point.

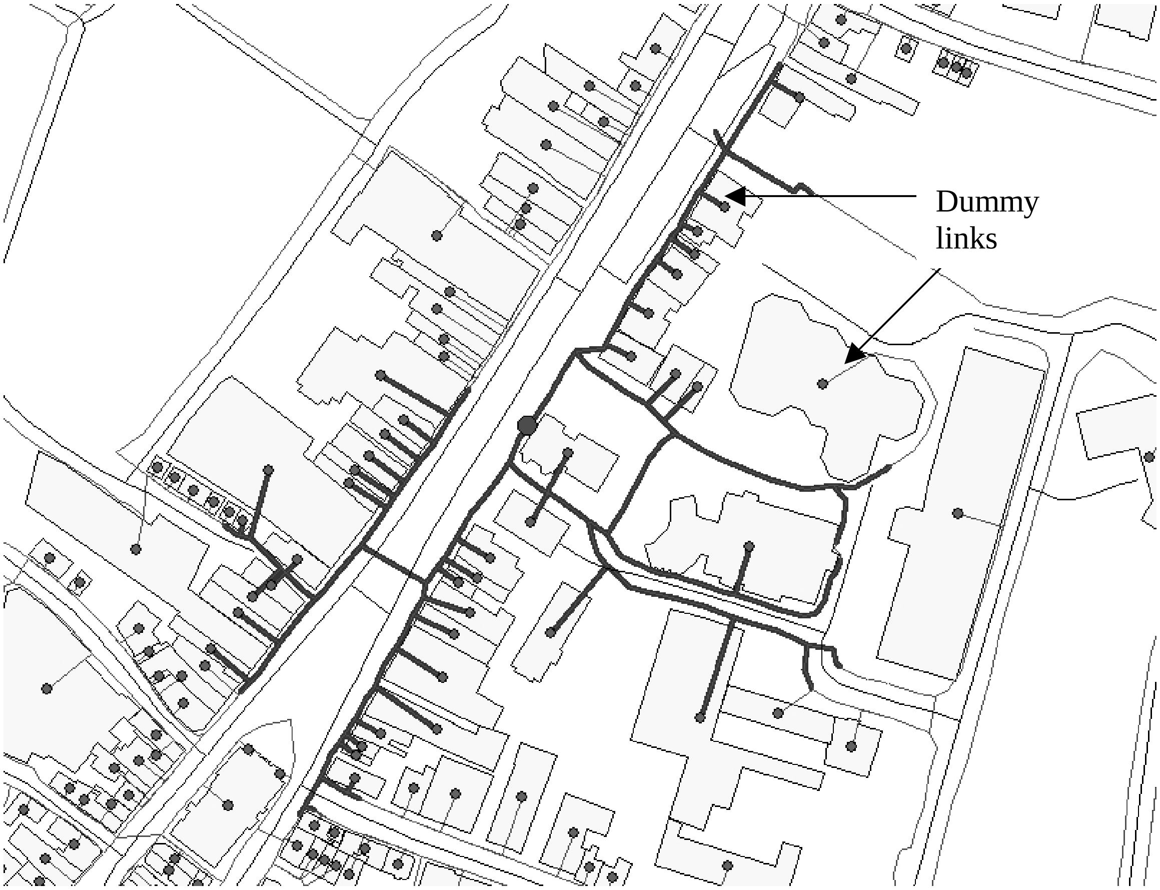

Figure 3. Network method

5. Conclusions

The paper discusses the methods of accessibility measures and problems of measuring pedestrian accessibility using existing methods. It also discusses the lack of availability of micro-level data for modelling pedestrian network and goes on to explain how these have been addressed in this project. Using a database, methods for measuring pedestrian accessibility are presented and discussed. A quantitative comparison of the methods in terms of the estimates and computation time is being carried out. The findings will be useful in informing those involved in accessibility analysis of the most appropriate methods for measuring pedestrian accessibility, whether these measures are being used solely to analyse the pedestrian environment or as part of macro-level location based accessibility measures.

6. Acknowledgements

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Kernel Density Estimation and Percent Volume Contours in General Practice Catchment Area Analysis in Urban Areas

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KEYWORDS: GIS, Kernel Density Estimation, Percent Volume Contours, Health Geography

1. Introduction

In the National Health Service (NHS) system General Practices (GP) are providers of Primary Health Services (PHSs). PHS are managed by Primary Care Trusts (PCTs) and are generally conceived as the first point of access to public health. Good provision of PHSs can avoid patient reliance upon secondary health services like Accident and Emergency (A&E) or hospitalisation – both of which tend to be much more expensive for NHS balances. The backbone of NHS policy is set out in *Patient Choice* (Department of Health, 2006), which states the right to access treatment of uniform quality where and when a patient decides. Accessibility in health policy is defined according to two main dimensions (Luo, 2004; Higgs, 2004). Social inequalities can erect barriers to equal health treatment. The effects of non physical distance upon healthcare received are sometimes compounded by physical constraints upon access to health facilities. Physical constraints may be conceived in terms of spatial accessibility (SA) of health services. Geographic Information Systems (GIS) are useful in deriving various SA to GP services, while geodemographic and lifestyle profiling can be useful in pinpointing local social inequalities in the access to healthcare.

This paper will illustrate the deployment of spatial analysis techniques in analysing spatial accessibility and assigning “core” effective demand to General Practices, based upon the experience of a Knowledge Transfer Partnership in Southwark, a borough based in south east London, UK.

2. Kernel Density Estimation and Percent Volume Contours

Kernel Density Estimation (KDE) techniques in geospatial analysis may be applied to line or point datasets with spatially extensive attributes (de Smith et al., 2007). In

Geographic Information Systems (GIS) the result of a KDE is usually a raster dataset (Longley et al., 2005) where each cell has a density value[1] that is weighted according to distance from the starting features. The user can choose the cell size of the output raster, the attribute field to be used in the calculation, its units of measure and the search radius or *bandwidth.*

Any of a range of different functions can be used to weight density values. One of the most used is a bounded quadratic approximation to the Normal distribution called the Epanechnikov function (de Smith et al., 2007) which is defined as follows:

$$\begin{array}{c} \frac{3}{4}\left(1-t^{2}\right) \text{ for } t=\frac{d}{h}\leq 1 \\ 0 \text{ for } t=\frac{d}{h}>1 \end{array} \qquad (1)$$

where *d* is the distance between the cell and the point in the dataset and *h* is the bandwidth.

Figures 1 and 2 show the kernel density estimation for a one and a two points dataset. On the left is shown a two dimensional raster (Fig. 1a and 2a), and on the right the three dimensional version where cell height values are taken from their density (Fig. 1b and 2b). Darkest colours show a higher weight to the cells closer to the points. Note how the Epanechnikov function is very similar in shape to the Normal distribution.

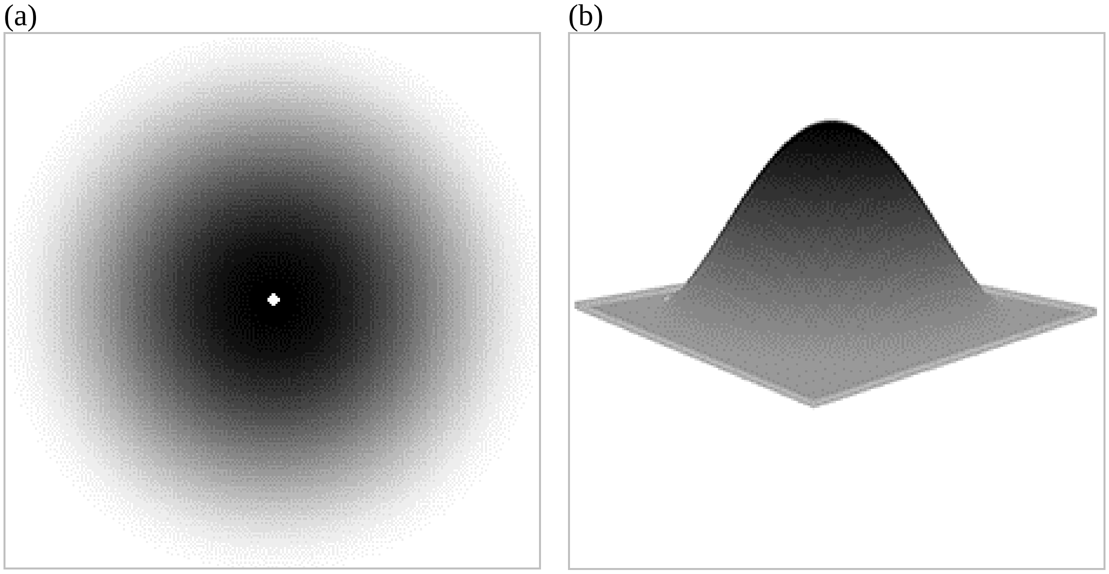

Figure 1 – Kernel Density surface and volume for a one point dataset.

When observing density values on the raster surface, it may be of interest to isolate areas that correspond to a given percentage of the total cumulative distribution. Figure 3a and 3b show the 50 *Percent Volume Contour* (PVC) for a KDE of a two points dataset. PVC is not a simple contour lines as it does not connect cells with the same value.

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[1] Density values vary according to the software used (see de Smith et al. 2006). The software used in the analysis for this paper was ESRI ArcGIS 9.1© with the Spatial Analyst© extension. Percent volume contours were calculated with a free ArcGIS extension called *Hawth's Analysis Tools* developed by Hawthorne Beyer and downloadable from the website http://www.spatialecology.com.

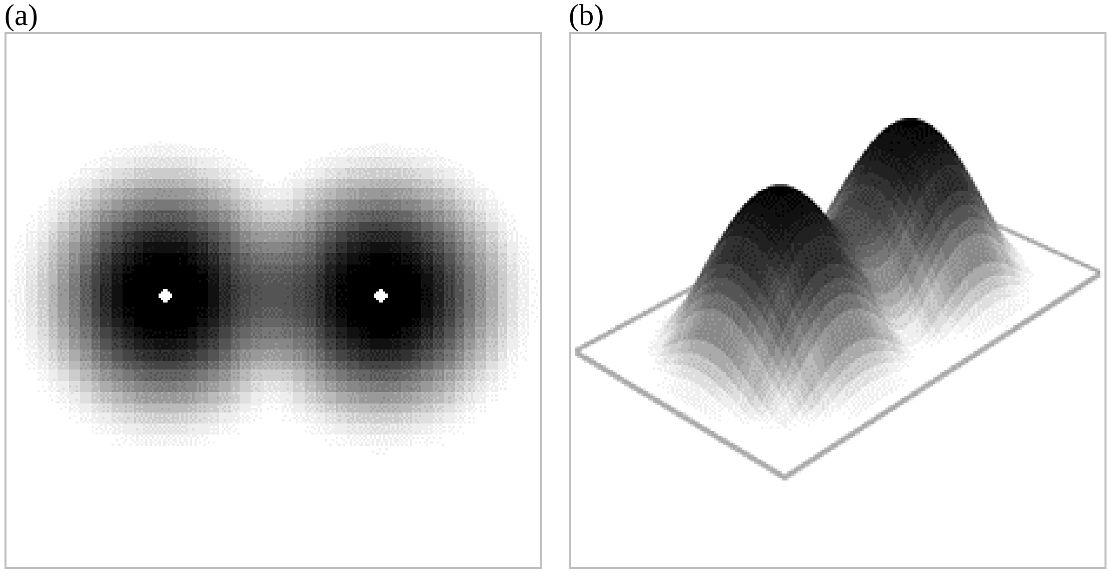


Figure 2 – Kernel Density surface and volume for a two points dataset

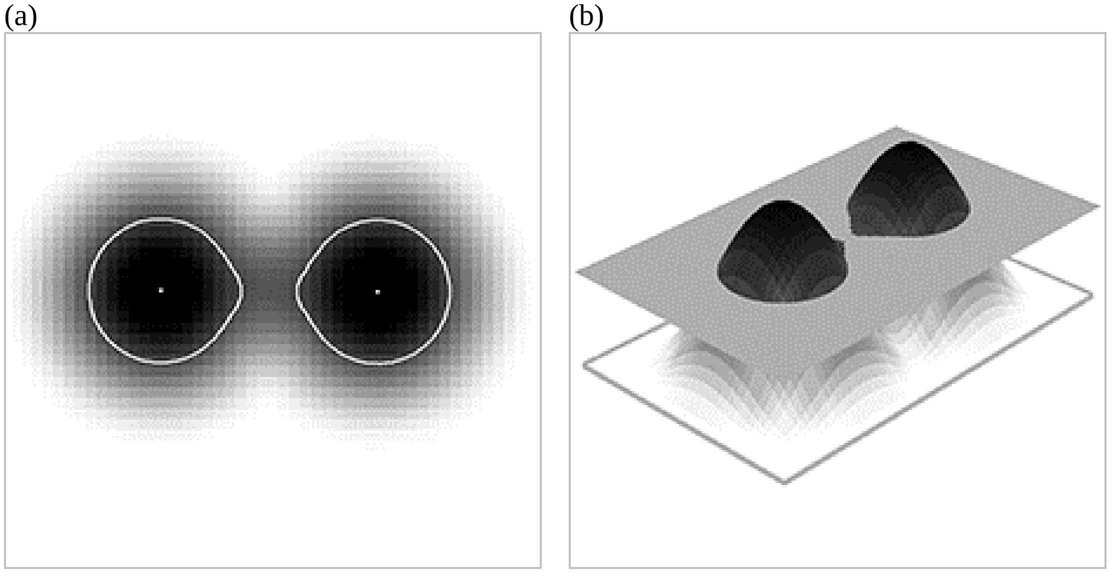


Figure 3 – 50 Percent Volume Contour for a two points dataset.

Spatial Social Sciences applications of KDE are based on spatially extensive variables (de Smith et al., 2007) such as socio-economic and health data. In the latter instance KDE is often used to measure Spatial Accessibility (SA) to health care services by comparing the densities of supply and demand in a given area (Guagliardo, 2004; Luo 2004), in order to detect uneven distributions of services as barriers of the general access and equity of treatment of healthcare mentioned above.

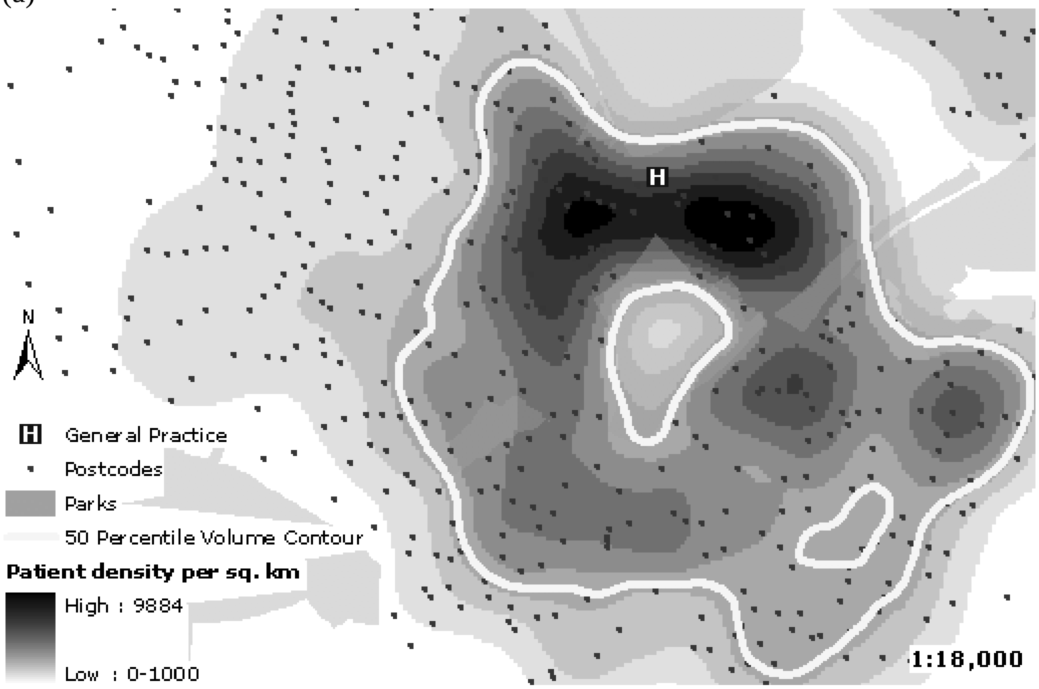
3. General practices and registered population in Southwark

Data pertaining to general practice registrations are collected at the individual level, but for dissemination purposes are often aggregated at postcode level in order to protect confidentiality. KDE techniques are particularly effective in the analysis of GP catchments areas (CAs) in urban environments because Primary Care Trusts allocate people to their closest surgeries. In the case of Southwark Primary Care Trust, the majority of patients generally live within a one mile radius of their closest surgery, although some longer distances occur when people subsequently move to another part of the Borough. Figure 4 shows the distribution of patient registrations[2] relative to a general practice in Southwark, using a point dataset and a raster with values of patient density per sq. km. The latter one is the result of a KDE applied on the postcode dataset using the attribute field containing the number of patient registered to the given GP, a bandwidth of 250 meters and a cell size of 10 meters.

If an appropriate bandwidth is chosen, the resulting surface detects the presence of physical features like roads or parks. KDE performs better than classic distance statistics and geographical dispersion measures like the standard deviational ellipse, because it takes in account the direction of distribution (Figure 4b).

A 50 percent volume contour was calculated from the KDE surface and it is shown by the thick line. Using a simple spatial query it is possible to calculate the actual number of patients registered in the 50% demand area by selecting the points falling inside the contour. These postcodes can be interpreted as the “core” CA and can be also linked with other socio-economic variables to obtain a profile of the area surrounding the GP. This is potentially very useful when targeting health campaigns

(a)



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[2] To maintain confidentiality postcodes with less than 5 people registered have been masked.

(b)

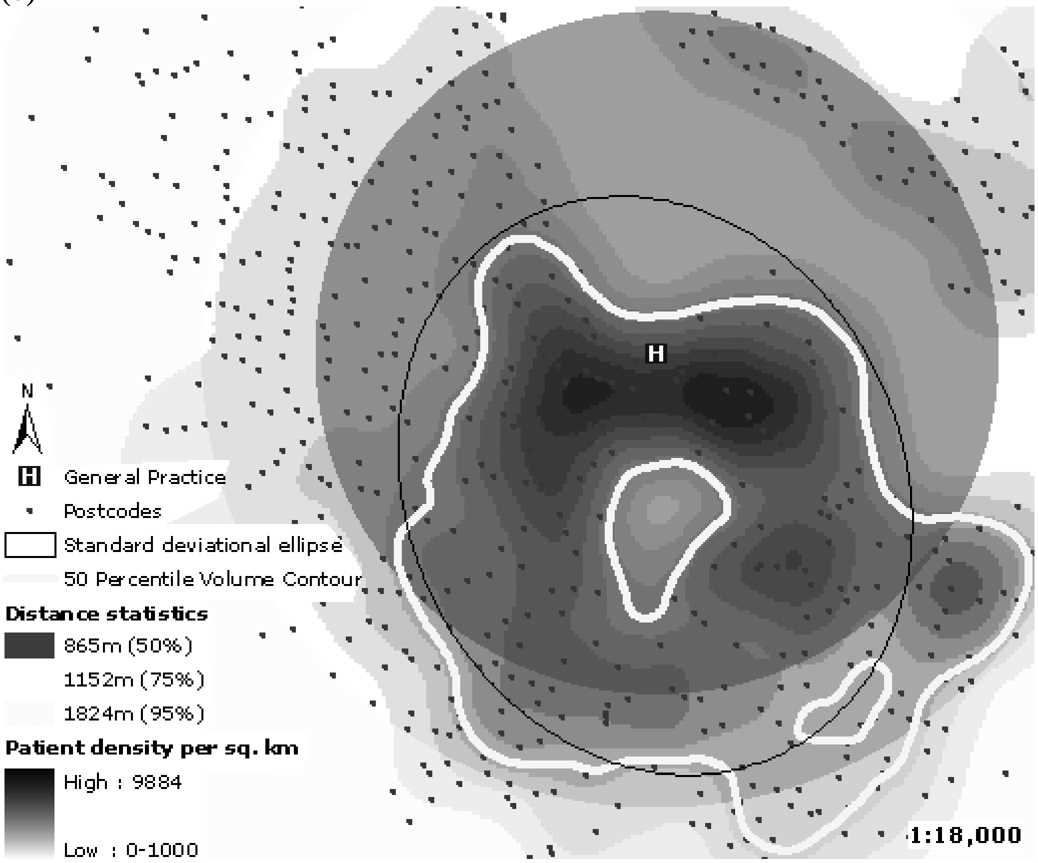
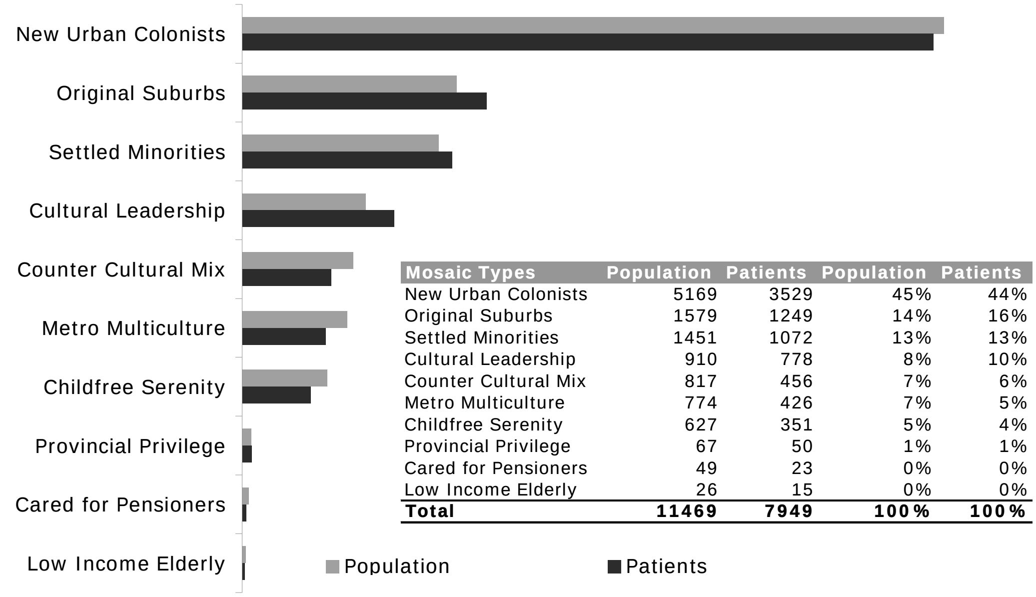


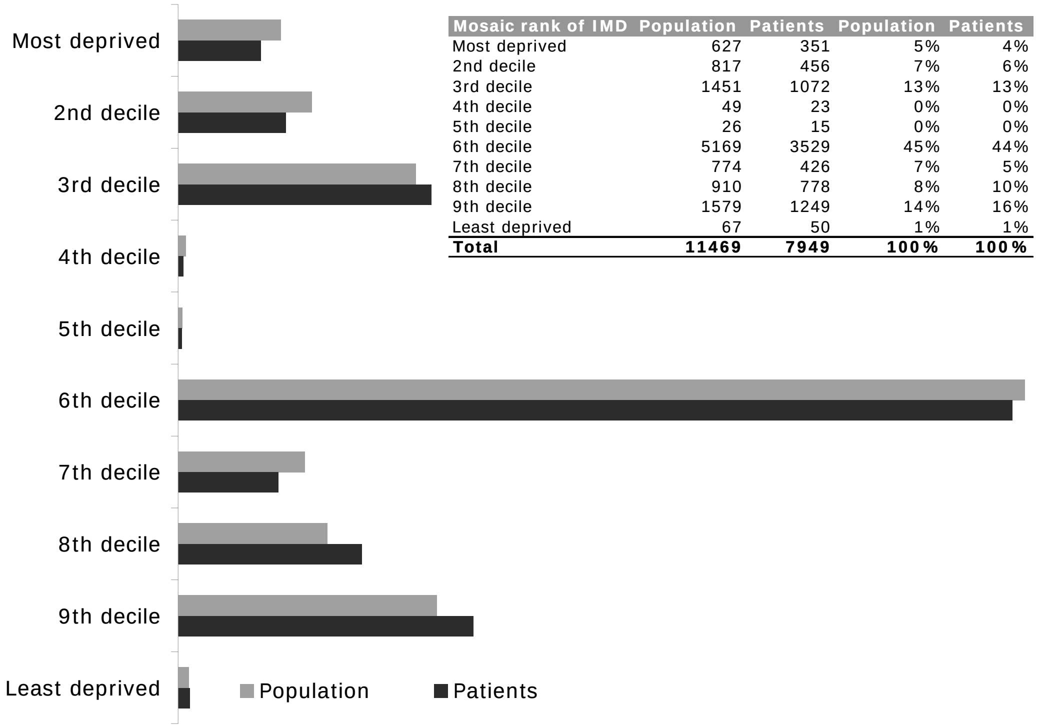
Figure 4 – Patient distribution at postcode level for a General Practice in Southwark.

(a)



Mosaic Types	Population	Patients	Population	Patients
New Urban Colonists	5169	3529	45%	44%
Original Suburbs	1579	1249	14%	16%
Settled Minorities	1451	1072	13%	13%
Cultural Leadership	910	778	8%	10%
Counter Cultural Mix	817	456	7%	6%
Metro Multiculture	774	426	7%	5%
Childfree Serenity	627	351	5%	4%
Provincial Privilege	67	50	1%	1%
Cared for Pensioners	49	23	0%	0%
Low Income Elderly	26	15	0%	0%
Total	**11469**	**7949**	**100%**	**100%**

(b)



Mosaic rank of IMD	Population	Patients	Population	Patients
Most deprived	627	351	5%	4%
2nd decile	817	456	7%	6%
3rd decile	1451	1072	13%	13%
4th decile	49	23	0%	0%
5th decile	26	15	0%	0%
6th decile	5169	3529	45%	44%
7th decile	774	426	7%	5%
8th decile	910	778	8%	10%
9th decile	1579	1249	14%	16%
Least deprived	67	50	1%	1%
Total	**11469**	**7949**	**100%**	**100%**

Figure 5 - Profile of the postcodes using the 50 percent volume contour.

Figure 5 shows the geodemographic profile of the 50% of the CA using Mosaic, a commercial geodemographic system developed by Experian. Mosaic types of registered patients have similar proportions to the underlying population distribution (Figure 5a). The predominant type is *New Urban Colonists*, characterised by young professionals living in high-density gentrified areas with easy access to the city.

In the health targeting decision-making process area deprivation plays a fundamental rule. Figure 5b shows the rank of the Index of Multiple Deprivation coded at postcode level for the 50% CA. Greatest part of the registered patients falls in the 6th decile, showing that the area surrounding the practice is not particularly deprived.

4. Conclusions

Use of surfaces and contours can improve exploratory spatial data analysis and help in communicating geographic information (GI) to the general public. Geodemographic information is particularly important for the health sector because of its correlations with health outcomes and policy performances.

PVC and KDE can be very useful in the analysis of GP registered population and can help in selecting the closest postcodes to the surgery. Postcodes profiles are a good source of information when targeting lifestyles associated with particular health conditions.

Selecting only the areas with high densities of patients can avoid issues of confidentiality in communication and data sharing. Although useful in preserving data confidentiality, KDE surfaces can lead users to believe that attributes are continuously distributed in the study area. In a cartographic representation this problem can be avoided by overlaying other sources of information in a sort of dasymetric mapping (in Fig. 4a, for example, the distribution of parks was overlaid on top of the density surface).

Optimising bandwidth remains one of biggest irresolvable problems (Brunsdon, 1995). Mathematical algorithms (Kao et al. 2002 and Silverman, 1986) can improve the selection process but are no complete substitute for personal experience and knowledge of the study area and of the attribute upon which density analysis is performed.

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Modelling Commuting Catchments in Ireland: A Hierarchical Approach using GIS.

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1. Introduction

Over recent years there has emerged an increased awareness of the importance of strategic spatial planning and of the extent to which concepts such as place and space really matter (Faludi, 2000). An enhanced understanding of the geography of living and the economy requires not only a knowledge of where people and objects are but also of how those places relate to one another to create functional spaces. This requires fundamentally sound data on movement patterns, of which the most important is probably the daily journey to work (Horner, 1999, McCabe, 2006 Pers Comm). In this paper we examine spatial modelling approaches to commuting patterns using data from the CSO 2002 Census of Population (CSO 2003a, CSO 2003b. CSO 2004a). This is a particularly apposite time to undertake this research. A number of national strategic initiatives including the next Irish National Development Plan and the current National Spatial Strategy provide a clear policy context for the study (Morgenroth and Fitzgerald, 2006). Additionally it is the specific intent of the CSO in providing this data set to stimulate geo-computational analysis and modelling. This research aims to map travel to work flows in 2002 from the 15% national anonymised individual sample (known as the POWSAR data set) and secondly to investigate the technical production of new Travel Catchments Areas (TCAs) for the state as a whole.

2. Literature Review

Sample travel to work data has been utilised in a number of developed economies to identify commuting and other economic catchments (Ball 1980, Coombes, Green and Openshaw 1986, Coombes 2002). With the advent of improved geo-computational power and the development of GIS, the Spatial Data Modelling elements of such investigations have been particularly enhanced (Longley et. al., 2005, Langford and Higgs, 2006). One of the most widely used algorithms used in the production of travel to work areas is the work of Coombes, Green and Openshaw (1986) which identified a series of Travel-to-Work areas (TTWAs) in England and Wales. The algorithm primarily focused on the notion of minimum thresholds of 75% workers living in the catchment area and an associated measure of self-containment in the commuting population. While successful in developing a single set of TTWAs, the Coombes algorithm, as it has come to be known, is limited by some of the specific conditions used within the process (Morgenroth and Fizgerald, 2006). Interestingly, the method was also used to identify eighteen separate TTWA areas for Northern Ireland (Hastings, 2004). Unpublished research by Morgenroth (Pers. Comm.) at a regional level in Ireland attempted to test the applicability of the Coombes algorithm in the West of the country. However, a number of issues arose concerning the use of the POWSAR data, especially related to small number problems and non-contiguity of the areal building blocks (Electoral Divisions or EDs) used. In both cases there are a number of ongoing problems which relate to a) the technical rule-base used in the algorithm and b) the single level at which such models operate. The research reported here attempts to re-work the original algorithm and to do so in a multi-level spatial hierarchy to get around some of the problems associated with generating a set of TCAs for the Republic of Ireland.

3. Data and Methods

Based on the 15% sample from the POWSAR dataset, approximately 220,000 individual records are available for analysis. In addition ot the home and work location, each record pertains to an anonymised individual and contains a range of demographic and socio-economic information. These include variables such as mode of travel, socio-economic group, age, gender, housing occupancy and travel and departure times.

As an initial modelling stage the proportions of the workforce in each of the 3440+ enumeration districts that travelled within prescribed distance bands were calculated and mapped. For each town along a hierarchical scale from city to large town to small town, a set of core and peripheral catchments were individually drawn. The Coombes algorithm was then used to amalgamate the individual towns and cities (employment cores) and calculate a three-level hierarchy for the country as a whole. The middle level was based on a set of urban Gateways and Hubs identified within the National Spatial Strategy to provide a form of spatial validation of the policy initiative. While the Coombes algorithm provides a single level top-down approach, the approach taken here was of a multi-level bottom up comparison and the results identified some interesting variations and problematic aspects unique to Ireland.

4. Results

The output initially identified those parts of the country that are beyond the commuting hinterlands of the Gateways and Hubs. At the smallest scale, the catchments of the major cities (Dublin plus 5 others) were plotted but were essentially unsatisfactory, incorrectly assigning large numbers of EDs, which had no real economic connection with the centre to which they were allocated. Even with the introduction of a medium scale, based on the 22 Gateways and Hubs identified in the NSS, large gaps or unallocated areas existed although the continuity of the surface was stronger when compared to the 6-centre solution. Figure 1 below identifies the largest scale analysis of TCAs in 2002 and clearly identifies 43 different centres at this scale.

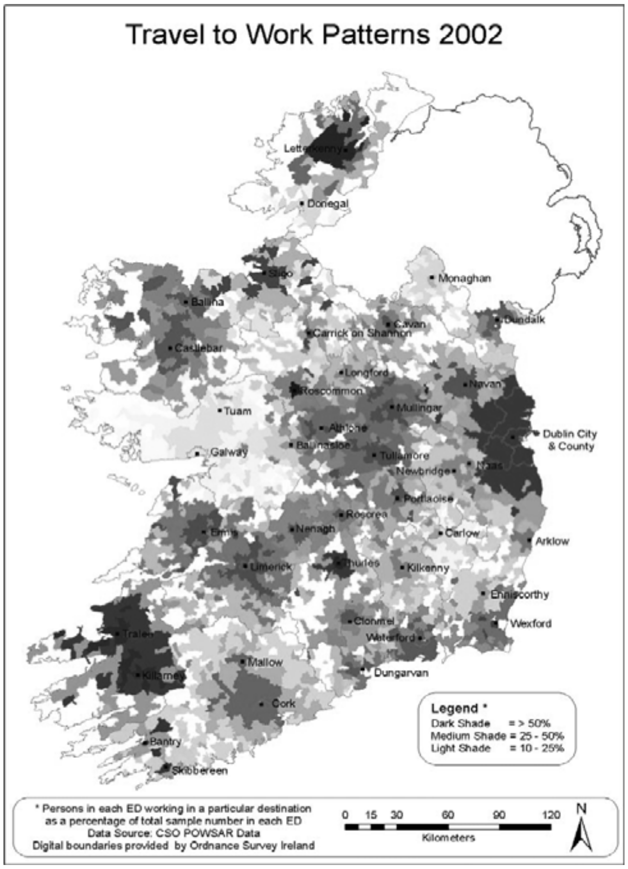

Figure 1. Draft Travel Catchment Areas (TCAs)

5. Discussion and Conclusion

Based on the modelling some doubt was cast on the appropriateness of a number of the hubs; there were also a number of areas identified as not being within the hinterland of either a Gateway or a Hub. The scale of analysis was partially responsible for the anomalies, as was the use of sample data. The particularly heterogeneous nature of EDs in Ireland presented some difficulties in running the algorithm due to small number problems in rural areas and also clustering problems in urban areas, where a number of quite different work locations within individual EDs threw up a number of anomalies. We conclude by identifying some policy implications arising from this research.

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Exploring the effect of a new railway on trips and travel as a component of personal mobility in rural West Yorkshire, 1840-1900

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1. Introduction

> John Kettlewell & me set off to Huddersfield Nov 29th and to Wakefield & was at Mr Herons all night the 29th and then to Low Moor and was all night with Dr Whitteron the 30th then home by way of Bradford Leeds & Starbeck & Knaresbro we was off about John Kettlewell's situation at Hopton they agreed Nov 29th that he was to commence on Jan 1st 1850 he came back Jan 29th 1850. (Hibbs, 1990)

While there is a wealth of literature concerning Geographical Information Systems (GIS) in solving current transportation problems, there is only a limited range of publications available on using GIS for historical research and hardly any for railway history (Gregory, 2003; Knowles, 2002). This is surprising as historians frequently use maps as a research resource and railway history draws on discussions of concepts such as space/time, line and connectivity. One obvious reason is that some researchers in the humanities can have a tendency to technophobia, with a fear or disdain of computer technology beyond word processing. It may also arise from a lack of a developed sense of spatial awareness or perhaps a lack of time to focus on learning new skills. While experienced users of GIS declare its facility, it does involve a considerable investment of time, planning and effort to produce useful results. This has clearly alienated most historians, who have featured rarely in previous presentations in the GISRUK conference series. Most historical applications appear to have been from geographers or spatial analysts.

This paper demonstrates a simple GIS application undertaken by an historian, illustrating a nineteenth century study of mobility and the impact of the railway.

There is a view that personal mobilities in rural England in the mid-nineteenth century were a relatively static and localised affair, especially before the railways had fully developed their comprehensive network (Freeman, 1999; Perkin, 1970). However George Whitehead, a wheelwright/joiner and farmer living in the small West Yorkshire village of Little Ouseburn, neatly captured above an example of the complexities of such mobilities in his diary in 1850. Short term components of mobility such as trips, visits and excursions are important, but these have featured rarely in discussions of nineteenth century mobility, which have favoured explorations of residential and social mobility, migration and emigration. While traditional sources such as census enumerators' books and parish registers provide invaluable evidence of mobility components involving permanent moves of residence, marriage and kinship for example, we are reliant on autobiographies, letters and diaries for evidence of short term travel.

Furthermore traditional approaches to railway history have tended to ignore the perceptions of large groups of people such as the rural workers in favour of a wealth of material about landowners, city dwellers, capitalists and engineers. An analysis of Whitehead's diary offers valuable contemporary evidence on a rural working class family's spatial mobility patterns, including 'hidden' forms of mobility, such as the cart and walking, at a time when the railway was offering a new option.

The focus in this paper is on the period from 1840 until the end of the century, to permit a long term analysis of rural mobility both before and after the railway came, while still unaffected by the development of the motor car or by World War.

2. Sources and methodology

This study uses a GIS tool to examine evidence on places and movements in Whitehead's diary, to allow layers of social activity in the study area to be spatially referenced.

George Whitehead was born in Little Ouseburn, in the West Riding of Yorkshire, in 1824. The village was around five miles south east of Boroughbridge, nine miles NE of Knaresborough and 13 miles NW of York. Whitehead was a joiner, wheelwright and farmer. He was clearly literate and kept a diary for over seventy years, covering the period between 1836 and 1909.

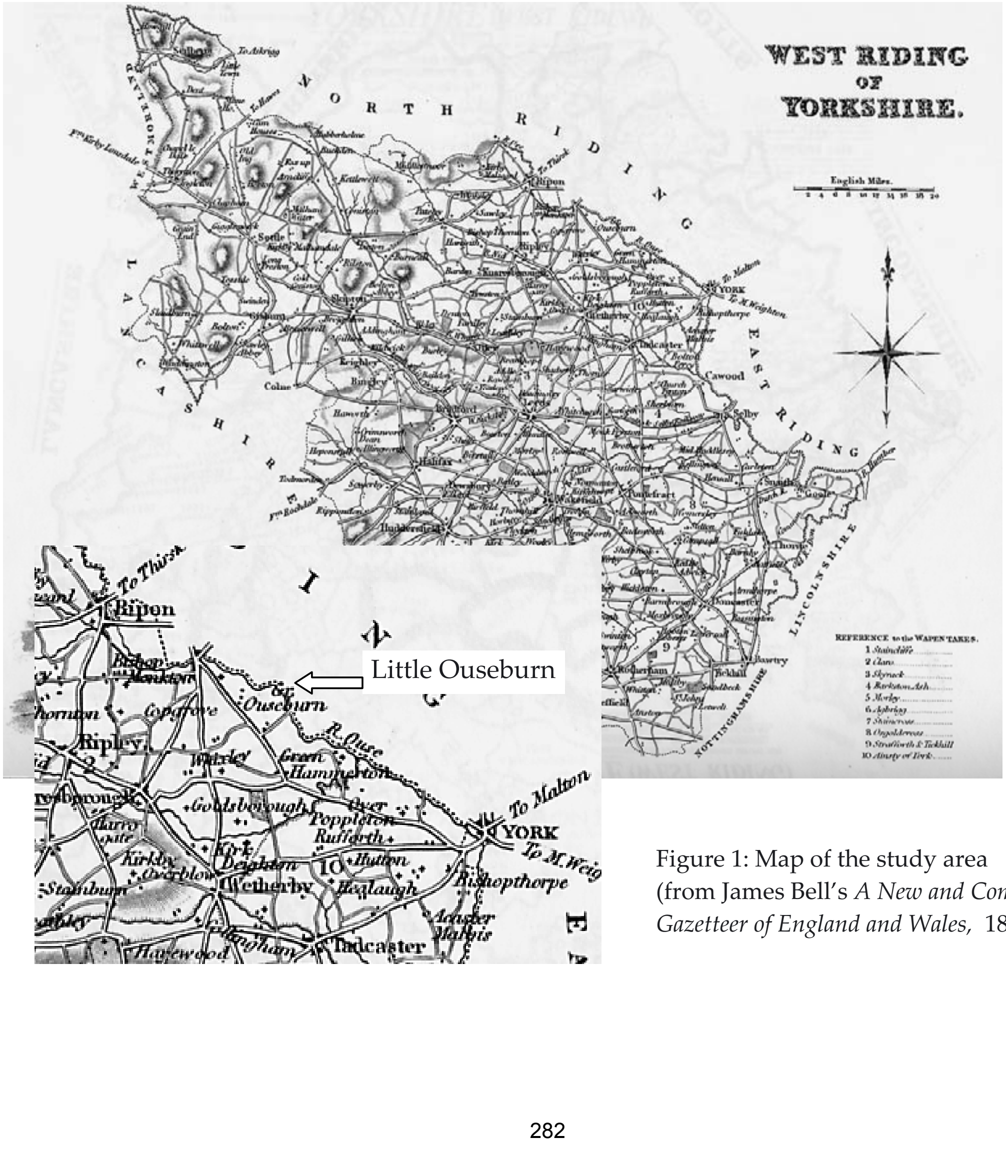


Figure 1: Map of the study area
(from James Bell's *A New and Comprehensive Gazetteer of England and Wales,* 1834.)

ArcInfo/ArcGIS 9.1 was used in this study, as it enables both visualisation and analysis, although this paper mainly demonstrates visualisation. It took advantage of Digimap Historical Ordnance Survey map data, derived from scanned images of the County Series 1:10,560 series 1st Edition 1849 -1899 sheets for Yorkshire (Digimap Historical Ordnance Survey Data, 2005). Relevant features from this base map were then digitised manually using ArcTools, creating a separate coverage for each of main roads, rivers, railway line segments and stations.

Where possible, the locations of places recorded in the diary were obtained from the Bartholomew gazetteer by linking the databases. However, there were issues relating to differences in spelling and multiple instances of some names in the gazetteer. Where a place name had multiple instances in the gazetteer, that which was closest Little Ouseburn was automatically selected, unless context indicated otherwise. Where location could not be determined in this way, other sources were consulted and the points entered manually. It was hoped to include details of trip frequency with the place names, but this proved impractical in the data format adopted. An alternative data structure using Oracle will be adopted for the next phase of this research.

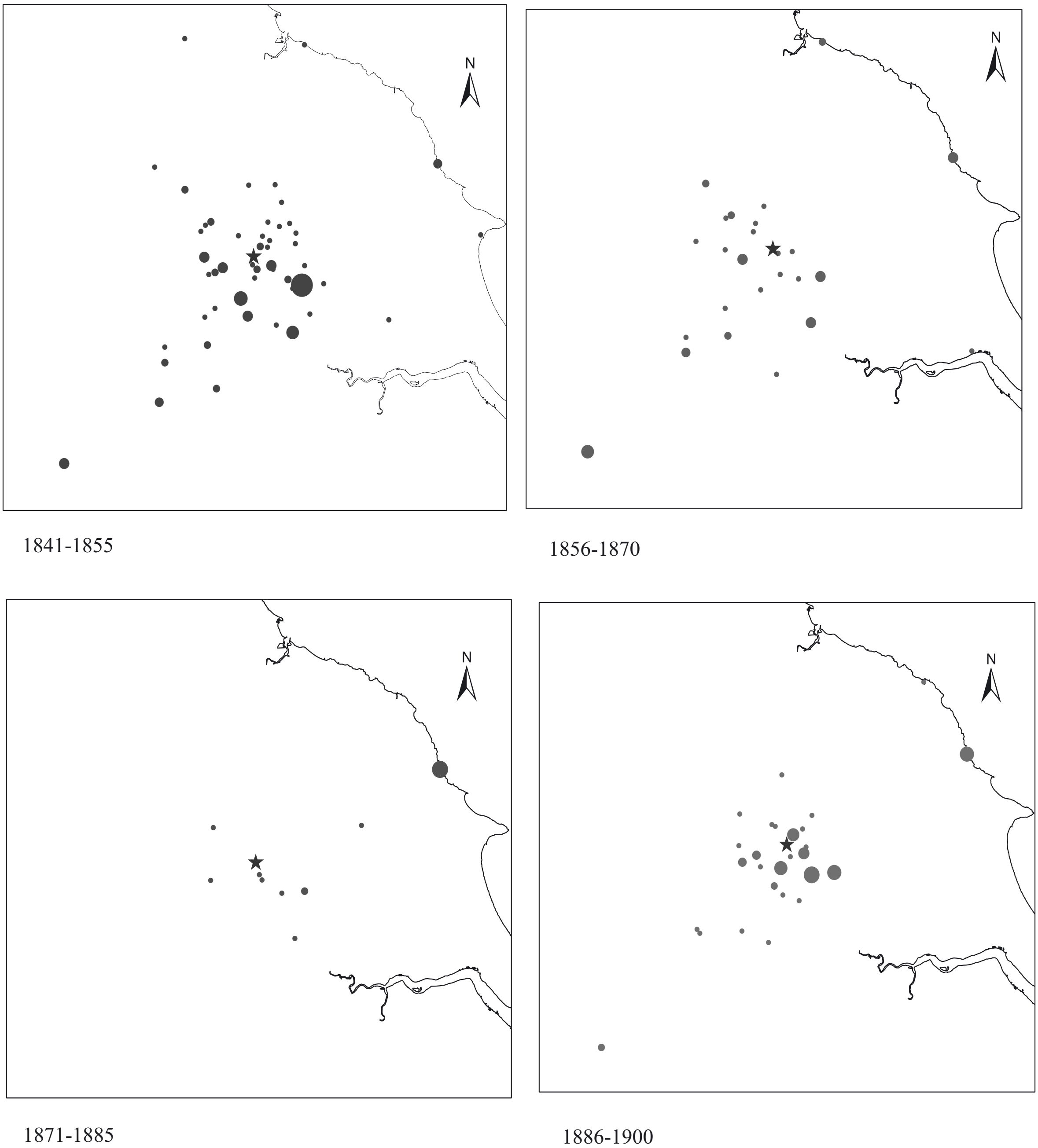
While GIS can include a temporal dimension, it cannot easily analyse or visualise space *and* time. Railway line segments and stations were given attributes in the GIS, showing when they opened to passengers, to help with the visual examination of the relationship between places visited and the availability of transport networks. One of the difficulties which this leads to, however, concerns the use of aggregation in assessing the relationship of groups of journeys by time period to lines available at a particular point in time. Accuracy would improve with increasing reductions in the span of years chosen, but to be completely accurate we would need to use a different map for each individual journey, showing the lines available at that point in time.

Future stages of this study will include the addition of attributes such as carrier routes, passenger statistics, river ferries and bridges. It might also include parish census enumeration data, using 1851 Historic Parish Boundaries from the AHDS History Data Service (Kain and Oliver, 2001).

3. Analysis

Whitehead was often accompanied by family or friends on his trips and he also records journeys made by other members of his immediate family without him. Their journeys were made for a wide variety of reasons, with many resonances to modern leisure patterns: purchasing stock, clothing and equipment, looking for work, visiting family members and friends, visiting feasts, fairs, shows, the seaside, attractions, sporting events and celebrations and trips for medical reasons.

Figure 2 shows the distribution of the places visited by the Whitehead family, using four periods 1841-55,1856-70, 1871-85 and 1886-1900. During the first period (1841-55), family travel was surprisingly widespread over the region, with a tendency to flow towards the industrial West Riding and to Manchester. This period includes a visit to London and visits to the North East. During the second period (1856-70) the travel pattern reduced very slightly, but Manchester featured slightly more. In the third period (1871-85) there was a substantial reduction in travel, apart from visits to Scarborough, almost certainly due to the lifecycle stage in Whitehead's mobility history. The last period (1886-1900) shows more travel in a closer area around the village, reflecting travel by the next generation and continuing visits to Scarborough.



1841-1855

1856-1870

1871-1885

1886-1900

★Little Ouseburn

(Size of place symbol is proportional to the number of times visited)

Figure 2: Distribution of places visited by the Whitehead family, 1841-1900

Settlements from Bartholomew data, (c)HarperCollins Publishers, used with permission.

Figures 3-6 show the area around Little Ouseburn, with constructed buffer zones indicating radii of 6,12 and 24 miles, visualising in greater detail recorded trips during each of the four time periods. Figure 3 (1841-55) shows a great number of visits, mostly within the 12 mile zone and many noticeably '*against the grain'* of the railway network, apart from York and Knaresborough, which do not feature as much as might be expected if the potential of the rail link was being taken up. Figure 4 (1856-70) shows fewer trips in total, mostly in the 12 mile zone and once again against the grain of the rail network available. Figure 5 (1871-85) shows a much reduced level of travel, at a time when Whitehead was growing older, almost all within 12 miles. Finally Figure 6 (1886-1900) shows an increase in mobility, mostly within 12 miles.

4. Results

This paper has looked at trips and journeys taken by a working class man and his family outside their normal living area. During the period 1841-1900, he recorded a total of 256 visits to places, taken either by himself or by other member of his immediate family, to other locations, covering a range of distances from Little Ouseburn. These reflect differing stages of his family life cycle, which inevitably impact upon travel patterns.

Frustratingly he rarely indicates the mode of travel for journeys, apart from special trips to Scarborough and to the Great Exhibition in 1851in London by train. The example quoted in the introduction to this paper is one of the few entries where rail travel can be directly implied because of the route. Thus the visualisation aspect of the GIS tool is helpful in guiding assumptions of likely modes of travel. His village was three miles north of the railway line between York and Knaresborough, which opened in 1848. The nearest new station was at Cattal, a small village three miles away. This linked Little Ouseburn to lines to York, Scarborough, Leeds, London and Scotland. To the east of the village ran the York, Newcastle and Berwick Railway (which had opened as the Great North of England Railway in 1841). Five miles to the north west of the village lay Boroughbridge, where the railway link to Pilmoor on the York, Newcastle and Berwick Railway line was opened in 1847. A further line from Boroughbridge south west to Knaresborough did not open until 1875.

Despite the above network of rail links developing around Whitehead's village, there is little evidence of a developing relationship between family travel and rail links. Figures 3-6 clearly show that his journeys were more efficiently made by road. As Whitehead was a wheelwright and part-time farmer the family had access to wheeled transport and horses which afforded carrying capacity for complex journeys. Interestingly there is little evidence that rivers were a barrier to mobility. The use of the GIS helps to illustrate that the places the family visited were directed by family links or were to events in rural places. Importantly these were usually 'against the grain' of the railway network, which generally linked larger market towns and cities, stopping at villages en route if they were on the line. This inevitably made train travel uneconomic in time and expense for many regional journeys.

5. Conclusions

The Whitehead family were surprisingly mobile even in the 1840s. Their level of travel mobility appeared to decrease with age rather than increasing with new forms of transport. From the evidence it appears that the family made use of the developing train network on very few occasions, favouring roads and wheeled transport.

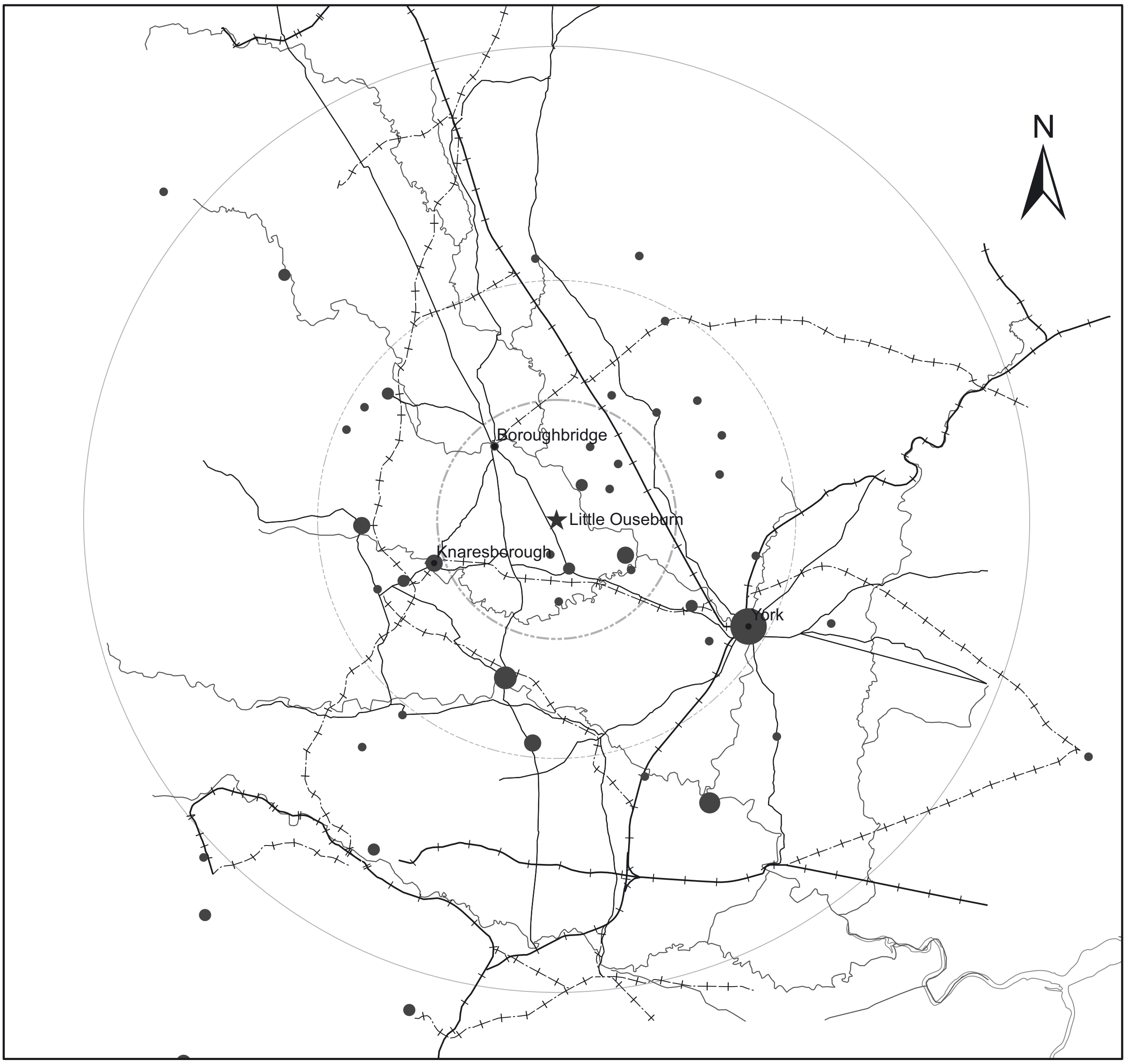


Figure 3. Places visited by the Whitehead family within a 24 mile radius of Little Ouseburn, 1841-55

Key

____ Rivers

____ Main roads

6 mile zone around Liitle Ouseburn

12 mile zone around Little Ouseburn

24 mile zone around Little Ouseburn

Places visited 1841-55

● 1 ● 5 ● 10

—+— railwaylines open by 1846

-·+-+ railwaylines open 1846-55

0 3 6 12 Miles

Settlements from Bartholomew data, (c)HarperCollins Publishers, used with permission. Railway lines, roads, rivers and stations are digitised from the AHDS HDS Historic Parish Boundaries data: Roger J. P. Kain and Richard R. Oliver, 2001, Historic Parishes of England and Wales, Colchester, History Data Service.

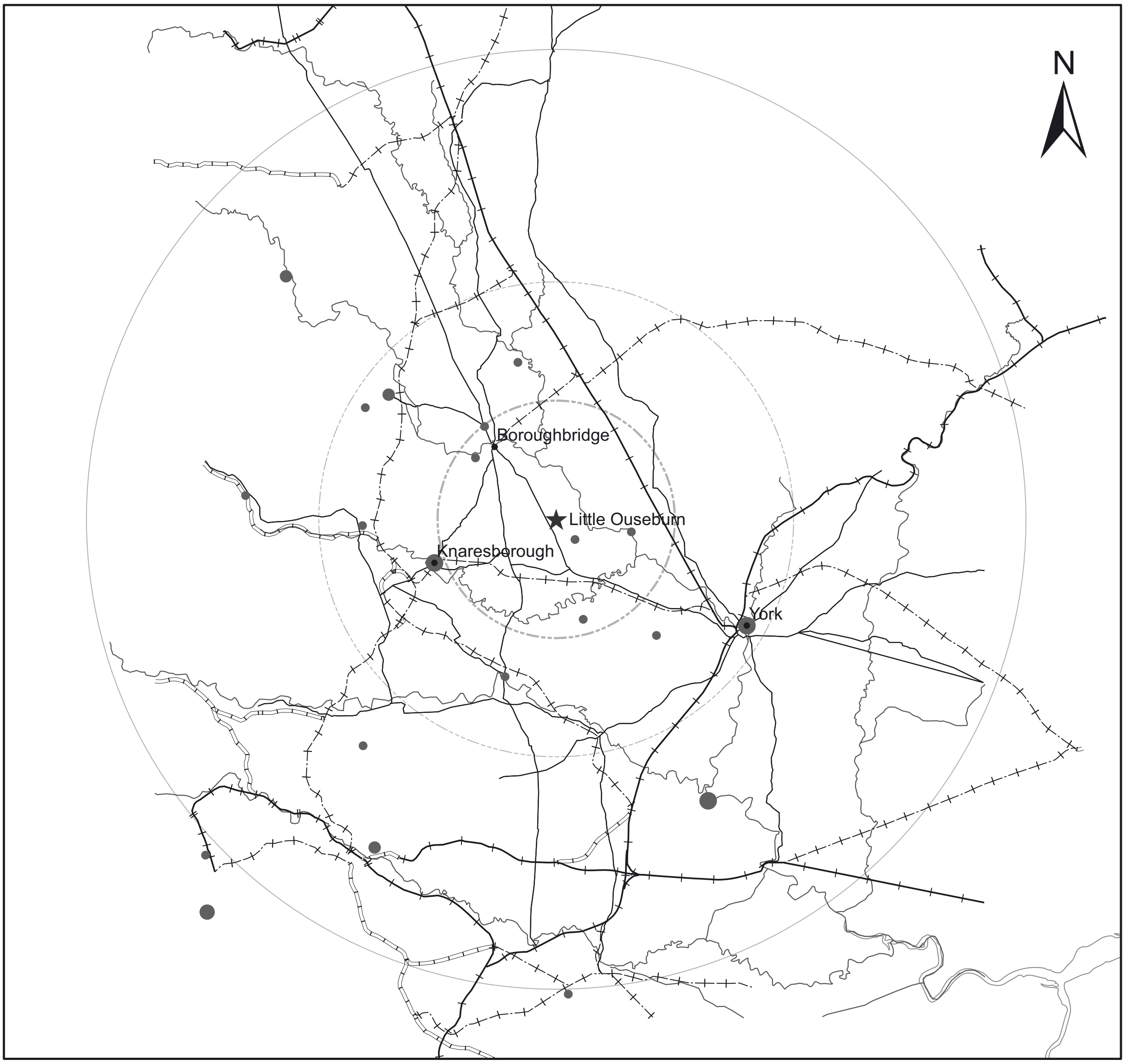


Figure 4. Places visited by the Whitehead family within a 24 mile radius of Little Ouseburn, 1856-70

Key

—— Rivers

—— Main roads

6 mile zone around Liitle Ouseburn

12 mile zone around Little Ouseburn

24 mile zone around Little Ouseburn

Places visited 1856-70

● 1 ● 5 ● 10

railwaylines open by 1846

railwaylines open 1846-55

railwaylines open 1856-70

0 3 6 12 Miles

Settlements from Bartholomew data, (c)HarperCollins Publishers used with permission. Railway lines, roads, rivers and stations are digitised from the AHDS HDS Historic Parish Boundaries data: Roger J. P. Kain and Richard R. Oliver, 2001, Historic Parishes of England and Wales, Colchester, History Data Service.

Figure 5. Places visited by the Whitehead family within a 24 mile radius of Little Ouseburn, 1871-1885

Key

Rivers

Main roads

6 mile zone around Liitle Ouseburn

12 mile zone around Little Ouseburn

24 mile zone around Little Ouseburn

Places visited 1871-85
● 1
● 5
● 10

railwaylines open by 1846

railwaylines open 1846-55

railwaylines open 1856-70

railwaylines open 1871-85

0 3 6 12 Miles

Settlements from Bartholomew data, (c)HarperCollins Publishers, used with permission. Railway lines, roads, rivers and stations are digitised from the AHDS HDS Historic Parish Boundaries data: Roger J. P. Kain and Richard R. Oliver, 2001, Historic Parishes of England and Wales, Colchester, History Data Service.

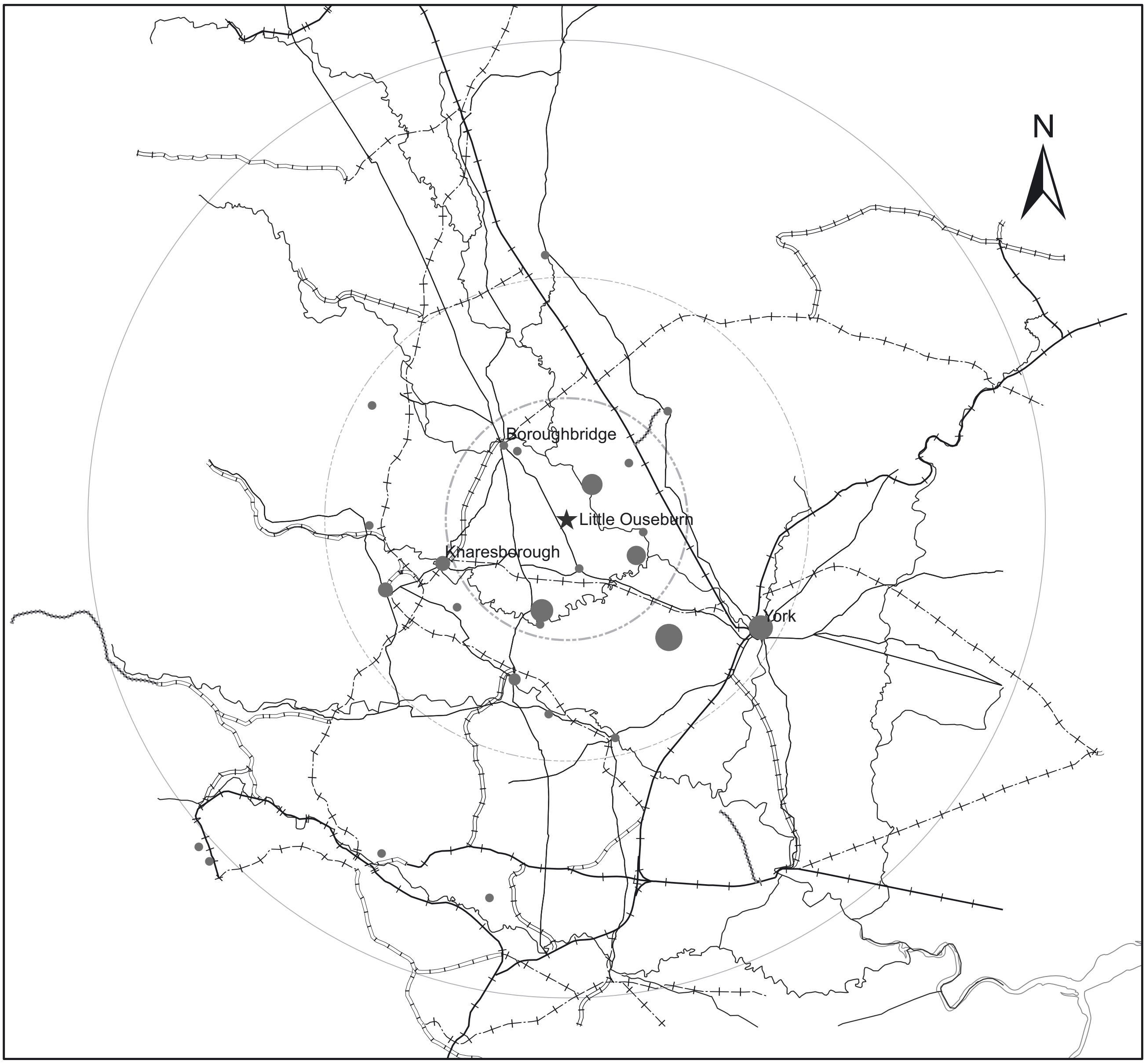


Figure 6. Places visited by the Whitehead family within a 24 mile radius of Little Ouseburn, 1886-1900

Key

Rivers

Main roads

6 mile zone around Liitle Ouseburn

12 mile zone around Little Ouseburn

24 mile zone around Little Ouseburn

Places visited 1886-1900

- ● 1
- ● 5
- ● 10

railwaylines open by 1846

railwaylines open 1846-55

railwaylines open 1856-70

railwaylines open 1871-85

railwaylines open 1886-1900

Settlements from Bartholomew data, (c)HarperCollins Publishers, used with permission. Railway lines, roads, rivers and stations are digitised from the AHDS HDS Historic Parish Boundaries data: Roger J. P. Kain and Richard R. Oliver, 2001, Historic Parishes of England and Wales, Colchester, History Data Service.

This study has been able to take advantage of an unusual source to shed light on a topic which features rarely in mobility literature, for lack of evidence. The use of the GIS tool for this small scale localised historical study has given the research a perspective which clearly shows the relationship of a component of mobility activity to transport networks available at the time. It demonstrates the utility of a GIS tool for a historian, with appropriate support and guidance. Once the data is in place then many further questions can be asked, using the analytical tools available in the GIS.

Acknowledgements

This paper is based on work conducted for a research masters degree in Railway Studies (Major, 2006). The author is grateful to her supervisor Barbara Schmucki and to Peter Halls, University of York GIS Adviser, for their invaluable support and advice for this study.

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Biography

Susan Major is in her first year as a part-time PhD student with the Institute of Railway Studies and Transport History at the University of York, having recently completed a research masters there.

Modelling school catchments for segregation studies

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1. Introduction

A number of recent publications by members of the Centre For Market And Public Organisation (CMPO) have shown that some of the UK's 'non-white' ethnic groups – notably those with Indian, Pakistani and Bangladeshi backgrounds – are spatially clustered in particular locations, suggesting processes of residential segregation (Johnston et al., 2002a, 2002b). These ethnic groups are also shown to be concentrated in certain schools (Burgess and Wilson, 2005; Burgess et al., 2005; Johnston et al., 2004, 2005), with ethnic separations across schools being at least as great as that across neighbourhoods (Johnston et al., 2007).

Empirical evidence such as these led Trevor Phillips, Chair of the (British) Commission for Racial Equality to warn in a speech (Phillips, 2005) that Britain is 'sleepwalking to segregation': "[there are some] white communities so fixated by the belief that their every ill is caused by their Asian neighbours that they withdraw their children wholesale from local schools." He later continued that, "the passion being spent on arguments about whether we need more or fewer faith schools is, in my view, misspent. We really need to worry about whether we are heading for USA-style semi-voluntary segregation in the mainstream system."

In fact, the evidence that Phillips cited is not longitudinal and therefore cannot support a notion that segregation is becoming more pronounced in the UK (a more longitudinal study is an area of on-going research within CMPO). Nevertheless, there is still a concern that the sorts of choice offered within a state-subsided education market (as suggested by the UK Government's recent White Paper, subtitled 'More choice for parents and pupils': HM Government, 2005), might lead to the sort of conclusion that Renzull and Evans (2005, p.413) do in regard to quasi-autonomous but state-funded charter schools within the US: "charter schools provide a public school option for white flight without the drawbacks of residential mobility."

Two problems in assessing whether an element of (constrained) choice leads to increased segregation vis-à-vis neighbourhoods in the UK are, first, that the causal process is hard to prove and, secondly, the more geographical problem of how to make the comparison: specifically, which school to compare with where. Papers such as Harris et al. (forthcoming) compare characteristics of schools against measures of the ethnic composition of neighbourhoods in which the pupils reside. So, the ethnic composition of a school is compared against the ethnic composition of the census zones containing one or more of the school's pupils. Alternatively, the composition of the school could be compared against the composition of some geographical zone (e.g. electoral ward), within which the school is situated. The issue is whether the two are really comparable: if the school is a magnet, do the definitions of neighbourhood really reflect the areas from which pupils are attracted? If not, then how might this 'mismatch' impact on measures that suggest fairly subtle increases in ethnic segregation from neighbourhoods to schools?

In this paper we focus on the geographical problem of defining the catchment areas of state funded schools and using these to consider segregation. Out study region is Birmingham: England's 'second city', with a population of 977,087 residents (390,792 households) recorded in the 2001 Census. It has been chosen as the study region because, as the local government website states, 'the Census confirms Birmingham as a diverse City, with residents from a wide range of ethnic and religious backgrounds' (www.birmingham.gov.uk). Although schools do not have fixed catchments, and parents can express a preference as to which school their child attends, ultimately each school has only a certain number of places available and, if oversubscribed, will operate selection criteria (for example, offering places to siblings and giving priority to those who live closest). Faith schools – those supported by religious groups – may also adopt selective practices as, of course, do single gender schools. The admissions criteria for each (non-private) secondary school in Birmingham are documented at www.bgfl.org/services/admissions.

Our argument is that the 'core catchment' areas of schools are knowable simply by looking at the geographical patterns of addresses of those attending the schools. The addresses are available to us from the Pupil Level Annual School Census returns (PLASC), released for research by the Department for Education and Skills (DfES). The PLASC data also contain the ethnicity of each student – recorded by staff at the pupil's enrolment but open to parental alteration.

2. Modelling school catchments

2.1 Definition

Here a 'core catchment' is defined as the area containing 50% of the pupils attending the school, the delimitation of which reflects the geography of the study region and the locations from which the school draws its pupils. There is no assumption that the school is at the centre or even necessarily within its core catchment area.

2.1 How is the core catchment delimited?

There is an infinite number of ways of delimiting a school catchment area. The starting point used here is knowledge of the (x, y) postcode grid reference for each of the pupils attending a school, permitting the median x and the median y point per school to be determined. Conceptually, a small rectangle is then positioned at the median centre and then allowed to grow-out at each iteration of the algorithm in either of the N, NE, E, SE, S, SW, W or NW directions, continuing until it contains 50% (or other) of the pupils. The direction of growth at each iteration is decided by the maximum gain – the direction returning the highest ratio of pupils per unit area grown. This implies two criteria for the catchments: that they be compact but also that they reflect the actual geographies of the schools' recruitments. The algorithm is implemented in the statistical/computing language 'R', finally using its 'chull' function to compute the convex hull of the set of points defining each school catchment for the purpose of visualizing their area boundaries.

3. Preliminary results

Figure 1 shows (shaded) the modelled core catchment for one secondary school in Birmingham and also (not shaded) the thirteen other secondary schools with catchments overlapping the first. It is evident that there is already considerable movement (implying choice) within the school system (Harris et al., forthcoming, suggests that in 2002 only 25% of pupils attended their nearest secondary school in Birmingham; see also Parsons et al., 2000). Unsurprisingly, for all state-funded secondary schools in Birmingham, the ten with the largest catchment areas are in some way selective (by gender or by faith) – Table 1.

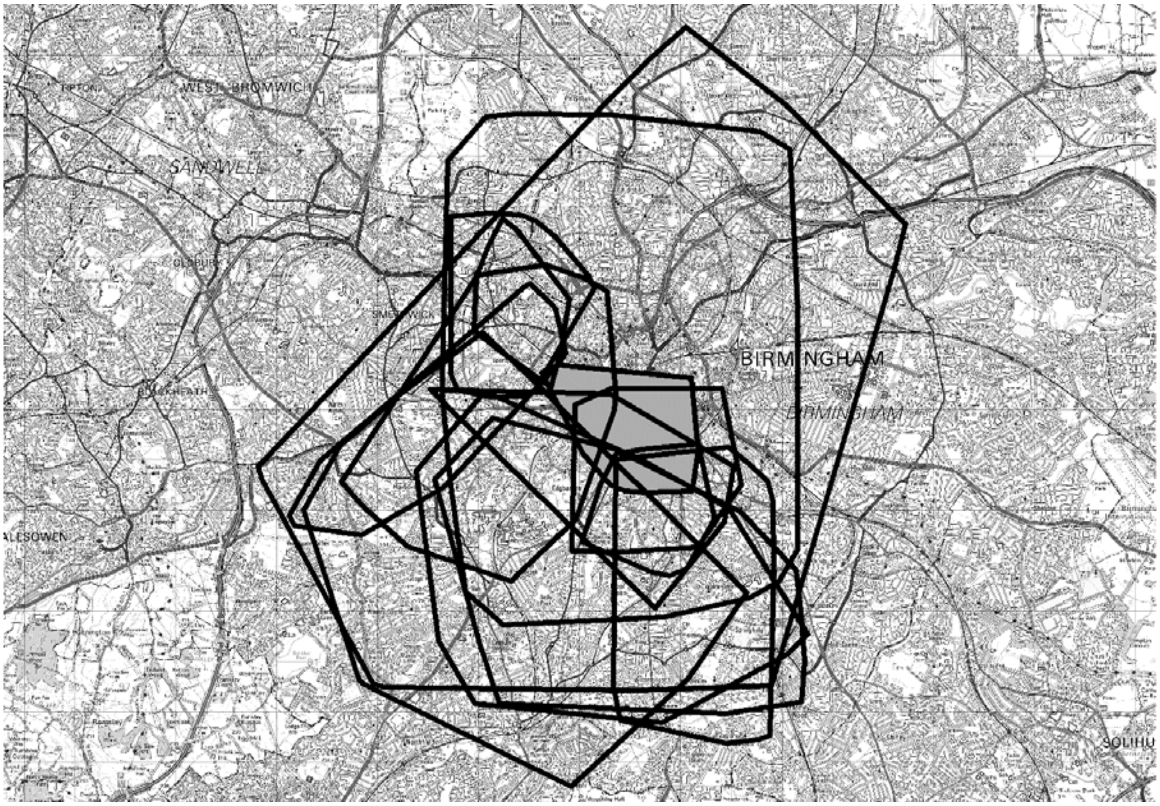

Figure 1. The core catchment area of a comprehensive school in Birmingham (shaded) and the catchments of thirteen other schools that overlap the first.

Type of school		**Gender**	**Faith**	**Admissions policy**
Voluntary aided	Secondary	Girls	Christian	Selective
Voluntary aided	Secondary	Girls	Roman Catholic	Comprehensive
Voluntary aided	Secondary	Mixed	Christian	Selective
Community	Secondary	Girls	Does Not Apply	Selective
Voluntary aided	Secondary	Boys	None	Selective
Voluntary aided	Secondary	Girls	Christian	Selective
Voluntary aided	Secondary	Boys	Christian	Selective
Voluntary aided	Secondary	Boys	Christian	Selective
Voluntary aided	Secondary	Boys	None	Selective
Voluntary aided	Secondary	Mixed	Roman Catholic	Comprehensive

Table 1. Some characteristics of the ten schools with the largest core catchment areas in Birmingham

3.1 Comparing the ethnic composition of catchment areas and schools

Having defined the core catchment areas of schools it is possible to use the PLASC data to calculate (a) the proportion of *all* pupils living within a catchment who are of a particular ethnic group, and then (b) compare it with the proportion when calculated for only those pupils within the catchment who attend the school. The result of (a) defines an expected proportion of an ethnic group to be found within a school, whilst the result of (b) defines the observed proportion. Comparing the two permits a direct answer to the question ‘does the ethnic composition of a school reflect the ethnic composition of the neighborhoods from which it draws pupils?’

For the 78 Birmingham secondary schools, the expected and observed proportions of white pupils are similar, although there are clearly schools attracting more white pupils than expected – Figure 2. There are also schools attracting more Pakistani pupils than expected – Figure 3.

4. Conclusions

In this short paper we have not considered why it is that any ethnic group may seek to educate their children in schools where that ethnic group is well represented; we have not modelled any aspects of the schools (such as their size, GCSE performance, curricula, etc.) which might explain any apparent processes of segregation; and nor have we considered any characteristics of the pupils themselves (e.g. their levels of material or social advantage) – other than their residential location. (See, instead, the reference list for examples of more explanatory modelling).

Here we have been focused on the more technical but geographical question of defining the core catchments of schools, enabling us to see whether the populations of schools reflect the populations of the areas from which they draw pupils, or whether there might be an ‘ethnic dimension’ to who attends where. The research is, at this stage, incomplete: we have not, for example, offered a sensitivity analysis to consider the effect of changing the definition of core catchments from the 50% of pupils threshold. Nevertheless, it hopefully still gives a flavour of the benefit of using explicitly spatial analyses informed by geocomputational thinking to inform substantive areas of policy-relevant debate.

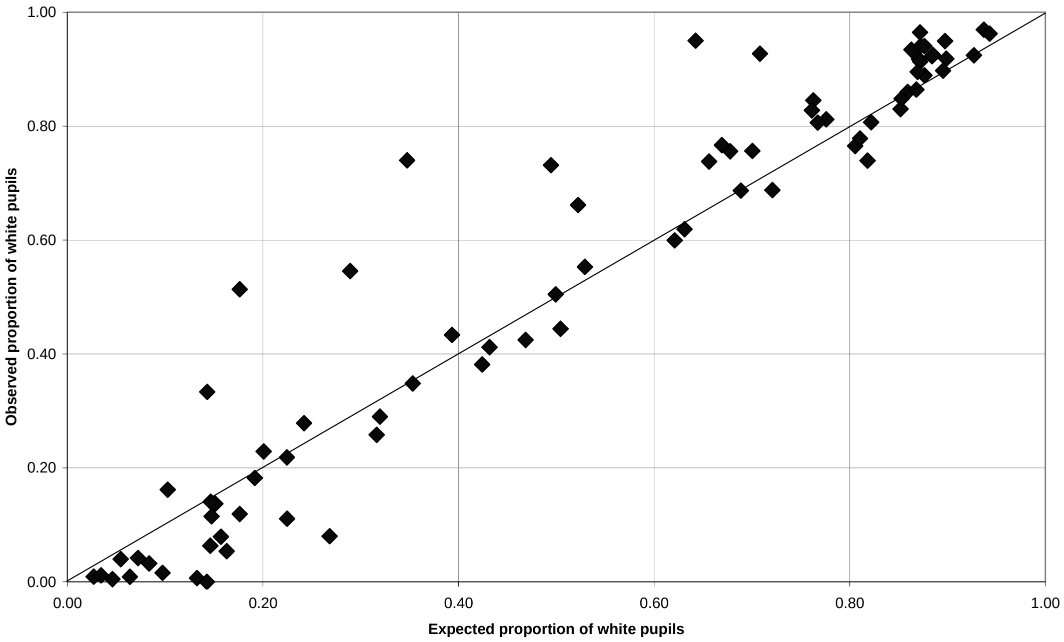

Figure 2. Expected and observed proportions of white pupils for the core catchments of Birmingham schools.

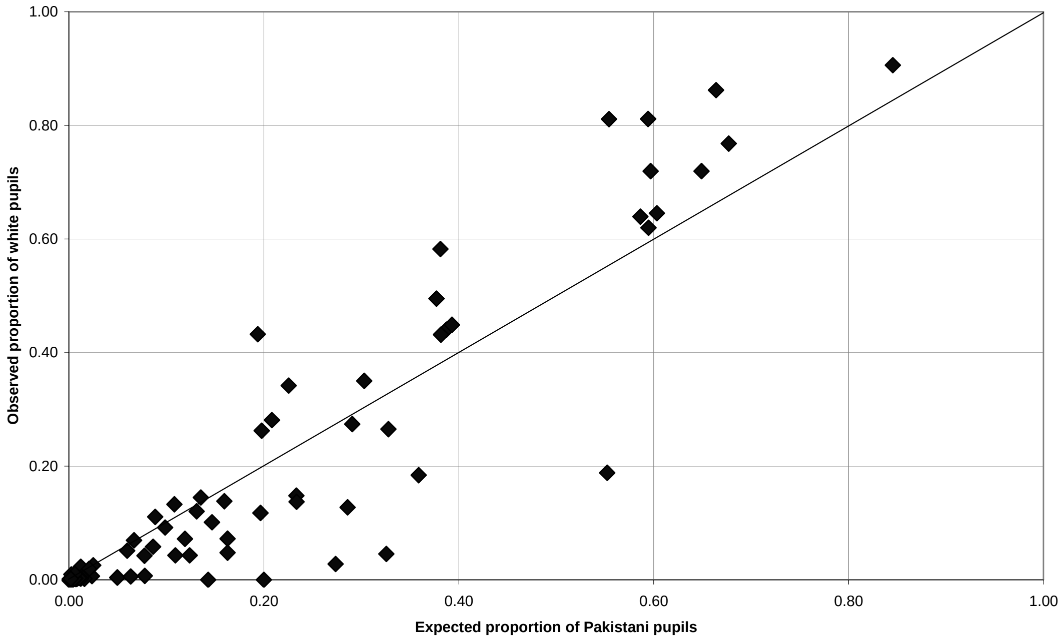

Figure 3. Expected and observed proportions of Pakistani pupils for the core catchments of Birmingham schools.

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Biography

Rich Harris is a lecturer in human geography at the School of Geographical Sciences, University of Bristol and a member of The Centre For Market And Public Organisation (a part of the recently formed Bristol Institute of Public Affairs). He claims to be immune to the 'Cameron effect'.

EuroSDR a multi-level network linking European Geoinformation production with Research and Development

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1. Introduction

In recent years, the emphasis of the typical European National Mapping and Cadastre Agency (NMCA) has seen rapid change

- from a provider of paper and digital map data to a data warehouse primarily concerned with maintaining, updating and disseminating modern reference geoinformation to support the development of advanced and integrated geoinformation infrastructures;
- from an agency using analogue technology and specialised hardware and software to one employing increasingly mainstream IT solutions;
- from an independent national agency to one of many players in a larger pan-European context of Galileo, GMES, INSPIRE and EuroSpec;
- from a national administrative body with in-house production to an agency with an increasing share of commercial activities, including outsourcing significant parts of its activities.

During times of change, such as these, knowledge about the latest technology and systems is recognised as a major advantage. Cooperation between European NMCAs and research institutions is the key to ensuring appropriate applied research is carried out and knowledge is transferred between the research laboratories and NMCA operations. This paper describes and evaluates the merits of a pan-European network, of over fifty years standing, linking NMCAs, leading universities and research institutes with the common goal of exploring the future needs of geoinformation infrastructures at national and European levels and addressing the outstanding and emerging issues through applied and focused research activities (EuroSDR, 2005).

2. EuroSDR as a multi-level network

Specifically EuroSDR aims to

- Develop and improve methods, systems and standards for the acquisition, processing, production, maintenance and dissemination of reference information and to promote applications of all such data.
- Encourage interaction between research organisations and the public and private sector to exchange ideas about relevant research problems and to transfer research results obtained to geoinformation production organisations.

At specific technical levels networks have emerged advising European organisations on new technology developments in areas such as digital camera calibration and development of standards to name but two. Most developments in the geoinformation sciences, technologies and systems affect production workflows in geoinformation production organisations. New spaceborne and airborne acquisition systems such as digital cameras and LiDAR require modifications to, or replacement of, existing workflows. By bringing together members of the production workforce and researchers from the same and other European countries a two-way synergy is developed whereby the GI producer can explore the detail of research outcomes with the researcher and the researcher can learn the impact and practicalities of his research. Furthermore the research plan of the organisation is drafted by production personnel and researchers together thereby ensuring that the research activities will be focused, applied and relevant (EuroSDR 2007).

The EuroSDR network operates at a number of levels.

2.1 A Network of Organisations

At one level, member organisations, through utilising permanent correspondents and the EuroSDR science committee, have immediate access to the collective experience of nearly twenty similar - but diverse - geoinformation organisations across Europe. Through this mechanism, many European joint ventures in production and research have been successfully realised.

2.2 A Network of Experts in Research and Production

On a second level EuroSDR delegates comprise a geoinformation production expert and a researcher from a university or Institute in each country. This leads to significant economies of scale and cost in the securing by geoinformation production organisations of contracted research and continuing professional development of staff.

2.3 A Network of European Contacts and SDI Participants

Thirdly, a series of focused workshops over recent years, particularly addressing the enabling research and development required for European initiatives such as INSPIRE and GMES, has resulted in the emergence of an effective network of individuals in Europe that are now actively contributing to the drafting of the implementing rules for the INSPIRE legislation.

3. From the Research to the Production Domain

3.1 Official Publications

In order to transfer the outcomes of research activities to production, the network publishes an official series of reviewed reports and proceedings, which reached its fiftieth volume in 2006.

A flavour of the extent of the research activities of the network can be gleaned from the subjects of the two most recent EuroSDR publications, namely reports on

- Evaluation of building extraction (Kaartinen and Hyyppä, 2006)
- Change Detection (Steinnocher and Kressler, 2006)
- Sensor and Data Fusion Contest – Information for Mapping from Airborne SAR and Optical Imagery (Bellmann and Hellwich, 2006)

- Automated Extraction, Refinement, and Update of Road Databases from Imagery and Other Data (Mayer et. al., 2006)

and proceedings of workshops on:

- Positional Accuracy Improvement 2: Achieving Geometric Interoperability of Spatial Data (Roensdorf, 2006)
- Next Generation 3D City Models (Kolbe and Gröger, 2006)
- Feature/Object Data Models (Woodsford, 2006)

3.2 Distance E-Learning Courses

The publication of reports alone is not sufficient to transfer the outcomes of research activities to the user domain, for example to key personnel in geoinformation production organisations and industry. To address this shortcoming EuroSDR commenced EduServ, a series of E-Learning courses based on research projects and recommendations of workshops (Heipke, 2004; Höhle, 2004; Mooney 2005). The Internet courses are preceded by a workshop at which participants meet tutors and receive guidelines for following the courses from their own locations. This paper will evaluate the effectiveness of such courses based on considered feedback from participants and tutors over five years.

Courses are designed to follow the principle of ‘Learning by Doing’ and therefore include practical assignments which require, for example, the participant to manipulate data or processes, evaluate the consequences and draw reasoned conclusions. It is generally accepted that active learning produces better results than purely passive learning. Participants come from diverse educational and cultural backgrounds and are not required to possess any formal academic or personal qualification because it is important not to impose barriers to accessing this type of educational resource. However, participants must possess a working competence in Information Technology (IT). A pre-course workshop helps to identify and remedy weaknesses in this area. Bringing course participants together from many European countries and from a variety of working backgrounds generates a synergy which results in fruitful exchange of experience. EduServ organizers have noticed a significant unanticipated benefit of the pre-course workshop, that of providing a forum for the inter-state exchange of ideas on the practical implementation of technologies and methodologies covered by the courses. This, in turn, informs the course tutors of the practical realization of theory in busy geoinformation production environments, which can only improve the effectiveness of current and future course development.

The experience of four years of EduServ suggests that E-Learning courses are of particular interest to the smaller states within Europe. This may be due to the existence of adequate CPD (continuing professional development) resources in the larger states. However, key staff members of geoinformation organisations in several countries may not have high levels of proficiency in the English language and, consequently, may feel that such courses are beyond them. Addressing the issue of capacity building and skills updating in those European states where a comprehensive geoinformation education resource does not exist (but where considerable training in geoinformation fields is still required) is seen by EuroSDR as a major challenge and is developed further in this paper. This is particularly so in light of a series of recent EC Directives that impact on spatial data and geoinformation.

4. Concluding Remarks

EuroSDR, an organisation of fifty-four years standing, is unique among pan-European organisations operating in the Geographical Information (GI) field in that it brings production and research expertise together through its delegates from eighteen European countries. It has published over fifty technical volumes covering applied research over the entire chain of spatial data provision and GI generation. In addition, annual short distance e-learning courses help in transferring the outcomes of its activities from the research to the production domain. However its strength lies in its multi-level networking activities that lead to a common set of goals and activities relevant to the spatial data and GI needs of a growing and connected Europe.

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Biography

Kevin Mooney is Senior Lecturer in the Department of Spatial Information Sciences, at The Dublin Institute of Technology (DIT), where he lectures principally in Photogrammetry. He gained a Diploma in Geo-Surveying (1976) from DIT; a Post-graduate Diploma in Photogrammetry (1977) from ITC, The Netherlands; and a M.Sc. in Engineering (1987) from Trinity College Dublin. His research interests are in extracting core spatial information from spatial and image data sets.

He is a Fellow of the Irish Institution of Surveyors and a member of the Irish Society of Surveying, Photogrammetry and Remote Sensing, where he has served as Council member, editor of the Survey Ireland journal, and currently acts as chairman of the programme committee of the Survey Ireland annual one-day conference of the Society. Since October 2003, he is Secretary-General of EuroSDR (European Spatial Data Research) a pan-European research organisation of eighteen member states..

Representing Spatial Geographical Data via variations of Volume and Tempo in Sound.

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KEYWORDS: sonification, spatial data, sound, volume, tempo

1. Introduction

The majority of spatial data are represented visually which can lead to an overload of information if too many data are represented. This study explores and evaluates the methods of representing spatial data using sound, with the aim of increasing the amount of spatial data that can be communicated without information overload. This study was performed for an undergraduate BSc Geography dissertation, and concludes that using variations in sonic volume and tempo can be used to represent spatial data. A particular application of this is using sonic data to augment visually displayed spatial information, but further research is needed in order to develop an effective application.

2. Scientific Background

Currently sound is a widely used medium for transferring information, both verbally and non-verbally. Multimodal communication is when more than one mode of communication is used at once - for example, sound (talking) and visual (body language). Mehrabiam (2006) found that for a typical spoken message, 55% of the understanding of the message came from the visual aspect, and only 45% from the audio aspect. Currently, the typical human's auditory system is significantly underutilised – Brewster (1994) reported that humans can tell the difference between any 2 of 400,000 sounds, and can remember up to 49 sounds at any one time.

When information is represented visually, users must focus their attention on the specific output device in order to receive the presented information. However, sound is omni-directional so it can be heard without concentrating specifically on the output device. Sounds are usually used for monitoring or warning purposes, as sound is good at representing rapidly changing data, rather than data that needs to be referred back to. McRoberts and Sanders (1992) have suggested that skills in non-verbal auditory perception are liked to spatial awareness. Currently geographical data tend to be presented in a visual format, whether it is a static map or a fully-fledged Geographical Information System, and sound is rarely used to display this type of data.

It is possible to represent many types of geographical data sonically – most easily are the data sets that represent actual sounds in the real world, such as the noise generated by an airport or traffic on a road. Normally this could be presented as a map with noise contours, but it could also be represented sonically with the sound being the noise of the aircraft at a specific location. Other data, which is not sonic in nature, could also be represented this way using a generic sound. This may be a better way of representing both audio and non-audio based data sets, because it would provide more flexibility in representing two data parameters – for example aircraft noise and aircraft frequency. Sound has a restriction on the amount of data it can contain, because of the fact that the majority of people can only access a limited amount of data from it. Jacobson (2002) reported that there were only 3 factors in sound that could be varied – tone, volume and tempo. Other factors in a sound could be used (for example having different instruments) but it would be too difficult for people to extract one data set from this. Jeong and Jacobson (2002) concluded in their study that tone was not effective at demonstrating variation in a data set, so volume and tempo will be investigated in this experiment. Some or all of these factors could be used to augment visual information with sonic information. This has the potential to create a very powerful method of interacting with multiple data sets.

The actual sound that will be used is important to select, as it will provide the main interface for the data. A series of beeps at a constant interval will be the easiest to understand – the tempo or volume of the beeps could then be varied to represent the variation in the data set. Using a series of beeps would allow the same data representation system to be used for a large number of different data sets which, after the initial learning period, would reduce subsequent learning periods.

The aim of the research reported in this paper is to develop a method to represent spatial geographical data using different aspects of sound, and to evaluate how effective these methods are on a sample of university students and staff. The technique created should be independent of the data, so it can be used to represent any type of spatial data, and should primarily be used for explaining data rather than predicting data. The effectiveness of volume and tempo will be compared and gender, musical ability and geographical experience will be analysed to see if they have an effect. The future uses of this method of representing spatial data will also be considered.

3. Methodology

The sampling design was intended to have a total size of approximately 50 people, with an even split between musical ability/no musical ability, male/female and geographical experience (geography or non-geography degree). The methodology involved interviewing 61 people, and asking them to complete a number of computer based exercises. The questionnaire asked for the data used to categorise people into different groups (gender, musical ability and geographical experience). Answers to the computer based exercises were also written on the questionnaire, with preferences on volume or tempo.

A Visual Basic computer program was written to assess the participant’s ability to use volume and tempo to differentiate between different sounds (Ordering Exercise), and to locate specific points within a variation of sounds (Population Density Exercise). Figure 1 shows the different parts of the program, and the order in which they are shown to the participant.

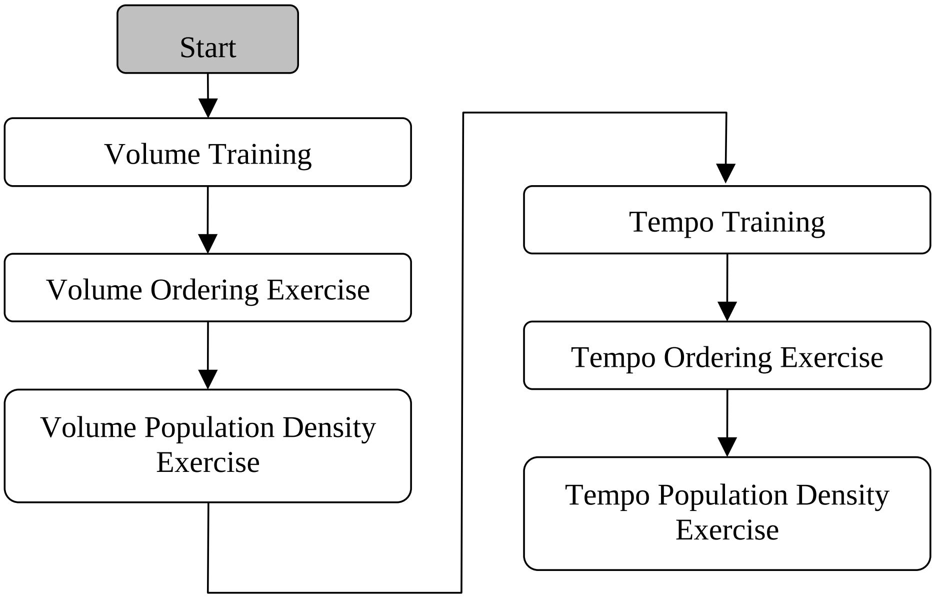

Figure 1. Flowchart of the stages the participant is taken though in the computer program.

The Training section allows the user to familiarise themselves with how data will be represented using sound. The ordering exercise allows the user to play six sounds, each with a different volume (or tempo) and asks them to write them down on the questionnaire, in order from lowest to highest.

The Population Density Exercise (see Figure 2) is the most demanding of the exercises, and should provide the most information about representing spatial variation with sound. The task was explained as the area in the rectangle representing a map, with the sound representing the population density, with higher values being represented by higher volume or tempos. The participants were asked to locate the three 'cities' and record the X Y coordinates. All activities were timed.

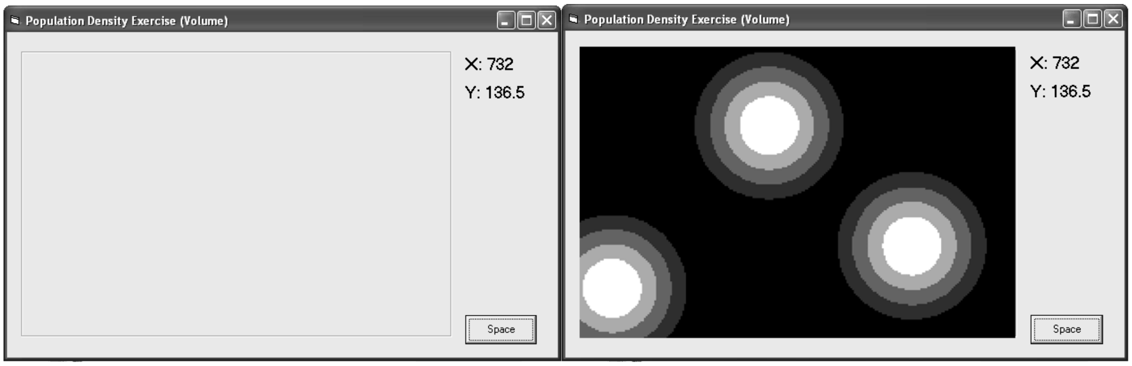

Figure 2. The Population Density Exercise shows the blank screen to the left shown to the user, and asks them to locate the 3 high volume (or tempo) locations. The screen to the right (not visible to the user) shows the variation in sounds played by the computer when the mouse is moved over that section, with a higher volume (or tempo) illustrated by the lighter colours.

4. Results & Analysis

There were a total of 61 participants, and the results are summarised in the tables below.

Attribute	*Number of people*	
Gender	Male = 31	Female = 30
Degree	Geography = 33	Non-Geography = 28
Musical Ability	Musical Ability = 33	No Musical Ability = 28

Table 1. Number of people involved. Total = 61.

	Average time for			
Category	**Volume Order**	**Volume City**	**Tempo Order**	**Tempo City**
All	1:01	1:32	0:55	1:15
Male	1:01	1:31	1:00	1:20
Female	1:01	1:33	0:49	1:10
Musical Ability	1:08	1:39	1:03	1:20
No Musical Ability	0:56	1:24	0:52	1:18
Student				
- Geog*	1:00	1:30	0:57	1:19
- Non-Geog*	1:03	1:39	0:54	1:04

Table 2. Average times (mins and seconds) for the exercises for different groups. Note: the ones marked * are sub-sets – i.e. the first one is people who are students and do a geography degree.

For the population density exercise, the average time for locating the three cities was 1:32 for volume and 1:15 for tempo. Overall, the majority of people preferred tempo over volume for both exercises, and this was reflected with better results for tempo.

	Musical Ability	Gender	Degree	Volume Cities	Tem Cities	City Result
Volume Order	0.657	0.51	0.43	0.304		
Tempo Order	0.667	0.613 (0.671327)	0.509 (0.653334)			
Musical Ability		0.251	0.011	0.381	0.119	
Degree				0.467	0.883	
Gender				0.61	0.782	
City (correct)	0.038	0.78	0.804			3.03
Order (time)	0.921	0.034	0.517 (0.590898)			
Order (result)	2.788	0.148	3.409			

Table 3. Chi-Square Results for the tests performed. Numbers in brackets are Fishers exact test results.

4.1 Analysis

The overall average times for tempo were lower than volume for both the ordering exercise (6 seconds lower) and the population density exercise (17 seconds shorter). This, combined with a larger number of correct tempo results for the ordering exercise (11 more) and a larger number of correctly identified cities (15 more) means that people generally found tempo easier to understand than volume.

A series of chi-square tests were performed on the data, and when the expected counts were less than 5, a Fishers exact test was performed (Rowntree 2000, Robson 1994). Of the relationships tested, only a few were statistically significant. These were the relationship between musical ability and correct identification of the cities (p-value = 0.038) and gender and time taken for the ordering exercise (p-value = 0.034). Participants with musical ability took longer on the city location exercise, but were more likely to correctly identify them. There was little or no difference between the genders for the volume exercises, but for the tempo exercises females were significantly faster than males.

5. Conclusions

One of the main objectives of the study was to understand how effective sound is at representing geographical data. Two ways of measuring effectiveness were used – the ordering exercise which asked people to compare six different sounds and put them in order, and the population density exercise, which asked people to locate the sound with a particular characteristic.

The results showed that people preferred tempo over volume, and were also more likely to get the correct results with tempo. It is possible that a learning factor made tempo appear easier than volume, but this is unlikely because out of 61 people, 44 preferred tempo. In a future study, half the participants could do volume then tempo, and half tempo then volume, but a larger sample would be needed for this. Many people likened the tempo sound to that of a Geiger counter, which probably made it easier to understand as it was a familiar sound. Gender seemed to have no significant effect on the volume results, but females were faster than males for the tempo exercises. Musical ability seemed to have a significant effect on the population density exercise, but not the ordering exercise. Participants with geographical experience were faster on the volume exercises than people without geographical experience, but the opposite was true on tempo exercises.

Due to the fact that little research has been done in this area, particularly in the discipline of geography, there are a number of aspects of the methodology that could be improved. The volume and tempo sounds in the population density exercise were calculated differently, resulting in a different resolution gradient for the cities. When asking whether people preferred volume or tempo, a closed, graded question would have provided more information for the analysis than the question used. The issues of novelty effects, which Geelan (2005) described as “the single greatest besetting sin in tech-related evaluations: ignoring the motivational effects of the cool new tech" should have been considered. It is possible that people put more effort into understanding this method of data representation because of the fact that it was new and something they hadn't seen before. If it was used on a much more day-to-day basis, people would potentially put less effort into understanding and using it, so may have lower levels of comprehension than demonstrated in this study.

This method of representing data could be used on an audio map, where a map (of any sort) would be augmented with an audio 'layer' of data, which could represent population density, height, the extent of radioactive contamination or potentially any spatial data. This also allows more information to be provided to people without causing information-overload, by using multi-modal communication. Depending on the data sets involved, augmenting spatial information with sonic information could be a very powerful, adaptable and flexible way of representing and interacting with spatial data. The sound gradient in the population density exercise (how quickly the volume or tempo of the sound changes with movement) could be altered and tested to see if interpretation could be made easier. Overall, tempo is a more effective way of representing geographical data than volume using sound. Further research is required to refine the process used to create the sound representing the data, but this study has shown that it definitely has potential as a technique to present and interact with data.

6. Acknowledgements

Nick Bearman would like to thank his dissertation supervisor Nick Tate, and all the participants of the study.

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Biography

Nick Bearman completed his BSc(hons) in Geography at University of Leicester in 2006, and this paper is based on that dissertation. In summer 2006 he was involved in a project looking at how a Virtual Reality theatre could be used to assess people's spatial memory skills. He will be returning to Leicester in 2007 to study for an MSc in GIS.

Analysing Mouse Movements to Infer Spatial Interests

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1. Introduction

Information overload is a well documented problem when displaying information to users through a GUI. This is also the case for spatial interfaces. We tackle this problem by logging user's mouse movements as they interact with our system. The logged information is analysed to create an interest model expressing each user's level of interest in the map features shown to him. Based on this interest model we can filter the information returned to the user, reducing information overload and tailoring the content to suit the user's tastes. This paper focuses on our methodology used to determine a user's interests based on his mouse movements over the corresponding spatial information shown to him.

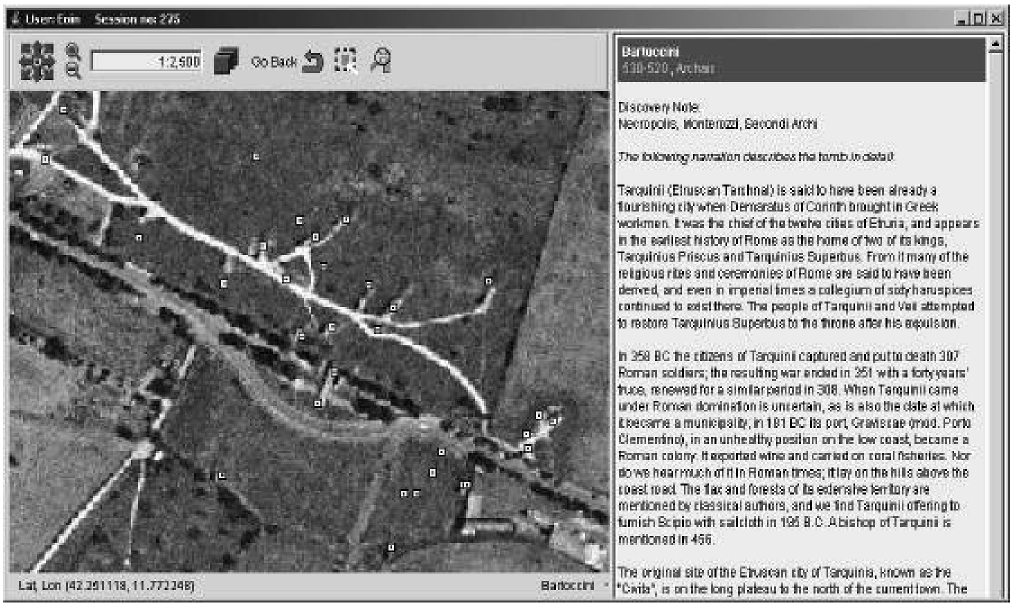
We introduce the TArcHNA (Towards Architectural Heritage New Accessibility) system. The goal of the TArcHNA project is to enhance the dissemination of archaeological heritage information. We offer a modern intuitive interface, which provides access to heritage information on the city of Tarquinia ('Tarchna' in ancient Etruscan). Access to this information is provided through the interface by interacting with a map of the region. There is a large quantity of heritage information in the database, consisting of information on burial tombs in Tarquinia. This information ranges from textual descriptions to images and videos. By maintaining individual user interest models we can filter out the less relevant information to reduce information overload, and provide more relevant content for each user.

The remainder of this paper is structured as follows; Section 2 provides the background to our research, and provides a brief discussion of related work. Section 3 introduces our methodology for information capture, visualisation and personalisation. An evaluation and analysis are outlined in section 4. Section 5 concludes with an outline of future work.

2. Background

Our system contains a large quantity of information compiled by expert archaeologists potentially available to the user. Previous work has shown that information overload has negative impacts on the user (Shardanand and Maes, 1995; Budzik and Hammond, 2000). We personalise the content returned to the user to reduce information overload. Several systems (Budzik and Hammond, 2000; Wilson et al., 2006) make use of personalisation to improve the user's experience. Before personalisation can take place, the system must be able to distinguish the user's interests and disinterests in relation to the content it provides. An interest model is constructed for each user, which maintains continuously updated information regarding the user's interests. These models are maintained using implicit profiling (Claypool et al., 2001).

Previous research has shown that a strong correlation exists between eye movements and thought processing (Chen et al., 2001). Research projects such as (Claypool et al., 2001; Mueller and Lockerd, 2002; Arroyo et al., 2006; Chen et al., 2001) have documented a significant link between user's mouse movements and eye movements. These projects examine the correlation between a user's mouse movements and his level of interest in the web data displayed The results are encouraging and show that incorporating mouse movement information can lead to a significant improvement in determining user's interests with non-spatial data. TArcHNA applies these techniques to spatial data. Several adjustments, as discussed in section 3, are made to the techniques used with non-spatial data in order to improve their accuracy and facilitate their use with spatial data.



Bartoccini
530-520 , Archaic

Discovery Note:
Necropolis, Monterozzi, Secondi Archi

The following narration describes the tomb in detail:

Tarquinii (Etruscan Tarchna) is said to have been already a flourishing city when Demaratus of Corinth brought in Greek workmen. It was the chief of the twelve cities of Etruria, and appears in the earliest history of Rome as the home of two of its kings, Tarquinius Priscus and Tarquinius Superbus. From it many of the religious rites and ceremonies of Rome are said to have been derived, and even in imperial times a collegium of sixty haruspices continued to exist there. The people of Tarquinii and Veii attempted to restore Tarquinius Superbus to the throne after his expulsion.

In 358 BC the citizens of Tarquinii captured and put to death 307 Roman soldiers; the resulting war ended in 351 with a forty years' truce, renewed for a similar period in 308. When Tarquinii came under Roman domination is uncertain, as is also the date at which it became a municipality; in 181 BC its port, Graviscae (mod. Porto Clementino), in an unhealthy position on the low coast, became a Roman colony. It exported wine and carried on coral fisheries. Nor do we hear much of it in Roman times; it lay on the hills above the coast road. The flax and forests of its extensive territory are mentioned by classical authors, and we find Tarquinii offering to furnish Scipio with sailcloth in 195 B.C. A bishop of Tarquinii is mentioned in 456.

The original site of the Etruscan city of Tarquinia, known as the "Civita", is on the long plateau to the north of the current town. The

Figure 1. Screenshot of the TArcHNA User interface

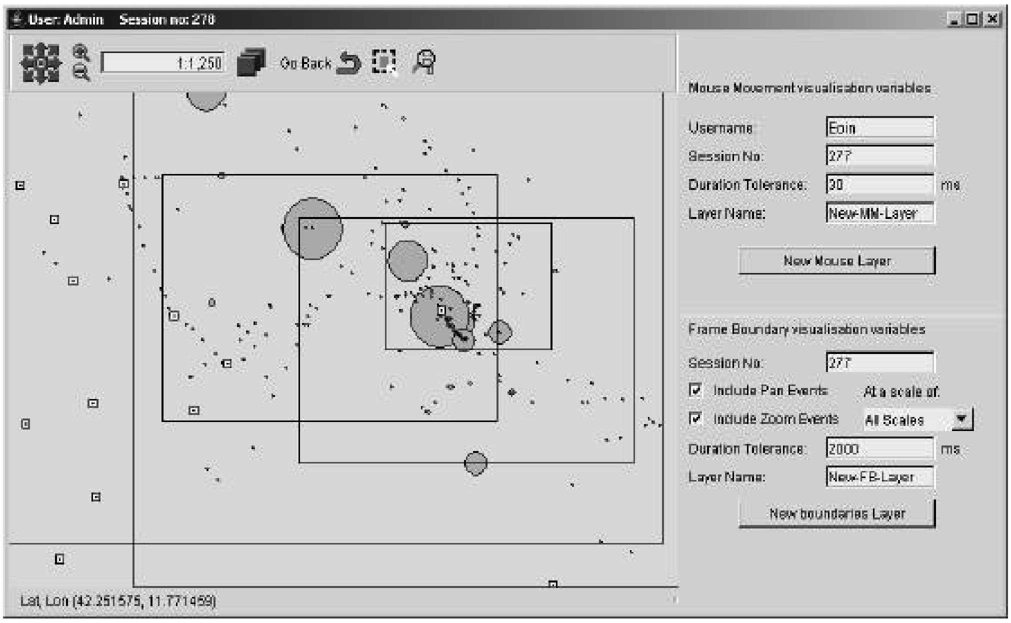
3. Methodology

The TArcHNA system is built on a client-server architecture. It includes an Oracle 9i spatial database, an information repository of non-spatial data (heritage information concerning the tombs shown on the map), and an intuitive interface, which permits the user to interact with the spatial information, to provide access to the non-spatial information. It is implemented primarily as a desktop system. A simplified mobile system is also under development. Figure 1 shows a screenshot of the interface. The spatial side of the interface is on the right. By clicking on a tomb object on the map, users can view its related heritage information in the information browser on the left.

Our system makes use of implicit profiling (Claypool et al., 2001). No explicit input is required from the user. As the user interacts with the system, panning and zooming the map and clicking on tombs to acquire information, his actions are logged Particular attention is devoted to the user's mouse movements. By logging the location of the mouse at all times we can, by inference (Arroyo et al., 2006), find the focus of the user's attention for the duration of his session.

In addition to continuously logging the latitude and longitude of the mouse pointer, we also log the exact time the mouse is moved or clicked This information is used to calculate the duration of each mouse movement, determining exactly how long the mouse rested in a given position. The coordinates of the corners of the user's view of the map are logged each time a navigational operation (i.e. pan or zoom) takes place. These coordinates determine the frame boundaries. They can be used to calculate the contents of a user's view frame at any particular point during his session.

The location of mouse movements and frame boundaries indicate the user's focus of attention during his session. Frame boundaries give us a crude indicator of the region focused on by the user. Mouse movements give a greater indication of the user's interests within each of these frames. Our visualisation tool (figure 2) shows in detail where the user's mouse rested during a session, and by association, which areas of the map were viewed. The circles represent positions where the mouse rested. Their size is proportional to the duration of the mouse resting in that position.



Mouse Movement visualisation variables

Username: Eoin
Session No: 277
Duration Tolerance: 30 ms
Layer Name: New-MM-Layer

Frame Boundary visualisation variables

Session No: 277
☑ Include Pan Events
☑ Include Zoom Events
At a scale of: All Scales
Duration Tolerance: 2000 ms
Layer Name: New-FB-Layer

Figure 2. TArcHNA Visualisation tool: Showing the user's mouse resting positions and frame boundaries for an earlier session.

This visualisation of the user's interactions also helps determine which of the (tomb) objects displayed are of greatest interest to the user. By ranking the objects based on analysis of the log files, we can return personalised content to the user, tailoring the information returned to suit his interests. We determine an object's importance by assigning it a value based on the distance between the object and all mouse points in the same frame boundary. These distances are weighted, giving a greater weight to points where the mouse rested longest. Further weights are applied according to the map scale when the action took place. Actions at a small scale are given a greater weight. The sum of the weighted distances for each object determines the user's interest level in the object

4. Analysis

An initial evaluation of our methodology is currently being prepared. Our test group consists of twelve users. Each user will complete ten tasks over ten different sessions. The tasks involve finding a specific piece of information on a named tomb, such as "Who is thought to be buried in 'Demoni Azzurri', locate three tombs in its vicinity from a similar era." Each user's tasks have a theme, drawing them to tombs with certain features in common. The volunteers will be uninformed that their mouse movements are being logged, as we do not wish to alter their browsing patterns, detracting from the validity of our results. The completion of these tasks by the volunteers will generate realistic user data for 120 sessions for analysis. As each user's tasks are themed, we would expect a clear distinction to emerge between features of interest, and those of little interest to a user.

Over a number of sessions we hope to show that it is possible to discern a user's preferences to some extent based on his mouse movements. This information can subsequently be used, in conjunction with other implicit indicators to strengthen spatial data recommendations.

5. Conclusions and Future Work

By analysing user's spatial interactions we create an interest model. It is subsequently possible to personalise the data set returned to the user, eliminating extraneous data that is of little interest to the user, and promoting the accessibility of further information deemed to be relevant to the user by his model.

While our case study is based in the cultural heritage domain, it is applicable to other areas, such as pubs or restaurants in a major city, by changing the dataset. We feel that our work will be particularly beneficial when applied in conjunction with other implicit techniques in order to improve the reliability of spatial data recommendations.

Possible future directions for our work include: 1) Exploring the implicit indicator value of mouse trajectories. 2) Studying the introduction of line and polygon objects (e.g. roads and parks) for comparison purposes with tomb objects (points). 3) The implementation of interaction logging for mobile users, relying on GPS position and stylus taps to infer user interests.

Acknowledgement

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Biography

Eoin Mac Aoidh is a PhD student at UCD Dublin; His research interests include GIS interfaces, user modeling and personalisation.

A comparison of morphometric and web prominence of mountain features

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1. Introduction

The new field of ethnophysiography was first proposed at the COSIT conference in 2003 by David Mark and Andrew Turk (Smith and Mark, 2003). The argument put forward was that there should be an ethno-science for the earth sciences, as landscape is as important to some cultures as plants and animals. The problem is that the classic model of an ethnoscience typically consists of a comparison between an indigenous typology and a scientific one. In the case of landscape morphometry there is no clearly defined scientific standard to compare. It is also more difficult to collate an indigenous typology of landscape than of plants or animals, as landscape features are typically less well defined. In any British context it has become even more difficult as the concept of "indigenous" is very hard to define, and so a slightly different approach is required.

This work will investigate the relationship between cultural and physical prominence of mountain features, using the number of web pages a Google search reports as being relevant to a search term as the level of cultural prominence. There are a number other ways in which one could describe the cultural prominence of a peak and any value of prominence is likely to change throughout time and with different cultural groups. The groups typically involved in the creation of webpages are English speaking hill walkers and so it could be said that any measure of "culture" is limited to that or similar groups.

It is worth observing that this methodology would not be suitable for measuring any local cultural significance in a place with little or no internet access. It can only measure the global results as considered relevant by Google, although some filtering of results by IP address could be considered. Although could be said to have some drawbacks, one advantage is that language is not considered a hindrance in this case as any page containing the place name would be included regardless of the language of the page.

The data collected from the webmining experiment will then be compared to some measures of physical prominence derived from digital data.

2. Method

2.1 Landscape

The creation of ratios for prominence all involve the creation of an area that delimits the peak in some way, which in combination with its relative drop will give a value that will serve as a measure of physical prominence.

The peaks known as the “Wainwrights” were chosen, these being those described in Alfred Wainwrights’ series of books that comprise *A pictorial guide to the Lakeland fells*. The important thing about the Wainwrights, as far as this research is concerned, is that they are not confined by specific topographic measurements, but are entirely subjective.

The locations of the Wainwright summit peaks were downloaded onto a GPS for a hill walking website (Stevens, 2005). A 10m DEM of the area was downloaded from the Digimap site and mosaiced to cover the entire area. Using the *Landserf* software, a peak classification exercise was carried out on the surface which produced a series of peak contributing areas, altitude and relative drops for each peak. The names of each Wainwright point could then be joined to the peak contributing area that they fell within. This contributing area divided by the relative drop of the peak gives the first ratio for prominence, referred to in this work as the P ratio.

The second method of attributing areal values to peaks was to use inverse watersheds. Watersheds are defined as the contributing area to a drainage point, where any drop of water falling within a watershed will drain down to a single point. Watersheds in combination define draining systems and have also been used to effect as a system of delimiting zones within other surfaces, such as detecting contours in images (Beucher S and Lantuejoul C, 1979). If one were to invert a drainage surface, a watershed algorithm applied to a surface would produce contributing areas that “drain” upwards towards a peak and this was effectively what was done. The elevation surface was multiplied by -1 and then added to by 1000 (so that there are no negative integers) resulting in an inverse DEM. The areas created were divided by the relative drop of the peak and the resulting value is known as the W ratio.

The third method of ascribing area to peaks was to create Voronoi polygons around each summit point. The area of each Voronoi polygon divided by the relative drop is known as the V ratio.

2.2 Google Web API

The Google Web API (now known as Google Code) is a public interface for expanding the functionality of Google. Using Simple Object Access Protocol (SOAP), a user can write services for search and data mining that can be automated or repeated and the results sent to a text file. An API application was written in VBscript that took a comma delimited text file containing search terms, and then searched for those terms and returned the number of pages that Google considered relevant to the search term.

The 214 Wainwright peaks were searched for and then those names together with one additional search term. These additional search terms were selected using all of the words associated with "mountain" from an online version of *Roget's Thesaurus* (www.thesaurus.com, 2006), along with three geographical terms, that referred to the region. The full list of additional terms were Wainwright, Cumbria, Lake District, Mountain, Hill, Summit, Peak and Climb. For this list only, an additional random word was added - in this case the word "envelope" – to see if a word not associated with mountain features would produce any change in correlation.

For ease of understanding this work will refer to the name of the hill as the *search term* and the additional term as the *additional search term*. For example, for the peak "Buckbarrow" the following list of search terms and additional search terms would be produced:-

"Buckbarrow"
"Buckbarrow" Wainwright
"Buckbarrow" Cumbria
"Buckbarrow" "Lake District"
"Buckbarrow" mountain
"Buckbarrow" hill
"Buckbarrow" summit
"Buckbarrow" peak
"Buckbarrow" climb
"Buckbarrow" envelope

The results of this automated search were repeated one month later and the results compared, to test how reliable the relationships between terms and numbers of relevant pages. There was no significant difference between the two sets of results, although some of the numbers of relevant pages had understandably changed.

The correlation for every paring of the normalised values for Altitude, Voronoi polygon ratio, inverse watershed ratio, peak contributing area ratio and the web mining results was found using the Pearson Correlation Coefficient. It can be seen (in Table 1) that the relationships between Lake District, and the Inverse Watershed Ratio, Voronoi Polygon Ratio, Altitude and relative drop were significant at least the 0.05 level.

This method is biased towards the highest peaks which are high outliers. To counteract this, data was transformed to the log of each value. The results of the correlation carried out on the log transformed values can be seen in Table 2.

3. Results

Correlation of Non-transformed Results

		Peak Contributing Area Ratio	Inverse Watershed Ratio	Voronoi Polygon Ratio	Altitude	Relative Drop
Name Only	Pearson Correlation	-.039	.006	.010	.127	.032
	Sig. (2-tailed)	.570	.929	.886	.063	.645
Wainwright	Pearson Correlation	-.014	.071	.035	.084	.088
	Sig. (2-tailed)	.839	.304	.611	.222	.197
Cumbria	Pearson Correlation	-.013	.016	.015	-.017	.041
	Sig. (2-tailed)	.848	.817	.823	.805	.553
Lake District	Pearson Correlation	.105	.167	.221	.174	.262
	Sig. (2-tailed)	.127	.014	.001	.011	.000
Mountain	Pearson Correlation	-.035	.051	.031	.150	.056
	Sig. (2-tailed)	.614	.460	.648	.028	.418
Hill	Pearson Correlation	-.039	.043	.027	.124	.062
	Sig. (2-tailed)	.567	.528	.698	.070	.365
Summit	Pearson Correlation	-.028	.034	.024	.143	.041
	Sig. (2-tailed)	.680	.622	.726	.036	.555
Peak	Pearson Correlation	-.035	.003	.011	.133	.028
	Sig. (2-tailed)	.609	.966	.877	.052	.688
Climb	Pearson Correlation	-.028	.008	.015	.146	.021
	Sig. (2-tailed)	.683	.904	.831	.032	.765
Envelope	Pearson Correlation	-.037	-.012	.002	.124	.013
	Sig. (2-tailed)	.595	.867	.979	.070	.845

Table 1: Results of Pearson Correlation Test

▓	Correlation is significant at the 0.01 level (2-tailed).
░	Correlation is significant at the 0.05 level (2-tailed).

Logarithm Correlations

		Peak Contributing Area Ratio	Inverse Watershed Ratio	Voronoi Polygon Ratio	Altitude	Relative Drop
Name Only	Pearson Correlation	0.105	.199	.177	0.145	.245
	Sig. (2-tailed)	0.125	0.003	0.009	0.034	0
Wainwright	Pearson Correlation	-0.002	0.069	0.049	0.077	0.075
	Sig. (2-tailed)	0.979	0.318	0.472	0.265	0.273
Cumbria	Pearson Correlation	.181	.231	.247	0.134	.300
	Sig. (2-tailed)	0.008	0.001	0	0.051	0
Lake District	Pearson Correlation	.279	.323	.340	.248	.430
	Sig. (2-tailed)	0	0	0	0	0
Mountain	Pearson Correlation	0.091	.185	.199	0.172	.202
	Sig. (2-tailed)	0.185	0.007	0.003	0.012	0.003
Hill	Pearson Correlation	0.096	0.167	.181	0.136	.205
	Sig. (2-tailed)	0.161	0.014	0.008	0.047	0.003
Summit	Pearson Correlation	0.105	.186	.209	.187	.221
	Sig. (2-tailed)	0.125	0.006	0.002	0.006	0.001
Peak	Pearson Correlation	0.099	.181	.200	0.164	.206
	Sig. (2-tailed)	0.149	0.008	0.003	0.016	0.002
Climb	Pearson Correlation	0.126	.214	.232	.186	.238
	Sig. (2-tailed)	0.066	0.002	0.001	0.006	0
Envelope	Pearson Correlation	0.069	0.164	0.14	0.164	.183
	Sig. (2-tailed)	0.317	0.017	0.041	0.016	0.007

Table 2: Results of Pearson Correlation for Log Transformed results

■	Correlation is significant at the 0.01 level (2-tailed).
□	Correlation is significant at the 0.05 level (2-tailed).

4. Some conclusions from the results

The results show that there are relationships between both the normal and log transformed sets of values and that it appears to be the case that the more physically prominent a peak is that the more culturally prominent it will be. There are some possible reasons for the patterns we see in the correlation tables. For example, in the non-transformed table, the strong relationship shown between altitude and all of the physical search terms could be a reflection of the "peak bagging" culture of British climbing – that is that the absolute elevation rather than the distinctiveness of a peak is what is driving the creation of web pages.

In the transformed data, there is a general pattern of correlation, with the exception of the search term "Wainwright". One reason for this may be that any page that mentions the name of a Wainwright peak and the term "Wainwright" is likely to contain a list of all of the other Wainwrights. It is likely to be a page for walkers which show the peaks as a group, with either links to the other peaks or a list of the peaks that constitute the group.

The fact that there is some correlation does not necessarily mean that this is the most appropriate method for comparing cultural and physical prominence. One could argue that comparisons of this kind are as inappropriate as comparing apples and oranges. Further investigation is required to understand why these patterns are found and whether they have any significance.

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Biography

Ian Greatbatch is in the third year of a PhD funded by City University.

A Classification of Spatial Processes Based on PDEs

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1. Introduction

Dynamic, or time dependent, spatial processes are becoming important subjects in the field of geographic information science and the development of geographic information systems (GIS). Examples for spatial processes are the spread of diseases (Newman 2002), human travel (Brockmann, Hufnagel et al. 2006), the migration of non-endemic species (Seppelt 2005), and the expansion of cities (Li 1999). Because of all the differences between processes in terms of spatial and temporal scales, involved parameters, suited models etc., the common grounds of processes are obscured. As part of our long term objective – extending GIS with elementary functionality for working on spatial processes – this paper presents our approach to identify the key elements of spatial processes. Our vision is that GIS can be used for communicating about processes on a qualitative level, when they are extended with functionality for working on processes. This can lead to an enhanced interoperability between GIS and specialized modeling packages.

Our approach to identify the common grounds of different spatial processes is an analysis of partial differential equations (PDEs) that can be used to model the processes. PDEs are generally used for describing dynamic processes mathematically. They are roughly classified into wave-like, diffusion-like, and equilibrium equations according to the type of phenomena they describe. This paper shows how we can build on this classification and which mathematical aspects should be included in a detailed analysis of PDEs.

2. Related Work

Geographic information systems (GIS) are generally used for managing, analyzing, and visualizing spatial data. They have been developed for managing extensive data collections in the 1970s. Currently proprietary GIS software is static, which means that the systems store one up-to-date state of the world (Worboys 2005). Worboys (2005) indicates the need for treating dynamic aspects of spatial phenomena when building models. He presents an approach that stresses the consideration of events in the common object/field models. Other works on time and dynamics in GIS include (Claramunt and Thériault 1996; Hornsby and Egenhofer 1997; Frank 1998; Galton 2004).

Martin Beckmann (1970) analyzed spatial diffusion processes in the context of location theory, which is concerned with the spatial location of economic activities. He presents basic models of innovation diffusion, expenditure diffusion, migration, and commodity flows and price waves. The outcome of his analysis is that all of those phenomena can be described with the diffusion equation or the wave equation. His intention is to build better models of economic processes rather than reproducing partial differential equations (PDEs). However, his analysis supports our assumption that processes have common grounds that can be identified by PDEs.

3. Partial Differential Equations

Our approach to identify the key elements of spatial processes is an investigation of partial differential equations (PDEs) that are used for modeling the processes. A PDE is “an equation that contains partial derivatives, expressing a process of change that depends on more than one independent variable. It can be read as a statement about how a process evolves without specifying the formula defining the process” (Encyclopædia Britannica 2006). PDEs are often used for computer-based analyses and simulations of continuous physical phenomena that occur in fields like mechanics, electrostatics, electrodynamics, and acoustics (Press, Flannery et al. 1986).

3.1 Describing a Process with a PDE

We discuss the advection equation as a concrete example for a PDE, based on explanations given in (Logan 2004). Advection is a term from biology for describing the bulk movement of particles in some transporting medium (e.g. pollutants carried downstream in a river, a swarm of insects that is moving from one place to another). The advection equation can be deduced from a conservation law. This law states that the change of some quantity in a region has to correspond to the amounts coming in, going out and being created or destroyed in that region. The flux F denotes the amounts of some particles coming in or going out, the sources *f* represent the amounts being added or removed, and the density *u* denotes the amount of particles existing in a region. Equation 1 is the expression of this conservation law:

$$u_t(x, t) + \phi_x(x, t) - \mathrm{f}(x, t)\, d\, x = 0 \qquad (1)$$

In the case of advection, the flux F is proportional to the density *u*. *C* is a constant (Equation 2). We omit the sources *f* and insert the statement for the flux F in Equation 1 to come to the advection equation without sources (Equation 3).

$$\phi = c\, u$$

$$u_t + cu_x = 0$$

3.2 Classification of PDEs

The advection equation presented in the previous section is a first order, linear, hyperbolic partial differential equation in one dimension. The order, linearity, and type are important for providing a classification of partial differential equations. The type of a PDE, hyperbolic, parabolic, and elliptic, indicates characteristics of the process that is modeled (Logan 2004):

- Hyperbolic equations like the wave equation or the advection equation are used for modeling wave-like phenomena. Waves occur, for example, in water, electromagnetism, and acoustics.
- Parabolic equations like the diffusion equation are used for modeling diffusion problems. Diffusion describes the random motion of particles.
- Elliptic equations like the Laplace's equation describe steady-state processes, like ground water flow.

For computational considerations the distinction into initial value and boundary value problems is more important than the classification stated above (Press, Flannery et al. 1986). The hyperbolic and parabolic equations fall into the class of initial value problems; they are also referred to as evolution equations showing how a process evolves over time. Elliptic equations are equilibrium equations that do not contain a time variable and fall into the class of boundary value problems.

4. Identifying Characteristics of Spatial Processes

The long-term objective of this work is to infer characteristics of processes from their mathematical description with PDEs. The general classification of PDEs presented in section 3.2 provides the basis for this investigation. The sensible issue is which mathematical aspects have to be included in the analysis of PDEs to reveal the characteristics of the modeled processes.

For studying the PDEs we propose to analyze the general classification aspects i.e. order, linearity, type, and if the equations include spatial reference and time. In addition we have to analyze if an equation can change its characteristics depending on boundary condition and the pre-or absence of sources. Concerning source terms, Logan (2004, p. 152, 153) states „a source term represents an outside influence in the system and leads to inhomogeneity in the PDE."

With this approach we can draw the following conclusions concerning the previously presented advection equation: the advection equation is a one dimensional equation and therefore a hyperbolic equation. Hyperbolic equations show a wave-like behavior which means that signals are propagated in a coherent way. It is an evolution equation belonging to the class of initial value problems. There are different forms of the advection equation including sources or not, and the equation can be combined with other equations like the diffusion equation.

5. Conclusions and Future Work

This work presented an approach for identifying the characteristics of spatial processes. The tools we are using are partial differential equations; by analyzing the PDEs, we can deduce properties of the processes that are modeled with the PDE. This approach was presented exemplarily for the advection equation.

The next step is to perform a detailed analysis of PDEs and to match them with spatial processes occurring in a GIS context. This proceeding will show if our classification is sensible enough for inferring characteristics of spatial processes from the equations.

6. Acknowledgements

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A Comparison between using Ordnance Survey Landline™ and Mastermap™ Products to derive Land Cover Data for use in Socio-environmental Area Classification

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1. Introduction

It is 30 years since the first national area classifications were produced using statistics from the 1971 Population Census for local authorities, parishes and wards in Britain within the Planning Research Applications Group in the Centre for Environmental Studies in conjunction with the Office of Population Censuses and Surveys (Webber and Craig, 1976; Webber 1977; Webber and Craig, 1978). Successive census enumerations have seen such national classifications extended to smaller areas, enumeration districts and most recently the postcode-based Output Areas, and updated by the inclusion of more and exclusion of less relevant demographic and socio-economic statistical counts (Sleight, 1995; Wallace and Denham, 1996). Such area classifications have helped to establish geodemographics as a viable tool in the armoury of commercial organisations marketing and selling goods and services to consumers, and in the range of techniques available to those in the public sector concerned with formulating area-based policies and allocating resources targeted towards certain sectors of society. Unfortunately the term ‘postcode lottery’ has tarnished the image of such an approach, especially with reference to public services, although the number of companies operating in the commercial arena shows signs of increasing (Sleight, 2004).

2. Background

It is characteristic of these classification systems that, although usually based on complex multivariate statistical techniques, they encapsulate the aggregate demographic and socio-economic nature of small areas by means of a simple, relatively intuitive, thumbnail description. Paradoxically, although these descriptions often refer to both the social and environmental character of the areas in which people live by employing such terms as ‘leafy suburb’ or ‘inner city terraced housing’, environmental indicators have not been incorporated into the analysis. The landscape of leafy suburbia is determined not so much by means of identifying the presence of housing in tree-line avenues as by recording inhabitation by ‘double income families with 2.4 children’. In other words there is an implicit inference that people with certain combinations of demographic and socio-economic characteristics reside in particular types of environment.

The authors’ previous research examined the effect on area classification of combining socio-economic data with environmental information, derived by using Ordnance Survey LandLine™ in conjunction with digital aerial and satellite and imagery (Walford and Armitage, 2005). The Ordnance Survey’s subsequent re-engineering of its unstructured digital point, line and text topographic data into a topologically structured and polygonised database known as MasterMap™ with general land cover/use attributes provides the opportunity of making a direct comparison between these two spatial data formats. This paper presents the results of this comparison and considers the additional types of data that might enhance socio-environmental area classification. MasterMap™ has been available to commercial and public sector partners since 2004, and will come online to the UK Higher Education community through the Digimap service in 2007. The authors have been granted access to MasterMap data in advance of this release to the HE sector for Salford and a contrasting local authority (Colchester).

3. Methodology

There are two main issues to be addressed when devising a suitable methodology for classifying small areas. The first concerns the choice and format of statistical counts, including whether these are absolute or relative and the nature of any standardisation to be applied. The second relates to the types of multivariate analyses, including both data reduction (e.g. factor or principal components analyses) and/or classificatory techniques (e.g. cluster analysis), to which the input data will be subjected (Charlton, 1985). Most geodemographic classifications have been hierarchical with families, groups and clusters of areas possessing a broad, intermediate and detailed degree of similarity. In all cases such analyses may potentially suffer from commission of the ecological fallacy and from the Modifiable Areal Unit Problem, although these issues may be alleviated by judicious variable selection and careful evaluation of the classification.

The authors’ previous research derived a set of land cover variables for census Output Areas in a case study local authority (Salford) within the Manchester Metropolitan area by applying image processing and spatial analytic tools with respect to aerial and satellite imagery in conjunction with OS LandLine™ data. These variables were combined with demographic and socio-economic statistics from the 2001 UK Population Census. Two forms of multivariate analysis were applied to test the impact of including environmental variables on area classification.

The first analysis replicated the National Statistics Office’s methodology for classifying wards (ONS, 2004), augmenting the 43 demographic/socio-economic standardised counts with nine land cover variables, including three mixed types. This was essentially a two-stage methodology involving an iterative allocation-reallocation (K-means) clustering to produce an optimum classification from an initial set of random cluster centres. This was followed by a classical hierarchical cluster analysis using Ward’s method, which was further refined to ensure each area (ward) was assigned to its correct subgroup. Second, an ordination approach was applied to explore the dimensionality of the socio-economic and land cover data.

Ordination can be achieved by either direct or indirect means, in the former case to identify the variation in a single dataset and in the latter to analyse trends in two datasets and establish the nature of the relationship between them by deriving a linear combination of one set of variables to explain the other set (canonical ordination). Redundancy Analysis (RDA) was applied with the socio-economic data entered as the "species" variables and the land cover ones as the "environmental" variables.

4. Results and Analysis

The present research has generated a similar set of land cover variables using the MasterMap™ data first using its land cover/use attributes and then with the addition of information from the ancillary aerial and satellite imagery, and repeated the previous classificatory analyses. This provides the opportunity to compare the classifications produced by both types of multivariate analysis as summarised by the analytical framework represented in Table 1.

43 census counts plus	PCA/Cluster Analysis	Redundancy Analysis
Land cover from aerial/satellite imagery and LandLine™	✓	✓
Land cover from MasterMap™	✓	✓
Land cover from MasterMap™ and aerial/satellite imagery	✓	✓

Table 1. Analytical framework

The results suggest that the MasterMap™ polygon data with its land use/cover attributes adds an environmental component to the classification. However, the relatively broad nature of these attributes is usefully supplemented by the additional information obtained from aerial imagery, for example distinguishing between concrete, tarmac and other types of hard surface material.

5. Conclusion

The paper presents results of the research as comparisons between the two multivariate analyses using the LandLine and MasterMap data as a means of delimiting and quantifying the extent of land cover types and environmental features in an urban mosaic. The results provide the opportunity to examine the potential impact of using MasterMap as opposed to LandLine data in applied academic research. The extension of the previous work to include a contrasting local authority (Colchester), which overall has a less urban character than Salford by including a rural hinterland of small towns and villages, also provides the opportunity to test out the methodologies in a different environmental context.

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Biographies

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The use of Kohonen mapping for the elucidation of space-time trajectories of multiple parameters: potential applications in fluvial geomorphology.

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1. Introduction

The Earth's large, dynamic river systems remain a major geo-hazard both in terms of flooding and erosion. For example, erosion of the Brahmaputra River in Assam, India, has been responsible for more the 400,000 hectares of land destruction since 1955, with more than 100,000 families displaced (Assam Disaster Management Cell, n.d.). Despite the clear need for improved prediction of the dynamics of such channels they remain poorly understood. Within the disciplines of geomorphology and hydrology approaches to predicting complex channel processes continue to focus on the development of deterministic techniques including computational and physical models developed for individual rivers (e.g. Zanichelli *et al*., 2004) or highly specific channel settings. They are commonly three-dimensional, employ highly-parameterised, reductionist approaches, are difficult to apply outside of the specific river settings for which they were developed and are difficult to scale up for regional or continental-scale application. Consequently it is difficult to imagine them as the key to unlocking successful and rapid prediction of large-scale channel dynamism.

Understanding river channel processes at larger scales requires engagement with available spatial data sets. Analysis of planimetric channel parameters from remotely sensed imagery (Mount *et al.*, 2003; Sarma, 2005) or the estimation of hydraulic parameters from digital elevation, digital surface and terrain models (e.g. Pistocchi and Pennington, 2006) remain popular and established techniques. However many additional parameters known to exert major control on channel dynamism can now be estimated at large scales via analysis of remotely-sensed imagery, although exactly how these parameters combine to control dynamism is still poorly understood. These include land use changes and land cover classes (Akbari *et al*., 2006 Boucher *et al*., 2006), inundation histories (Jain *et al*., 2006), riverbed aggradation (Fan *et al*., 2006), bathymetric measurements (Carbonneau *et al*., 2006) and riparian vegetation (Goetz, 2006). The result is a large-scale, multi-parameter analytical environment, in which techniques are required that are capable of integrating and analysing the changing spatial and temporal patterns within parameters deemed to be important in controlling channel dynamism. Should such techniques be applied, an analytical approach more suited to predicting channel dynamism at large-scales may emerge.

In this paper, spatio-temporal self-organising maps, an extension of the standard Kohonen mapping clustering technique (Kohonen, 1990, 1995), are employed to quantify space-time trajectories amongst the values of multiple parameters in some simple river channel datasets. Once computed, the space-time trajectories associated with locations known to have undergone a particular dynamic process can be compared to emerging trajectories across the entire spatial extents of the analysis. Similar trajectories, indicating a high likelihood of the given processes occurring in new locations can then be identified and isolated. The algorithmic processes outlined in this paper are those employed in GISTSOM, a software package developed by the authors for the definition and comparison of space-time trajectories in multi-parameter, spatio-temporal data.

2. Kohonen mapping of multi-dimensional data

A Kohonen map, commonly known as a self-organising map, is an unsupervised neural network capable of representing high-dimensional data in a low-dimensional form through multi-dimensional clustering. Commonly, the output from a Kohonen map is a 2-dimensional array in which there are a predefined number of elements (e.g. 10 x 10) to which input data are assigned. Importantly, it spatially organises input data according to similarities in the values of the multiple dimensions at given locations, so that locations exhibiting similar values in their associated dimensions are represented proximal to one another and those exhibiting dissimilar values are represented distal to one another.

The classic explanation of Kohonen maps exemplifies the organisation of the three dimensions Red, Green and Blue (RGB) associated with image pixels (the sample data) into a two-dimensional output array, such that similar colours are clustered together according to the values in each of the three RGB dimensions. The individual RGB values are viewed as weights which, together, form a weight vector describing the location of the colour in the three-dimensional, RGB space. In the example given in Figure 1, the Kohonen map algorithm will cluster those pixels with the most similar weight vectors (i.e. the most similar colours) together within a two-dimensional array whilst maintaining the maximum possible distance between those pixels with dissimilar weight vectors.

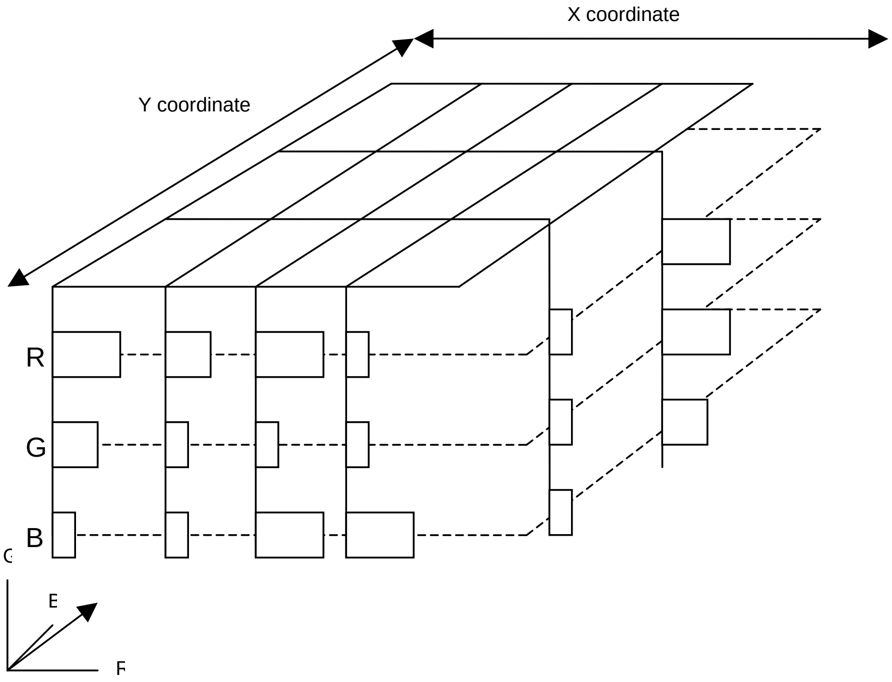


Figure 1. A pixelated array of RGB values (i.e. an image). Each pixel is an input sample to the Kohonen mapping algorithm, with the RGB values forming a weight vector that can be compared to the weight vectors assigned to each element of the Kohonen map. The RGB weight vector for the bottom left pixel is shown schematically.

The Kohonen map clustering algorithm firstly initialises an array of elements (often termed neurons), and assigns weight vectors (most often randomly) to each element of the array according to the dimensionality of the input weight vectors. The distance between each element's weight vector and the weight vectors of the sample datum is then computed according to equation 1.

$$dist = \sqrt{\sum_{i=0}^{n} x_i^{\,2}}$$

(equation 1)

where,

x_i is the value at the *ith* dimension of a sample

n is the number of dimensions to the sample data

The element with the most similar weight vector (i.e. smallest distance) is then termed the best matching unit (BMU) and is made more similar to the sample weight vector according to a learning function which controls the magnitude of modification. Neighbouring elements to the BMU are also made more similar, but to a lesser degree as defined by a neighbourhood function. The key attribute of this process is that the further away an element is from the BMU, the less it learns to be similar to the sample data. The algorithm then iterates, randomly selecting a sample datum each time and identifying the BMU. Crucially, as the number of iterations increases, the size of the neighbourhood around the BMU declines and the learning function decreases. In this way stability in the mapping of the input weight vectors to the weight vectors contained in the output array can be attained. In the case of an RGB image, similar colours will cluster together in the output array and clusters of dissimilar colours will be located distally in the array. The result is a mapping of multidimensional pixel values from the original image to the output array (Figure 2.)

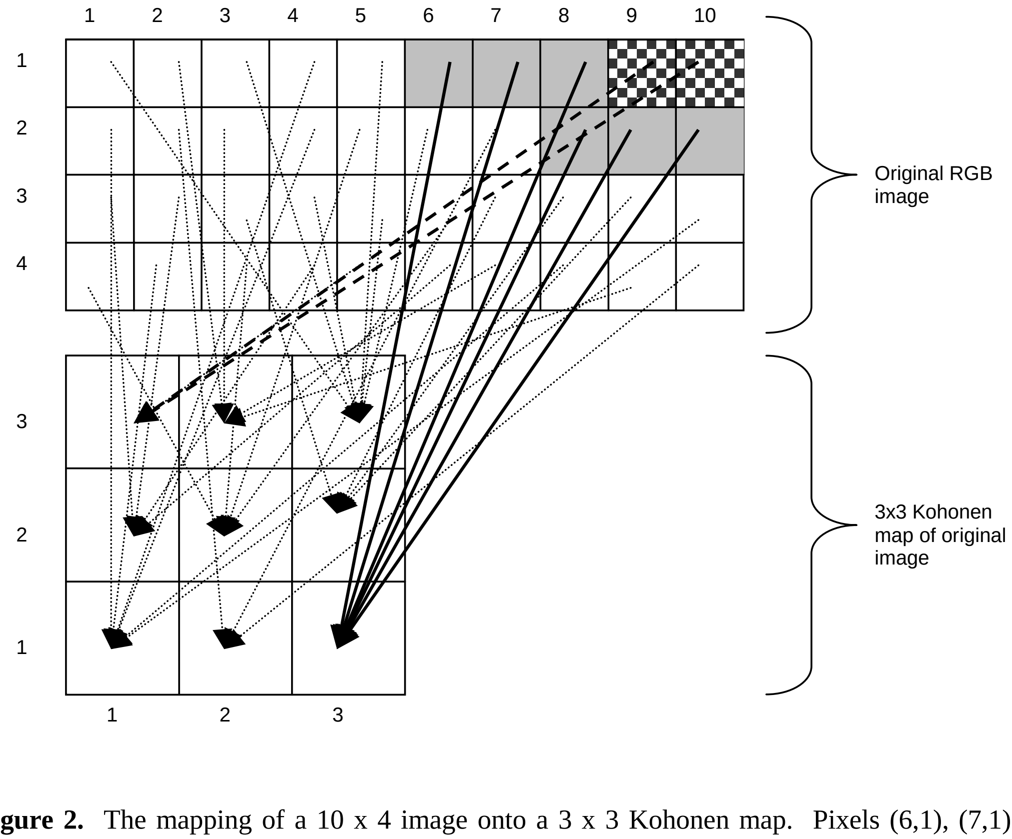


Figure 2. The mapping of a 10 x 4 image onto a 3 x 3 Kohonen map. Pixels (6,1), (7,1), (8,1), (8,2), (9,2) and (10,2) have all mapped to element (3,1) indicating they are all of similar colour. Similarly, pixels (9,1) and (10,1) have both mapped to element (1,3) indicating that

they are of similar colour. These two colour groupings have mapped to elements a long way apart on the Kohonen map indicating that the two groups of pixels contain very different colours.

3. Extending the Kohonen mapping algorithm across time.

The standard Kohonen mapping algorithm described above is applied to sample data collected at one point in time. However, it can be *repeated* on data existing across several time periods, an extension for which GISTSOM has specifically been developed. In GISTSOM, the sample data weight vectors used in the training of the initialized SOM are taken randomly from across *all* of the time periods for which data are available. In this way, the weight vectors against which the Kohonen map learns implicitly include a temporal dimension, and a spatio-temporal Kohonen map evolves.

By comparing the locations in the spatio-temporal Kohonen map to which input data for each time period have been mapped, a set of coordinates describing the trajectory of the sample data across the Kohonen map through time can be extracted (Figure 3). These space-time trajectories represent the changes in the multiple dimensions of each sampled datum (i.e. pixel in an image) through time. By comparing the space-time trajectory coordinates for all of the input sample data, similar trajectories can be identified. In the case of GISTSOM a simple coordinate tolerance measure has been used as a measure of similarlity. Sample data with similar space-time trajectories can then be identified as samples whose multi-dimensional values have changed in a similar manner through time. In the case of multiple RGB images, samples with similar space-time trajectories would have experience similar colour changes through time.

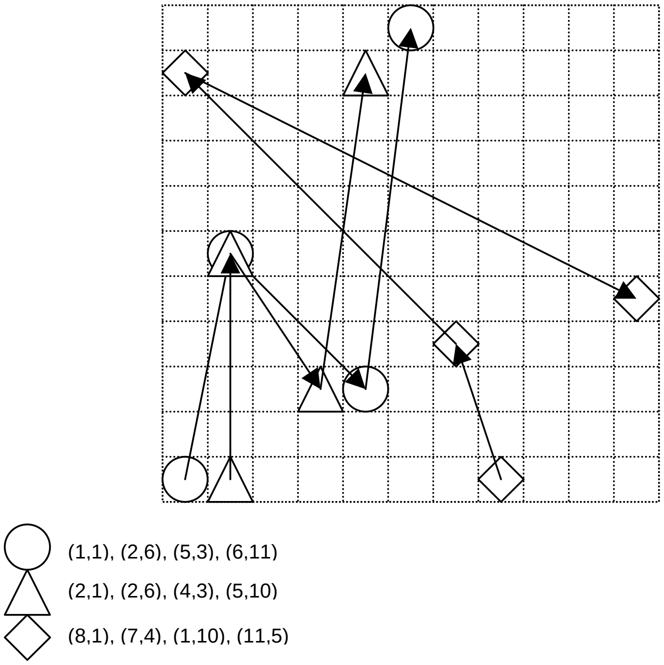


Figure 3. Space time trajectories for three samples in an 11x11 Kohonen map. Clearly the trajectories of the circle and triangle data are very similar indicating that all of their multiple parameter values have responded in very similar manner through time. By contrast, the trajectory of the diamond data is very different indicating a very different response in its multiple parameters through time.

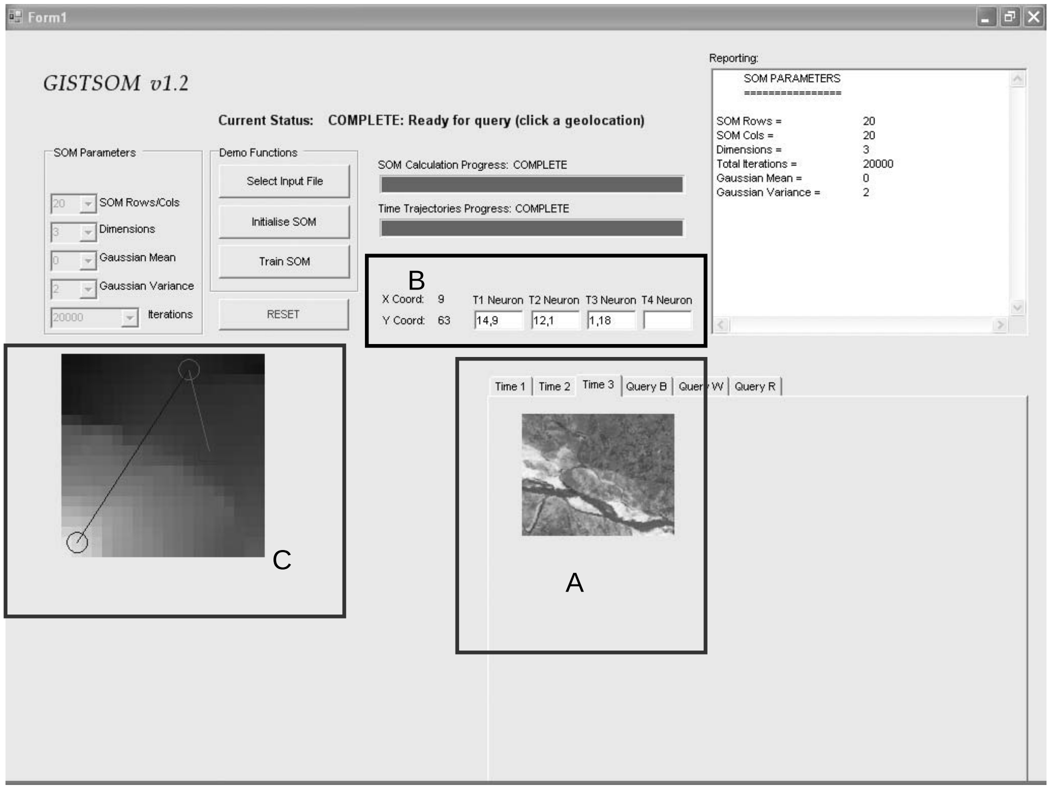
4. Beyond RGB: Kohonen maps in dynamic river channels

Moving beyond the example of RGB values, the dimensions within the sample data of a Kohonen map can be representative of any phenomena. In the case of understanding dynamic river channels, the sample data at a given point in time can be represented by any number of rasters, each defining the values of an individual parameter considered an important control of river dynamism (e.g. roughness, bed load size, vegetation type, land use type, inundation histories etc.) over a given spatial extent. These data can be held in multi-dimensional arrays, sampled, and mapped to the spatio-temporal Kohonen map space. By repeating the mapping for additional time periods, the space-time trajectories associated with each cell in the data's spatial extent can be defined.

According to the analysis outline above, space time trajectories for a cell known to have experienced a given form of channel dynamism can be extracted from available spatio-temporal datasets of relevant parameters recorded *prior* to the occurrence of the dynamism. In this way, the space time trajectory for the multiple parameters which is *predictive* of the given dynamism can be computed. It then follows that by searching for the occurrence (or it's apparent development) of this space-time trajectory throughout contemporary data, cells in which multi-parameter responses are indicative of the given dynamism can be isolated.

5. GISTSOM exemplar

The graphical user interface of GISTSOM during an example analysis of panchromatic river channel data over three temporal periods is given in figure 4. GISTSOM provides both a visual and numerical output of the space-time trajectories associated with any cell in the input raster data set. It allows user selection of a given trajectory for any cell and the selection of all cells displaying similar trajectories according to a tolerance value. Data may be output to any proprietary GIS for further analysis (Figure 5).



Current Status: COMPLETE: Ready for query (click a geolocation)

20 SOM Rows/Cols
3 Dimensions
0 Gaussian Mean
2 Gaussian Variance
20000 Iterations

SOM Calculation Progress: COMPLETE
Time Trajectories Progress: COMPLETE

```
     SOM PARAMETERS
     ================

SOM Rows =              20
SOM Cols =              20
Dimensions =            3
Total Iterations =      20000
Gaussian Mean =         0
Gaussian Variance =     2
```

X Coord: 9
Y Coord: 63

T1 Neuron	T2 Neuron	T3 Neuron	T4 Neuron
14,9	12,1	1,18	

Figure 4. The GISTSOM graphical user interface (GUI). Three parameters of the input data for each time period are displayed using the RGB colour guns (A) allowing input data visualisation. Following the initialisation and training of the Kohonen map, interaction with A allows the space-time trajectory for any cell of the input rasters to be displayed as coordinates (B) or visually in the Kohonen map (C).

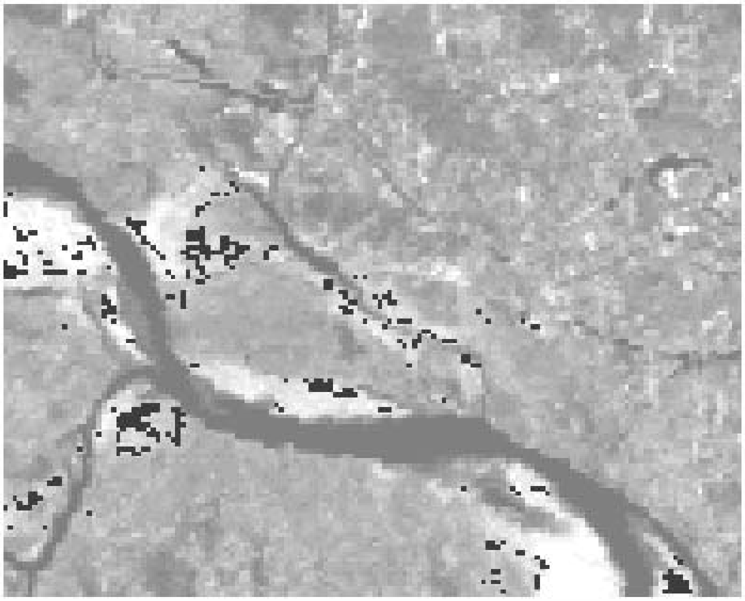


Figure 5. GISTSOM output. Black cells indicate the locations of cells which display a similar space-time trajectory amongst the panchromatic parameters to that selected within the GISTSOM GUI.

6. Discussion

There is little doubt that the ability to analyse the multi-parameter data sets relevant to the prediction of river channel dynamism through space and time represents a significant advance over the present analytical procedures employed by fluvial geomorphologists. These often rely on the visual interpretation of data, contain an over emphasis on either the spatial, or temporal dimensions contained within the data, and are not automated. Consequently they remain restricted in their ability to predict channel dynamism at large spatial and temporal scales. The analysis of Kohonen map space-time trajectories offers a solution to these issues, affording equal emphasis to space and time, removing the need for visual interpretation and analysis of complex data and automating the analytical process.

However, the procedures are dependent on the availability of raster data sets encompassing all of the parameters which drive channel dynamism. For many important parameters good spatio-temporal data are available (e.g. land cover mapping and inundation histories from Landsat TM imagery), but for others, particularly those reliant on ‘flown-for-purpose’ data, data availability may be a significant restriction to the application of the technique. In addition, during high river stages it is likely that increased inundation area will limit the completeness of the data records for many important parameters, falsely indicating major changes in key parameters. For example, a highly vegetated area at time t_1 which is inundated at time t_2 will appear as ‘losing’ its vegetation under the inundated area. Therefore, enormous care is needed in selecting data for use in analysing space-time trajectories.

7. Conclusions

The quantification of space-time trajectories of spatio-temporal Kohonen maps offers an exciting development for those analysing dynamic systems driven by changes in multiple parameters in both space and time. It offers automation of frequently manual analyses and removes bias in the analysis of the spatial or temporal dimensions. Importantly, it offers a method for the prediction of locations of future dynamism, by analysing the patterns of spatio-temporal change in the parameters governing the dynamism at locations where it has already been observed. However, the technique is dependent on the availability of raster data sets which fully describe the governing parameters through space and time, and this may limit its application to certain problems.

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Automatic identification of Hills and Ranges using Morphometric Analysis

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1. Introduction

The breadth of cartographic techniques developed over the centuries for representing the earth's morphology is testament to its importance (Imhof, 1982). The shape of the earth's surface reflects a multitude of geomorphological processes interacting with the surficial geology. Altitude, slope and aspect have a huge bearing on patterns of land use and habitation. The correct interpretation and 'reading' of the landscape is critical to navigational tasks and safe route planning and execution (Purves et al., 2002). A variety of cartographic techniques have been developed to convey morphology – from the very fine scale, using hachuring (Regnauld et al., 2002), hill shading and contouring (Mackaness & Stevens, 2006), through to the very coarse scale in which colour tints and text are used to convey highly generalised caricatures of components of the earth's surface (Figure 1).

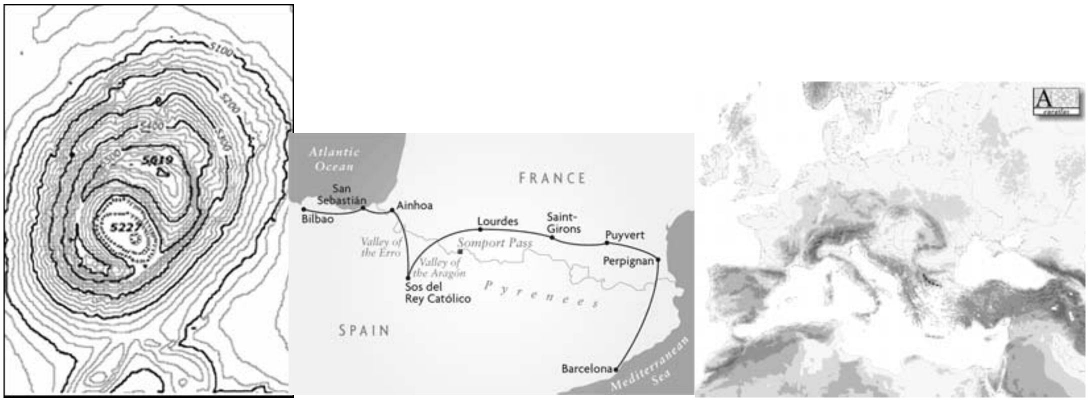

Figure 1: A variety of techniques used to convey generalised views of morphology increasingly (from individual hills to mountain ranges)

It is not simply the case that as the scale changes it convey less detail in a feature; more the case that at smaller scales one begins to see different types of features - from the individual hill to the connected set of ridges, and from the collection of hills to a mountainous region. Partonomically speaking (Chaudhry & Mackaness, 2006b), macrogeomorphic features (such as those in Figure 1) are comprised of a collection of prominences having sufficient distinction from adjoining landforms, of sufficient density, frequency and extent that they collectively define a labelled region. From a generalisation perspective, and in the context of multiple representation databases, the intention is to record attributes of geographic space at only the very finest scale, and to then automatically derive higher order objects whether it be deltas from collections of meandering rivers, or cities from dense collections of buildings (Chaudhry & Mackaness, 2006b). Here we present an approach to the automated identification of objects representing landscape features such as hills, mountains and ranges from a high resolution digital terrain model (DTM). The development of such an approach has important implications in terms of spatial analysis and for the generalisation of spatial databases which are prerequisite to cartographic generalisation.

2. Methodology

What constitutes a hill, a mountain chain or region depends on the scale of observation (Fisher et al., 2004). Many researchers have arrived at different definitions for identification of these kinds of features (Bonsall, 1974; Campbell, 1992; Cohen, 1979; Dawson, 1995; Purchase, 1997) reflecting their fuzzy nature and our conceptual prototypical view of them. Various approaches have been proposed for modelling the fuzziness in landscape features (Fisher, 2000; Robinson, 1988, 2003; Robinson et al., 1988; Usery, 1996; Wood, 1998). But still most of the GI Systems rely on discrete objects for analysis and for cartographic portrayal of these features. Here we present an approach for the creation of discrete objects from a high resolution DTM. The overall methodology is presented in Figure 2. In the following sections we will present different stages of the approach in more detail.

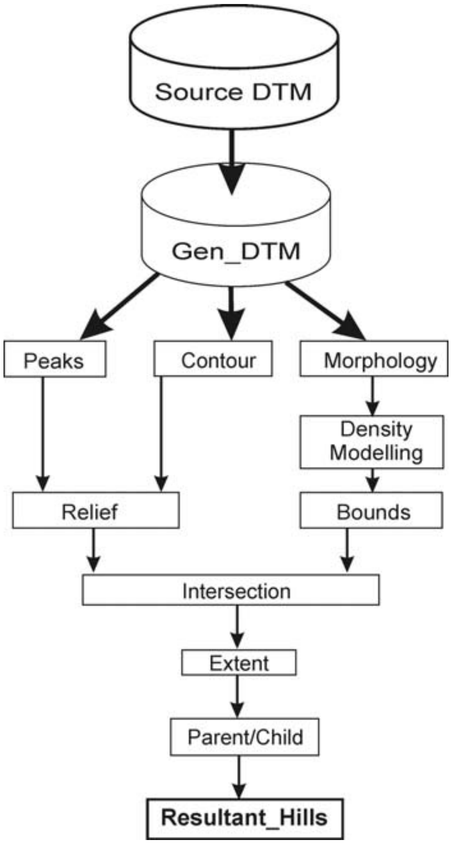

Figure 2: The overall method by which hills are identified.

2.1 Relief/Prominence Calculation:

Relief or Prominence is a concept used in the categorization of hills and mountains. It is the vertical distance between the highest and lowest points in the map area (Press & Siever, 1982). Prominence for each peak can be calculated by its key col or key pass. Col or pass is defined as the point that connects a ridge or a path of a peak to higher terrain. The key col or key pass for a peak is the highest among all its cols. If the peak is the highest point in the given area then its key col will be the ocean, and its prominence will be its absolute height. The key col occurs at the meeting place of two closed contours, one encircling the peak of interest and the other containing at least one higher peak (Bivouac.com, 2004) (Figure 3). In this research the prominence was calculated as the elevation difference between the ‘key contour’ (i.e. the contour that encircles the given peak and no higher summit) and the summit of the peak of interest (Figure 3 and Figure 4).

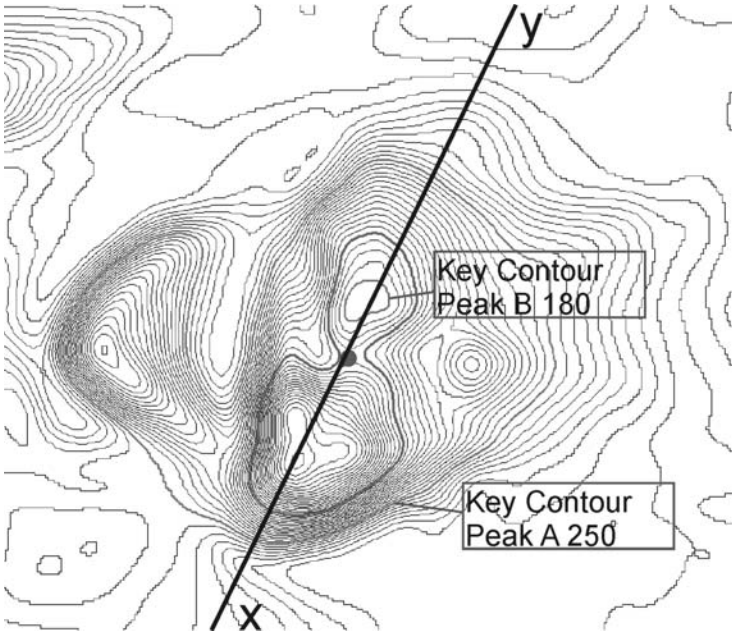

Figure 3: Contours created from a given DTM. Key contours for peak A and Peak B are highlighted in red. The key col for peak B (in green) is present at the meeting point of two contours (highlighted in blue). (Mapping is Ordnance Survey ©Crown Copyright. All rights reserved).

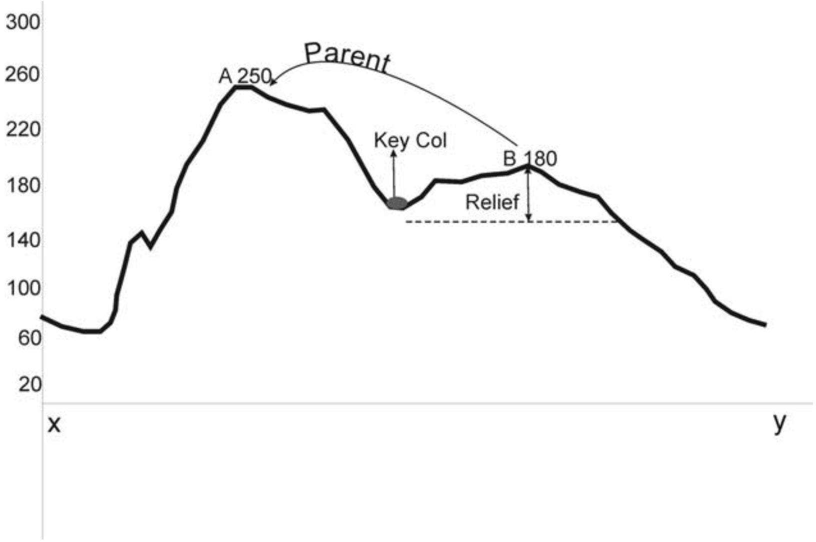

Figure 4: Relief and Key Pass of the line transect in Figure 3

2.2 Morphological Bounds

It is possible that part of a surface may be quite plane between the peak and the key contour (Ben Nevis and the UK's coast). Therefore in addition to prominence we also need to model the change in surface in terms of its morphology. Several methods exist for the identification of morphometric features (Evans, 1972; Maxwell, 1870; Peucker & Douglas, 1974; Tang, 1992). Here we have used the techniques developed by Wood (1996). The approach is based on the quadratic approximation of a local window (kernel) and assessment of the second derivative. The second derivative is a function of the rate of change of slope. Wherever the surface is plane the second derivative is ϕ (Wood 1996a). Due to the scale dependent nature of the phenomena different kernel sizes result in different classification of each pixel. The kernel size for this research was empirically determined and was set to 25 cells. All non plane (non-zero) cells were converted into polygons. A clustering algorithm (Chaudhry & Mackaness, 2006a) was applied to create boundary polygons. The area of the resultant polygon is used as a threshold for elimination of small polygons since a hill or mountain needs to have a significant area to be identified as such (Figure 5).

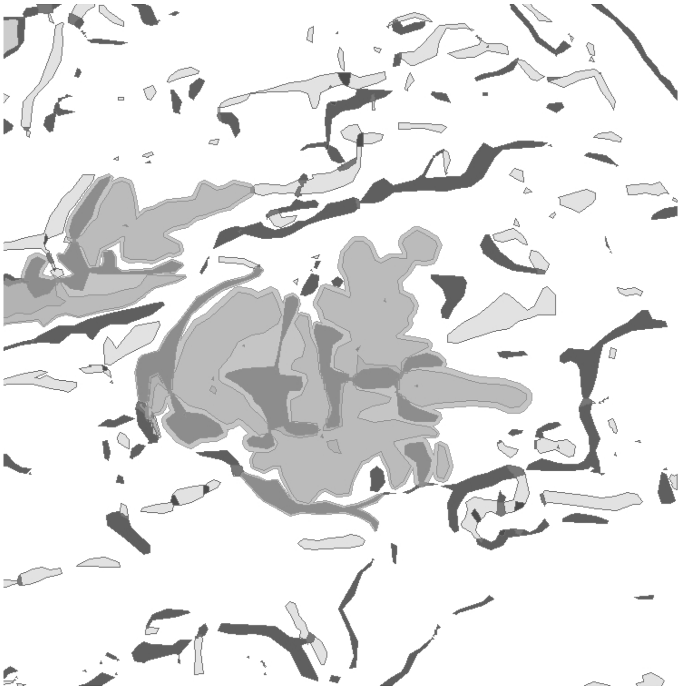

Figure 5: Morphology classes (second derivative >ϕ yellow, <ϕ zero in blue, ϕ in white). Resultant boundary polygons (pink).

2.3 Extents of Hills and Mountain Ranges

Once the morphological bounds, relief and key contour have been identified we can identify the extent of a hill. For each peak we start with its key contour and we asses how much the landscape varies within that contour. This is done by finding the amount of overlap between the contour polygon and the morphological boundary polygon. If the result is below a threshold then the surface is not changing (i.e. most of the surface is quite flat) and the next higher contour is selected. This process is repeated until the degree of change is above or equal to a threshold. The contour polygon selected is assigned as the extent of the given peak. This sequence of events is illustrated in Figure 6.

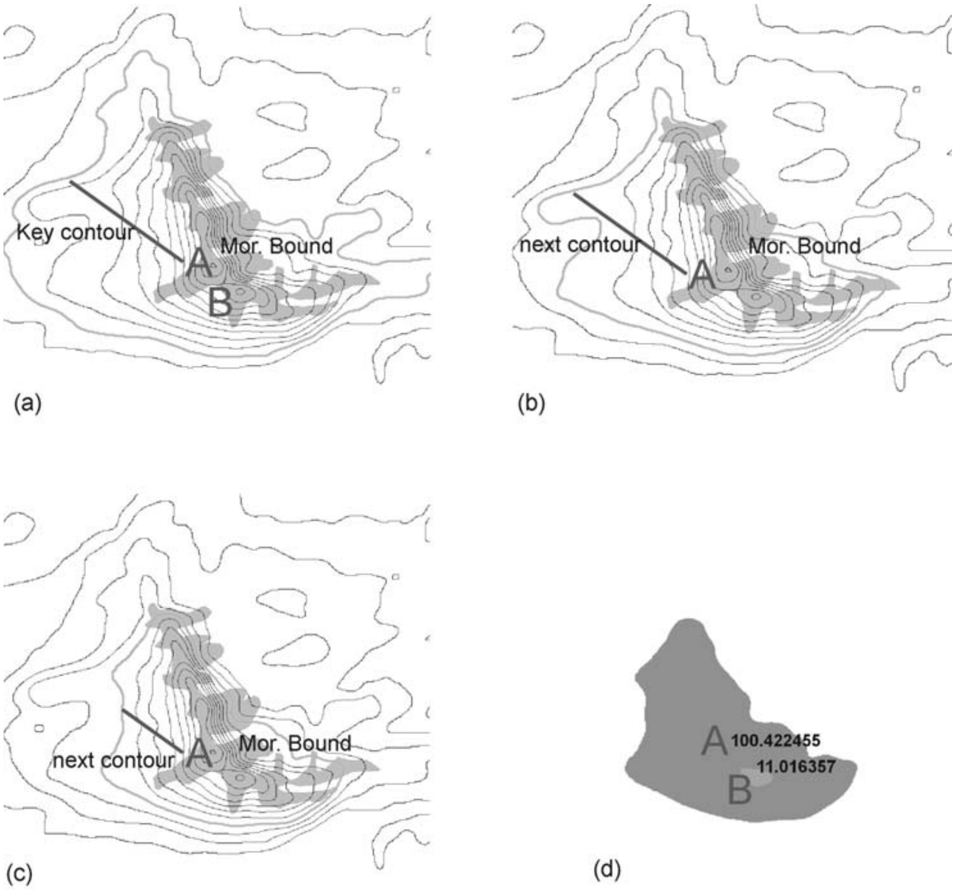

Figure 6: (a) Start with the key contour (highlighted) for the peak (red circle) and calculate the amount of area intersection, (b) Select the next inner contour and calculate the area of intersection, (c) calculate the next inner contour since the area intersection is greater than the threshold. This is the extent of the highlighted peak, (d) Resultant extents for two peaks along with their prominence values.

3. Case Study

This methodology was applied in the derivation of hills and mountain range extents directly from a large scale digital terrain model (OS LandForm Profile). The platform selected for the implementation was Java, ArcGIS 9.0 and LandSerf. (Wood, 1996). In this section we present results for a region around Edinburgh (Figure 7). Text points representing hills in this region were selected from OS Strategi dataset (1:250,000). Figure 8a shows the resultant hill extents and Figure 8b shows extents for only those hills that have a relief greater than 100m.

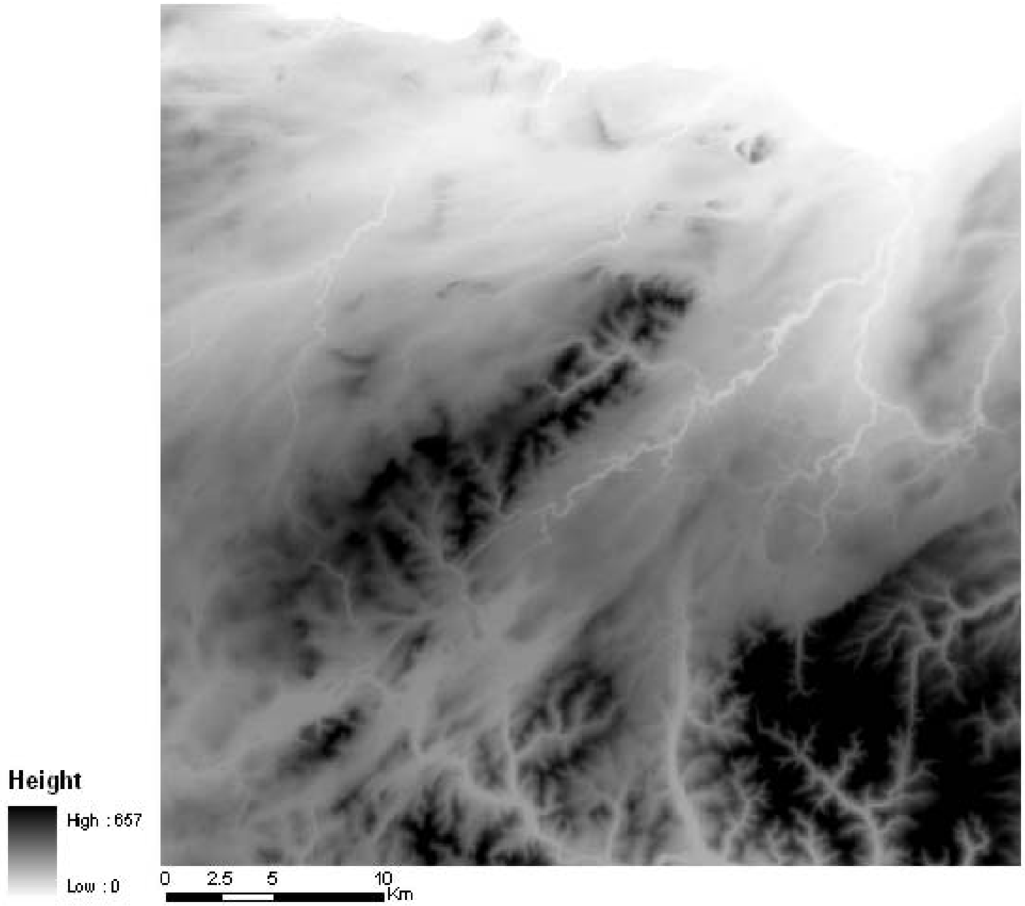

Figure 7: DTM (OS LandForm Profile) Edinburgh and Pentland Hills. (Mapping is Ordnance Survey ©Crown Copyright. All rights reserved).

a b

Figure 8: (a) Resultant hills and range extents for Figure 7 (b) Hill and Range extents with relief greater than 100m (Edinburgh and Pentland region)

4. Evaluation

Using the name points from OS Strategi (1:250,000) and OS Explorer (1:25,000) we performed the evaluation by checking if the named points representing hills and ranges fall within the boundary created by the algorithm (Figure 9 and 10). It is important to point out here that both Strategi and Explorer are cartographic products thus there are several cartographic considerations (size, clutteredness, significance) taken into account before a text point is created for a feature. As shown in the Figure 9 and 10 most of the font points lie within the boundaries generated by the proposed approach. The important thing to note here is these cartographic products (Strategi and Explorer) were created without any link between the text point and the place being named. But once the boundaries such as those generated here are identified they can then be used to create this link. This will facilitate both the cartographer and development of automatic cartographic generalisation techniques.

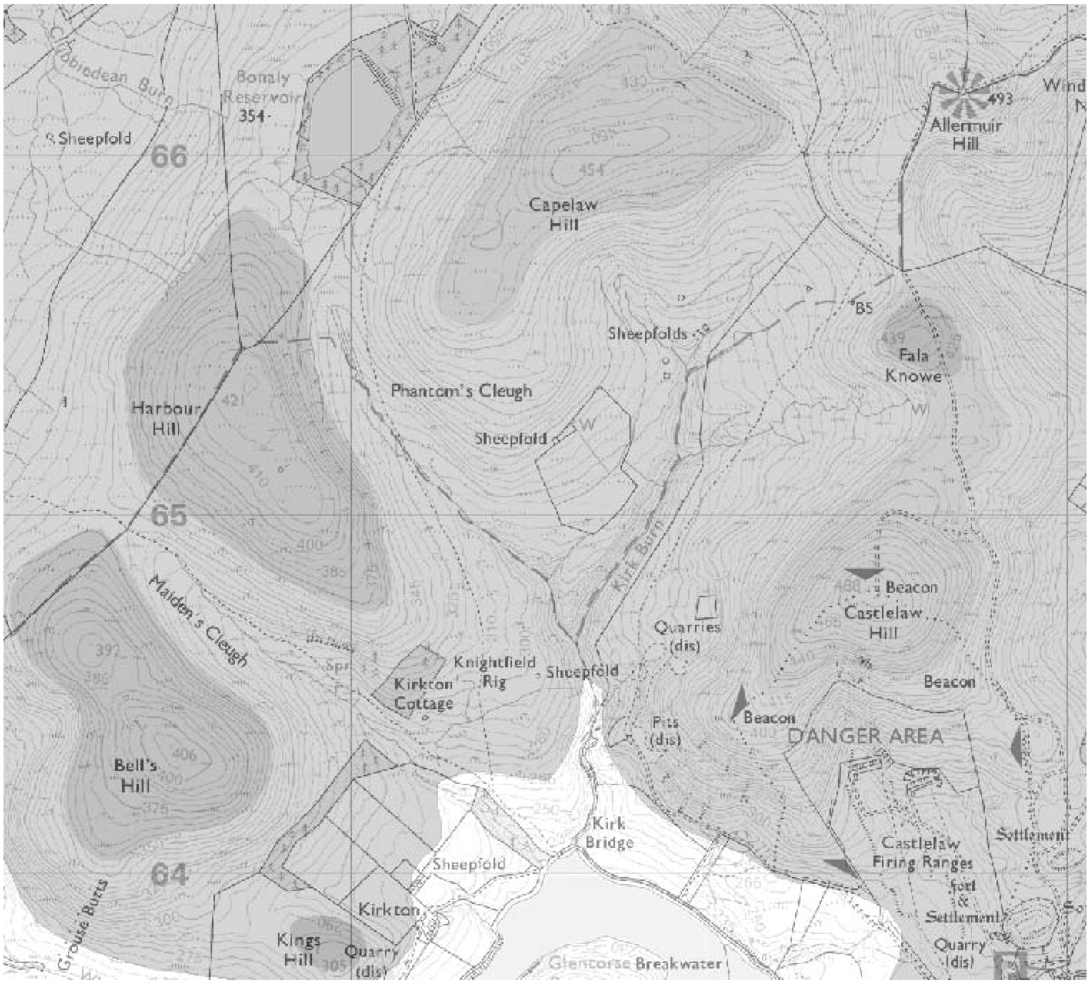

Figure 9: OS Explorer (1:25,000) overlaid on hill extents derived by the proposed methodology. Bell Hill, Harbour Hill, Cape Hill. King Hill and Castlelaw Hill annotations lie within the footprint generated. (Mapping is Ordnance Survey ©Crown Copyright. All rights reserved).

Figure 10: Text points selected from OS Strategi lie within the footprint of the hills derived from the implementation (relief above 100m). (Mapping is Ordnance Survey ©Crown Copyright. All rights reserved).

The resultant extents can also be used to find the parent and child relationships between hills. This enables us to create ranges. Once the relationships have been identified, hills with prominence or height less than a threshold can be aggregated into their parent hills. This results in the creation of composite objects present at higher level of abstraction (such as those in Figure 1).

5. Conclusion

In this paper we have demonstrated an approach for finding the extents of continuous phenomena such as hills and mountain ranges so that objects representing these concepts can be made explicit in the database. Research presented in this paper illustrates the possibility and utility of defining and extracting boundaries of continuous real world phenomena into database objects. Once these objects are generated they are useful not only in cartographic generalisation in terms of symbol placement but also for model generalisation for aggregation of source objects and also for spatial analysis. Future extensions will take into account their fuzzy membership. Future work will also look into applying similar approaches for the extraction of settlements or forest regions.

6. Acknowledgement

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Biography

Omair Chaudhry is in the third year of his PHD at The University of Edinburgh. The area of study is on the automatic derivation of small scale topographic databases directly from OS MasterMap. The focus, as part of model generalisation, is the automatic detection of higher order phenomena from large scale databases.

William Mackaness is a senior lecturer at The University of Edinburgh, and is PhD supervisor to Omair.

Classifying Buildings Automatically: A Methodology

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Introduction

In this paper, a pattern recognition based methodology is proposed to automatically classify the buildings by using their morphological properties (i.e. area, perimeter, orientation) and topological spatial relationships (i.e. Adjacency, Neighbourhood). Recognition, analysis and classification of urban structure is an important issue in urban land use modelling (Batty 1992). In order to understand overall urban morphology and land use classification, importance of calculating the structural and behavioural properties of built up land parcels is well studied (Batty 1992; Batty and Longley 1994). Most of the pattern recognition methodologies adopted and applied in the past, to ascertain urban land use and its structural identification, are based on remotely sensed data and driven by image processing techniques (Barnsley, Moller-Jensen et al. 2001). Researchers have applied both: (a) visual interpretation and (b) automated methodologies to extract the built up features and also to infer their uses/functions (Bauer and Steinnocher 2001). One of the fundamental weaknesses of such approaches is that it is difficult to extract land parcel functional information solely from the identification of land surface characteristics and it requires ancillary data to improve the classification (Barnsley and Barr 1997; Barnsley, Moller-Jensen et al. 2001; Bauer and Steinnocher 2001). In the UK there has been a substantial research towards creation of national level land use database at Government level. For example; national land use classification (NLUC) 1975, The land use change statistics (LUCS) early 1980, national land use stock survey during early 1980, and national land use database (NLUD) (Harrison 2000; Tompkinson, Morton et al. 2004). The studies to assess the feasibility of a National Land Use Stock Survey (e.g. Roger Tym and Partners, 1985 and Dun and Harrison, 1992) commissioned by former Office of Deputy Prime Minister (ODPM) currently Department of Communities and Local Government (DCLG) concluded that land use should be calculated and maintained using large scale digital mapping (Harrison 2002; Wyatt 2002). The results of the research work done based on these recommendations have figured out that there is a need for methods to automatically classify built up land parcels (Harrison 2002; Tompkinson, Morton et al. 2004; Wyatt 2004 ; ODPM 2006.). Therefore this paper presents a methodology that uses pattern recognition techniques for automatically classification of buildings.

Problem Definition

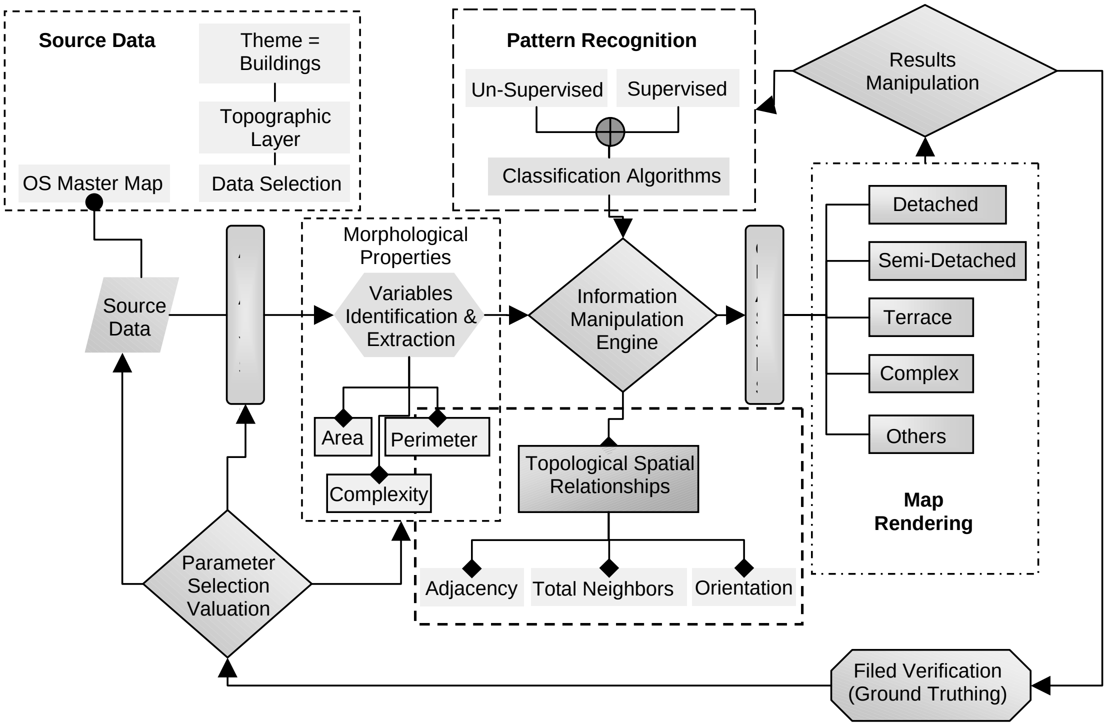
The pattern recognition techniques used for identifying the built up land parcels, computing their characteristics and inferring urban land use, utilises human intuition of map or image interpretation (Barnsley, Moller-Jensen et al. 2001; Bauer and Steinnocher 2001). Given a map or satellite image, humans intuitively study the spatial context of topological features (e.g. adjacency, distance, orientation) within overall environment along with the morphological properties (e.g. size, perimeter, shape) and infer the function of features (Barnsley, Moller-Jensen et al. 2001; Tompkinson, Morton et al. 2004). The obvious disadvantage or weakness of this approach lies in the fact that the task becomes manually intensive when applied to anything larger than the local scale. If intuition of this nature could be modelled along the lines of how maps or satellite images are interpreted, it would become possible to classify buildings automatically (Barnsley, Moller-Jensen et al. 2001). The objective of this part of research is to automate the classification of buildings using morphological properties and topological spatial relationships. This will then provide evidence for the examination of the emergent properties of building complexes and surrounding land.

Proposed Solution

In order to automate the classification of buildings, a methodology is proposed in this paper which applies the pattern recognition algorithms on morphological properties and topological spatial relationships for building features to infer their function (useage). The first step requires extracting and computing the morphological properties and topological spatial relationships.

For the purpose of this research, the UK has been chosen as study area. In the UK, all the topographic features both natural and man made (e.g. roads, land parcels, buildings etc) are captured, managed, maintained and updated in digital format by Ordnance Survey (OS). The digital product that provides the spatial and non-spatial information about real world features is called OS MasterMap (Harrison 2002; OS 2006; ODPM 2006.). Other countries use an equivalent for example Digital Cadastral Data Base (DCDB) in Australia. OS MasterMap has been used in this research to extract all the building features. The main advantage of OS MasterMap is that the building features are planimetrically accurate and can be selected as single theme. However one major disadvantage is that the theme based organization in OS MasterMap does not provide any information about the function of buildings but can be used as minimum mapping unit for building sub-classification (ODPM 2005; OS 2006; ODPM 2006.). Once the buildings are extracted from OS MasterMap, next step involves the computing the morphological properties and spatial relationship. Finally applying both supervised and un-supervised pattern recognition algorithms for segregating the buildings into separate classes. The results then rendered onto map and visual inspection performed and model calibrated. The need for calibration will be discussed in coming section. Figure 1 shows the proposed model in block diagram.

Figure 1: Proposed Buildings Classification Model



Implementation

A Geographical Information System (GIS) was used to compute the morphological properties and topological spatial relationships. Figure 2 describe the process involved in building feature extraction from OS MasterMap topographic layer. The extracted layer implicitly contains the some of morphological properties i.e. area and perimeter for each building. However, topological spatial relationships and complexity of the buildings needs to be computed explicitly. For both of the computations, ESRI ArcGIS package was used and some of programs were written in Visual Basic for Application (VBA) using ArcObjects (ESRI). Figure 3 explains the two topological spatial relationships that were computed i.e. "Adjacency" and "Total Neighbours". There is no prior information that which of the pattern recognition technique would be suitable for this application. Therefore, both *supervised* and *un-supervised* classification algorithms were used for segregating the buildings into appropriate groups. *K-Means* and *Self Organizing Maps (SOM)* are two algorithms that were used to cluster the buildings with similar characteristics by feeding in the morphological properties and topological spatial relationship information. Where as discriminant analysis was used for supervised classification. The discriminant analysis approach divided the buildings into classes corresponding to representative sample of the buildings function type.

Adjacency:	This gives the measure about how many buildings are sharing common border or side;
Total Neighbours:	Describe how many buildings are present in local cluster of buildings all sharing at least one side. This variable is helpful in identification of single building and group of buildings;

Figure 2: Extraction of Buildings from Topographic Database (Digital)

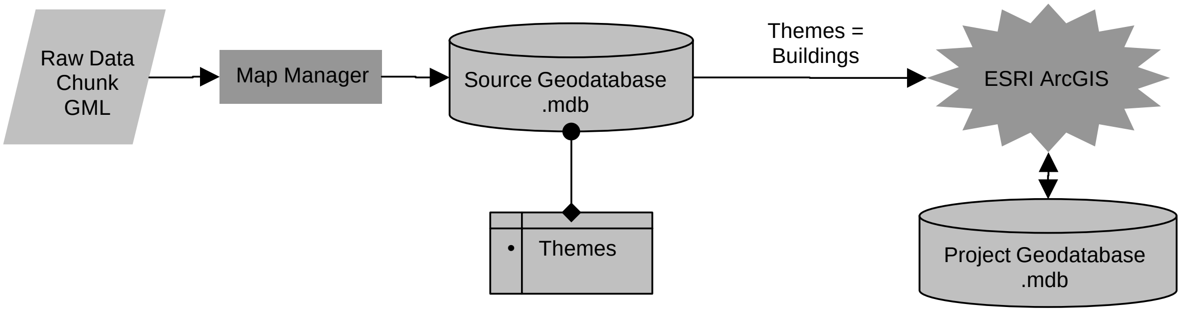
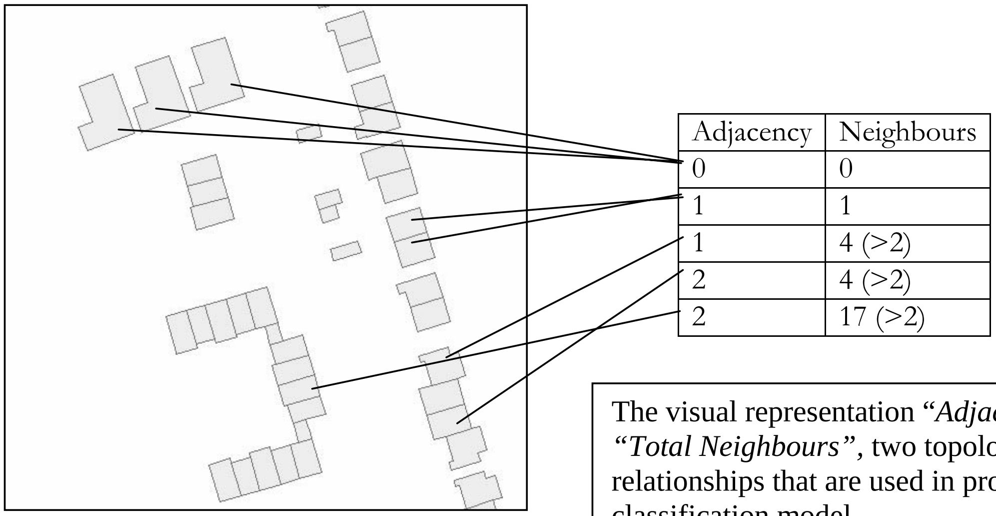


Figure 3: Explanation of Topological Spatial Relationship calculated



Adjacency	Neighbours
0	0
1	1
1	4 (>2)
2	4 (>2)
2	17 (>2)

The visual representation "*Adjacency" and "Total Neighbours"*, two topological spatial relationships that are used in proposed classification model.

Conclusion

This paper has presented a methodology for automating the classification of buildings. The proposed solution suggested deploys a supervised and un-supervised classification technique by using morphological properties of each building feature and topological spatial relationships.

The automated classification approach proposed in the model proves to be feasible for deriving the function of building features (Masroor 2007). The essential step in this process is the adjustment of the number of parameters and clusters for un-supervised algorithms (K-Means and SOM) and more accurate prior classification of training dataset for supervised algorithms (Discriminant). By testing different configurations of morphological characteristics and spatial relationship it is possible to populate a rule base for building classification. The same rule based would be applied in next step to automatically segregate all the buildings in appropriate groups. The main types of housing are picked up quite nicely i.e. Terraced, Mid-Terraced, Semi-Detached and Detaches housing. However a building type that caused major problem were garages. It was concluded that it is necessary to identify garages and isolate then before applying algorithms to identify any other building type. *Address Point* is another dataset within suite of OS product and holds key information. Address Point is set of points representing the location where post is delivered. It is assumed that no mail is delivered to a garage. Therefore it is possible to identify and isolate garages by integrating this information with existing one. Initial verification of the results produced by the model is based on the visual interpretation of the MasterMap with an overlay of AddressPoint layer. However, to further test the accuracy of the out puts (classification) of the model, site visits are needed to be arranged to compare the out puts with the reality. Also, further tests are planed to be carried at final stage of research (Masroor 2007) to gage the sensitivity of method to classify similar cluster groups.

It can be seen that automation of buildings classification process can be achieved using a Pattern Recognition Methodology. The methodology has proven to be flexible, adaptable and allows some level of evolution of the approach. However the adoption and evolutionary processes maintain the integrity of the fundamental concept of buildings classification.

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Empirical experiments on the nature of Swiss mountains

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1. Introduction and aims

Issues related to the nature of the existence (or not) of mountains and the difficulties of defining the extent of such *fiat objects*, are well known in the philosophical and GIScience literatures. Smith and Mark (2003) point out that such a question has profound practical implications, since many users of GIS conceptualise space by dividing it into distinct objects whilst working with data which are best represented by fields. As a trivial example, consider the question of "what are the average gradients found on the Matterhorn?" The first part of the question requires us to define gradient, which can be calculated across different scales and using a variety of different models of our continuous surface and algorithms to extract the magnitude of the first derivative of the terrain surface. The second part of the question, and the focus of this paper, requires that we define the extend of the Matterhorn.

Fisher et al. (2004) addressed this issue by comparing the landforms (and in particular peaks) identified by multi-scale morphometric analysis with a toponym database for the English lake district. Ontological research has shown that mountains are one of the most commonly reported forms of "natural earth formations" (Battig and Montague, 1968 in Mark et al., 1999) and taken empirical approaches to deriving information about *geographic objects,* defined as being bounded spatial objects consisting of parts which may be complex (Mark et al., 1999). In gathering information about the nature of geographic objects a range of questions can be considered. For example, what terms are associated with a given geographic object, how can the boundaries of such objects be defined, and what are typical attributes of a geographic attribute.

In this paper we report on ongoing work aimed at further investigating the question of "What is a mountain" through a mixture of empirical investigations, data mining and morphological analysis. Here we report on the empirical part of the work, where our aim is to gather information that we can apply in morphological analysis.

2. Methodology

Since it has been found in previous work (e.g. Mark and Turk, 2003) that categories associated with geographic objects differ for people from different locations and cultures, our study focused on a group of subjects from similar backgrounds (Swiss geography students) and investigated only mountains in a Swiss context.

The study was carried out through a questionnaire, delivered over the internet, which subjects could complete in their own time. To control for bias occurring as result of question order, four versions of the questionnaire, differing only in terms of question order, were prepared. On starting the questionnaire, subjects were randomly allocated one of the four possible versions of the questionnaire. The questionnaire contained a total of 17 questions, of which 2 were open format (i.e. the users could type a response) and the rest closed format (i.e. the user selected a possible value from a list).

The questions could be divided into categories related to terms, attributes and boundaries. Terms associated with mountains were collected through an open question, where users were simply asked to enter up to three terms that they associated with mountains.

Data about the following attributes were collected: height; slope; tree line; influence of civilisation, dominance and prominence, where dominance relates to the distance to neighbouring peaks and prominence to the difference in altitude between neighbouring peaks. Height values were collected through an open question, with the remaining attributes being closed questions where the users were asked to select a value from a range associated with some form of illustration. To compare the effects of differing types of illustration, users were presented with illustrations in three forms: schematic sketches, 3D visualizations generated from Google Earth and photographs. Figure 1 shows a typical question, in this case for prominence illustrated in the three ways described above. For each question, users are asked to select from a range of values lying between 1 (not a mountain) to 7 (clearly an individual mountain) based on the following question: “How ‘mountain-like’ is object A?”

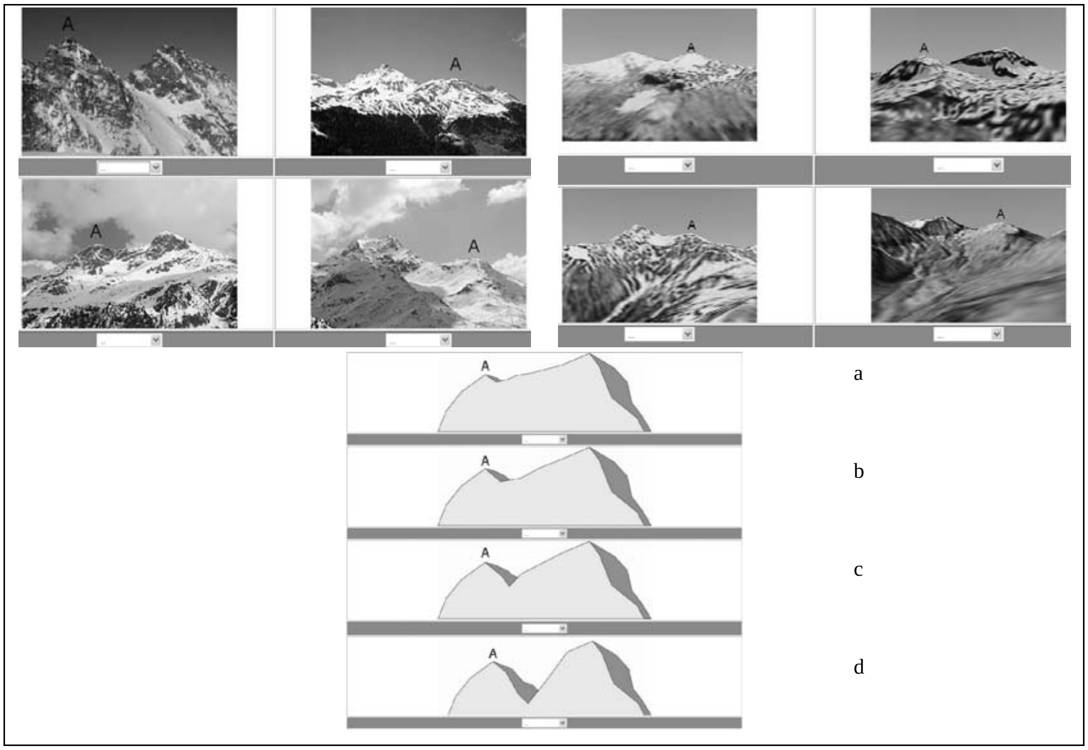

Figure 1: Example of attribute question for prominence, using photograph, 3D visualisation and schematic illustration. Results for schematic illustration are illustrated in Figure 3.

Finally, a set of questions investigating the boundaries of individual mountains, all based on the use of photographs were posed, where subjects were asked to select a single photograph which best described the boundaries of an individual mountain.

3. Results

The questionnaire was completed by 61 subjects. Of these 61, ~85% originate from the main urban regions of Switzerland (the "Mittelland"), some 10% in the Alps and the remaining 5% from outside Switzerland. Table 1 shows the terms which more than one subject associated with mountains.

Hoch (high)	20	Steinbock (ibex)	2
Fels (rock)	17	Sonne (sun)	2
Schnee (snow)	17	Spitze (peak)	2
Steil (steep)	15	Wandern (hiking)	8
Natur (nature)	7	Snowboarden (snowboarding)	3
Aussicht (view)	6	Klettern (climbing)	3
Mächtig (huge)	6	Freizeit (leisure)	2
Alpen (alps)	4	Ski (skiing)	2
Gipfel (summit)	4	Bergsteigen (mounaineering)	2
Stein (stone)	4	Matterhorn	4
Eis (ice)	2	Schweiz	3
Gletscher (glacier)	2	Eiger	2
Massiv (massive)	2		

Table 1: Terms associated with mountains

Figure 2 illustrates the height values chosen by subjects as being the minimum height of a Swiss mountain, where the mean was 1364m with a standard deviation of ± 713m.

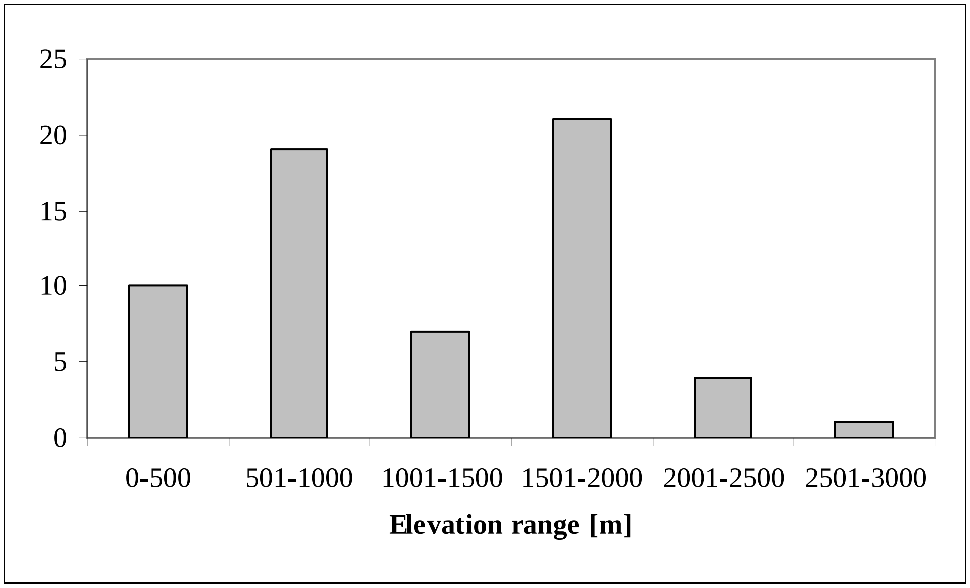

Figure 2: Distribution of representative Swiss mountain heights

Figure 3 shows a set of illustrative results for the schematic illustration of prominence in Figure 1.

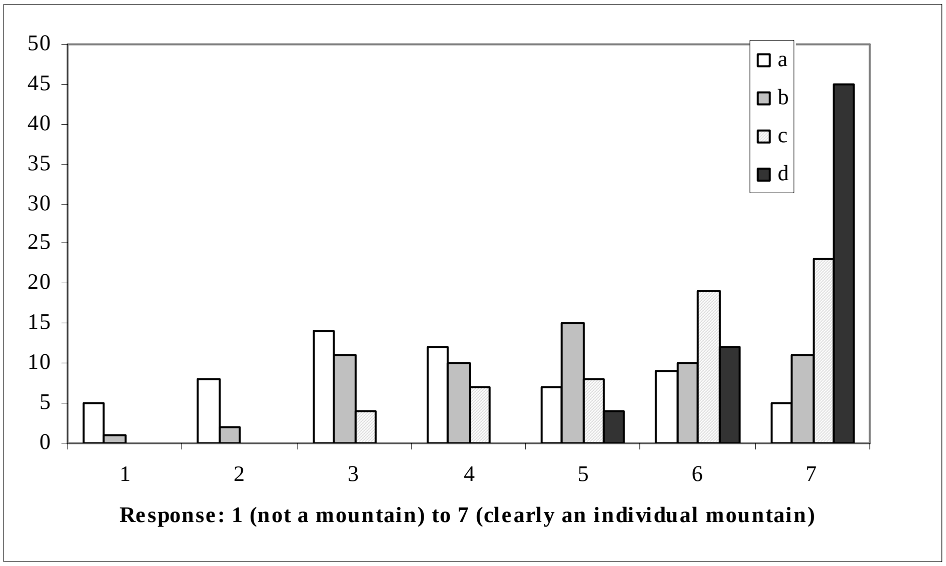

Figure 3: Responses to the question, how mountain like is this picture for the schematic illustrations in Figure 1

Table 2 shows, for each attribute, firstly whether the subjects' responses to different questions produce statistically significantly different distributions, and secondly whether the attribute values are correlated (e.g. is there a relationship between prominence and the degree to which an image is considered "mountain-like").

Attribute	**Visualisation type**	Schematic	3D Visualisation	Photograph
Prominence	**Friedman Test**	$p<0.001$	$p<0.001$	$p<0.001$
	Spearman Correlation	$r^2=0.62$	$r^2=0.45$	$r^2=0.20$
Dominance	**Friedman Test**	$p<0.001$	-	$p<0.001$
	Spearman Correlation	$r^2=0.42$	-	$r^2=0.17$
Slope	**Friedman Test**	-	$p<0.001$	$p<0.001$
	Spearman Correlation	-	$r^2=0.35$	$r^2=0.45$
Civilisation	**Friedman Test**	-	-	$p<0.001$, $p < 0.001$
	Spearman Correlation	-	-	$r^2=0.21$, $r^2=0.12$
Tree line	**Friedman Test**	$p<0.001$	-	$p<0.001$, $p < 0.001$
	Spearman Correlation	$r^2=0.52$	-	$r^2=0.17$

Table 2: Significance testing for results of question distributions and correlations between attribute values (non-parametric tests)

For the case of selecting the boundary of an individual mountain, in all 3 cases the majority of our subjects simply selected the largest possible extent given as an option.

4. Discussion

We are still in the preliminary stages of analysing the large dataset collected in this work, but several interesting observations are possible. Firstly, a wide range of terms were used to describe mountains, but those occurring most often all described attributes of the mountain itself rather than activities or locations (e.g. high, rock, snow and steep).

Secondly, the range of heights suggested as defining a Swiss mountain was very broad, with conspicuous peaks in values of 1000m and 2000m. Furthermore, the standard deviation in elevation (700m) describes some 20% of the total variation in elevation in Switzerland. Thus, our results show clearly that elevation is not a useful descriptor of Swiss mountains.

Thirdly, our results show that the attributes chosen do go some way to allowing us to characterise mountains, with statistically significant answer distributions for different representations of the attributes tested. Furthermore, correlation values based on ranks for each question show relatively strong correlations (r^2~0.5-0.6) for prominence and tree line and slightly weaker correlations for slope and dominance. The relationship between the anthropogenic objects in the images is on the other hand weak. Also noteworthy is that correlation values are in general higher for the more abstract representations than for photographs. This suggests that other properties of the image come into play in these representations – for example, in photographs the subjects use objects in the scene (e.g. trees) to estimate the size of the mountain, and apply this as a discriminating factor rather than simply the variable under investigation (e.g. dominance). This result has some resonance with the work of Smallman and St. John (2005), who suggest that when presented with more realistic displays users often underperform and that simplification and caricaturing task relevant elements of a representation (as in Figure 1c) is likely to improve performance.

We are currently working on applying these results to extract the degree of "mountainousness" of different regions in the Swiss Alps by applying the relationships extracted from our empirical studies to Digital Elevation Models.

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Extending Irregular Cellular Automata with Geometric Proportional Analogies

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1. Introduction

We exploit the similarity between irregular Cellular Automata (CA) and Geometric Proportional Analogies (GPA), as both involve manipulations of geometric objects (points, lines and polygons). We describe how each GPA effectively defines a CA-like transition rule and we adapt an algorithm (called *Structure Matching*) used for solving GPAs to solving CAs. Irregular CAs improve on regular CAs by allowing an irregular tessellation of the plane, while further extensions support transition rules that lie beyond the scope of traditional CA. We describe three facets of the resulting model; layered inferences, incremental structures and the merge operation. Examples describe how *structure matching* (Mullally *et al*, 2005) is used to update and enhance a topographic land-cover map.

2. Regular and Irregular Cellular Automata

Regular CA were conceived by Ulam and Von Neumann in the 1950's and consist of a regular grid of *cells*, each in one of a finite number of *states*. The state of a cell at time t is a function of two values. First, the cell's state at time $t-1$ and secondly, the states of each of a finite number of *neighbourhood* cells at time $t-1$. Neighbouring cells are defined relative to the central cell and all cells have the same update rules (or transition rules). Irregular CA use an irregular tessellation of the 2D plane and are thus more easily applied to vector data. We also include *point* and *line* features in our irregular CA, as they are regularly found in GPAs and in vector data.

While irregular CA have been proposed (O'Sullivan, 2001), no standard means of describing neighbourhoods has emerged. We exploit the similarity between the transition rules of irregular CAs and geometric proportional analogies (GPA), applying the same predicate calculus representation (Gentner, 1983) of GPAs to our CA.

2.1 Knowledge Representation and Geometric Proportional Analogies

Both irregular CA and GPAs manipulate collections of geometric objects. GPAs are IQ-test type analogy problems involving collections of geometric objects, specified in the form A:B :: C:D (read as, A is-to B as C is-to D) – see Figure 1. The objective of these problems is to generate the missing information (D) given the three other pieces of information (A, B and C). The A & B pair specifies a transformation which must be applied to C, to generate the missing D.

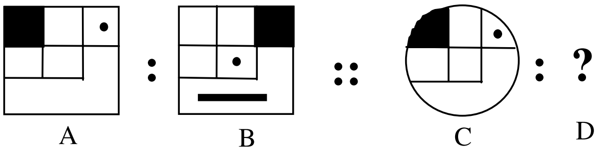

Figure 1. Apply the A-to-B transformation rule to C, thereby generating D.

Part A of Figure 1 defines the *before* part of a transition rule, while B defines the situation *after* applying the rule. In a typical GPA the A-to-B transformation will involve modifying, adding or removing information about the collection of objects introduced in A. Applying this transition rule to C allows us to generate the missing part D.

We describe parts A, B and C of a GPA using predicate calculus, thus part D can be generated by standard analogical reasoning models (i.e. Gentner, 1983, Keane *et al*, 1994; O'Donoghue *et al*, 2006). Parts A, B and C contain *points, lines* and *polygons* and each part corresponds to a CA neighbourhood. Areas that share a common boundary are neighbours to each other in a Voronoi spatial model (Gerevini & Renz, 2000) and neighbourhood topologies are described by binary relations including: *line-adjacent*, *point-adjacent* and *hasPoint*. Note these descriptions may be replaced by relations from the Region Connection Calculus (Chon, 1997) or DE9IM (Egenhofer & Herring, 1990) without affecting the remainder of the algorithm. Neighbourhoods additionally record the defining characteristics of each point, line and polygon, such as categorical information, which is recorded as unary attributes associated with the point, line or polygon.

3. The Structure Matching Algorithm

Structure Matching (O'Donoghue, 2006) is a multi-phase algorithm essentially combining Structure Mapping (Gentner, 1983), Attribute Matching (Bohan and O'Donoghue, 2000) and Copy with Substitution and Generation (CWSG) (Holyoak *et al*, 1994) processes – which we now describe.

i) Structure Mapping: Identifies the isomorphic 1-to-1 mapping between parts A and C. Structure mapping is a computationally expensive operation, being a variant of the Largest Common Sub-graph member of NP-Complete problems (Johnson and Garey, 1979). For efficiency reasons, we first apply a rough-cut filter that only allows structure mapping to proceed when the neighbourhood and the transition rule have the same number of cells in each of the states. A key output of this phase is the object-to-object alignment between the geometric objects of parts A and C.

ii) Attribute Matching: Ensures that all paired objects in the object-to-object alignment are in the same state (category or theme), as described by the objects attributes. For example, a building polygon can only be placed in correspondence with another building polygon and a text feature can only be aligned with another text feature, *etc*.

iii) CWSG – the Copy with Substitution and Generation algorithm generates the missing part D. This copies part B while substituting the mapped objects identified during the structure mapping phase.

4. Extended Cellular Automata

Many geo-spatial applications require inferences other than altering the state of a neighbourhoods central cell, adding and removing information associated with points, lines and cells, as well as changes to the topology of the neighbourhood itself. These modifications are supported by the *structure matching* algorithm as alterations to the neighbourhood definitions of each cell. However, it is important to place constraints on the (arbitrary) inferences that can be generated by the CWSG phase of *structure matching,* as it is too profligate and may destroy the integrity of the CA itself. The following three extensions overcome specific limitations identified in previous CA.

4.1 Neighbourhood Frequency

A typical map will have some neighbourhoods that occur very frequently (*e.g.* a house surrounded by a garden), while other neighbourhoods occur very infrequently. We highlight a power-law distribution in the frequencies with which neighbourhoods occur. So, a small number of neighbourhoods occur very frequently, while large numbers of other neighbourhoods will only be found once in any given map. Some categories of geographic object (e.g. roads and road-side) regularly have large numbers of neighbours requiring a large number of transition rules. But defining a transition rule for every possible neighbourhood can prove impractical. For example, a road-side's neighbourhood may contain over 60 polygons from 13 different categories, requiring an astronomical number of transition rules (Tobler, 1979) $S^N = 13^{60} = 6.8*10^{66}$ - even before topology is taken into account. We propose a solution to this problem, using the incremental structures described below.

4.2 Incremental Matching Method

As stated earlier, structure matching can be an expensive process, particularly for neighbourhoods with large number of objects. We now present an efficient strategy for identifying extensive structures (*eg* roads, railways and rivers) and irregular structures (*eg* hospitals, universities and schools). Our solution uses an incremental matching method (Keane *et al*, 1994) that involves two key aspects. First we identify a "root" neighbourhood that defines a starting point. Secondly, we identify a number of incremental neighbourhoods that can be iteratively added to that root or a previous incremental collection. Identifying a composite building can be achieved by identifying a "root" structure and iteratively adding connected buildings to the collection (Figure 3).

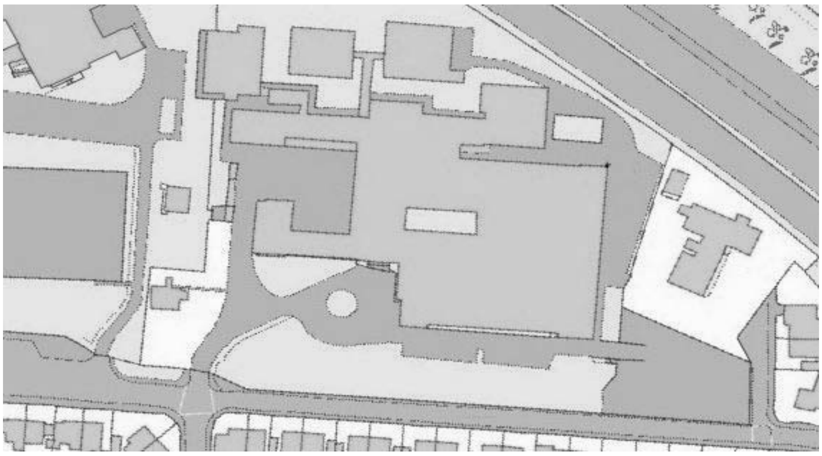

Figure 3. A composite building identified incrementally.

4.3 Layered States and Type 1 CA

Wolfram (1994) identifies four categories of CA, one of which (Type 2) converges to a unique steady state within a finite number of update cycles. Type 2 CA are particularly important as the start and final states of the CA may correspond to some situation in the real world. We ensure convergence to a final state by introducing additional states and by layering the inferences generated by *structure matching*. We define L extra states, in addition to the K initial cell states and refer to these L additional states as first-order states if they are derived directly from the initial K states. States belong to layer N if they can only be derived from the states in layer N-1. Additional states may correspond to sub-categorizations of the initial K states contained within a topographic map.

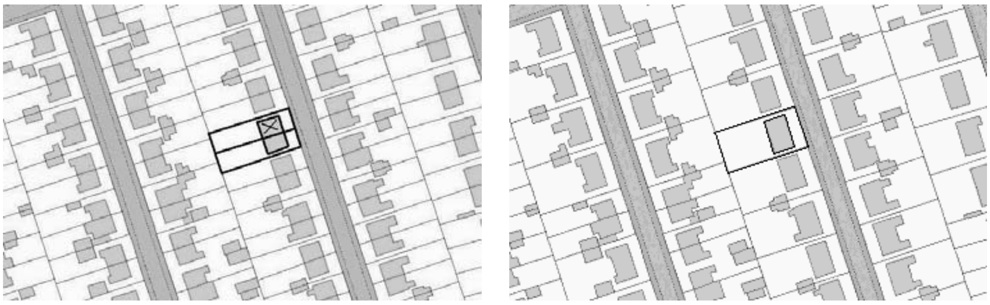

Figure 2. (left) Neighbourhood rule identifies a semi-detached dwelling. Generalisation by merging select neighbourhood polygons (right).

4.4 Merge Cells

The inferences of our extended CA may alter properties of points and lines as well as cells. As our neighbourhoods are essentially topological descriptions, modifications to the neighbourhood topology are easily achieved by changing the relations in the updated neighbourhood description.

Problematically, modifying or deleting cells can destroy the crucial contiguity of the CA, creating cells with incomplete neighbourhoods – such as that used by Shi and Pang (2000). To overcome this problem we use a *merge* operation which ensures that no boundary cells are ever accidentally created. This *merge* operation can be applied to points, lines and cells. Figure 2 illustrates how merge can be used for detail reduction and generalisation. Features may still be removed by simply merging them with existing cells without negative consequences and therefore reach the final solution state. However, no constraints are required on modifying or deleting existing points or lines. Furthermore, no constraints are required on inserting new points, lines or cells.

5. Conclusion

We exploit the similarity between irregular Cellular Automata (CA) and geometric proportional analogies (GPA), as both involve manipulations of specific configurations of geometric objects (involving points, lines and polygons). We adapt the knowledge representation and algorithm used for solving analogy problems to the domain of geometric information.

We introduce three extensions to the basic CA, overcoming some practical limitations on the application of CA to some problems types. First we introduce layered states that increase the number of states in the CA while ensuring it will converge to a stable state in a finite number of steps. Secondly, an incremental matching method addresses the problems of processing large structures that extend across many neighbourhoods. This incremental method is also useful in identifying irregular structures that are difficult to represent with standard transition rules. Finally, we describe some limitations that are placed on the modification and deletion of cells in the CA to maintain the crucial contiguity of the CAs cellular structure. These three methods have been successfully implemented to enhance the data contained within topographic maps.

6. Acknowledgements

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Biography

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Quantifying Urban Visibility Using 3D Space Syntax

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1. Context

A city is a container of activities – a palimpsest of inter-related processes operating at various spatio-temporal scales. Examples of these social processes include pedestrian movement (Hillier et al, 1993; Jiang, 1999), crime (Hillier and Sahbaz, 2005; Nubani and Wineman, 2005), and social deprivation (Vaughan et al., 2005). In various ways these processes are affected by the architectural space and the built form. Furthermore these structures affect other key activities such as way-finding processes in complex built environments (Peponis et al., 1990), vehicle driver movements (Penn et al., 1998), and environmental processes such as traffic pollution (Penn and Croxford, 1997). It is not surprising then that much effort has been devoted to how we can model the various characteristics of the urban environment, in order to improve their design, and to understand the interdependencies and interactions between the built world and its occupiers. Hillier and Hanson, in the early 80s, developed the idea of space syntax to help simulate the likely effects of their designs on the surrounding area (Hillier and Hanson, 1984). Space syntax is defined as 'a family of techniques for representing and analysing spatial layout of all kinds' (Hillier 1999, 165), and its aim is to develop strategies of descriptions for configured, inhabited spaces in such a way that their underlying social logic can be recognised. The primary focus of the current literature examines urban spaces in reference to two dimensions (2D). Ratti (2005) suggests that using three dimensions would be the best means to describe a city enabling a more complete analysis of urban texture, importantly taking into account the height of buildings. Asami et al. (2002) stated that there is an urgent need for new space syntax methods that can capture and take into account the curvature of the surface of the space. The inclusion of the third dimension, either as the height of buildings or as the change in the topography of the surface, would allow researchers to more accurately depict the urban environment as an individual located in the setting sees it and to model other human and environmental processes and provide a vivid and more complete description of urban space. In this paper we describe the methodology and implementation of a 3D spatial syntax with a specific aim of creating a surface of visibility that summarises the varying degree of visibility among a set of buildings. We provide a literature review, explanation of the methodology, its implementation and evaluation for a small subset of buildings from the central business district of Wellington, New Zealand.

2. Space Syntax in Two Dimensions

The general idea underlying space syntax techniques is that space can be broken into components and analysed in the form of maps and graphs that describe the relative connectivity of those spaces. “In the studies of cities, one representation and one type of measure has proved more consistently fruitful than others: the representation of urban spaces as a matrix of the ‘longest and fewest’ lines – the axial map” (Hillier, 1999, p. 169). The axial map depicts the minimal set of axial lines required to completely connect areas within the space whilst also ensuring that the space is entirely surveiled (Turner et al. 2005). It therefore shows the least number of axial lines required to cover a layout and their connections. Figure 1 is an example 2D axial map for the French town of Gassin.

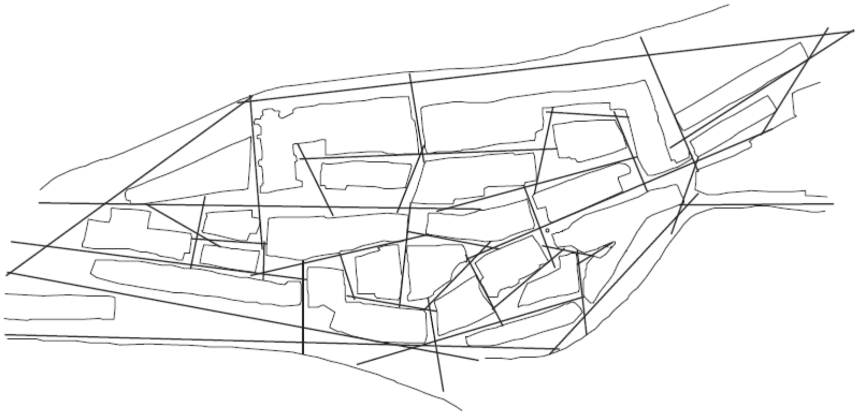


Figure 1. 2D Axial Map for the French town of Gassin (Hillier and Hanson, 1984, p. 91).

3. Space Syntax in Three Dimensions

The methodology focuses on the extension of the axial map into simple 3D block space (taking into account the height of buildings, but assuming a flat underlying elevation). The development of the 3D axial lines has been based on algorithms identified by both Peponis et al. (1998) and Turner et al. (2005) for the creation of ‘all line axial maps’ in 2D space. Within three dimensional space, the all line axial map algorithm has been extended to take into account the height of the buildings. The algorithm presented here was developed and tested within ESRI’s ArcGIS software using Visual Basic for Applications (VBA) and ArcObjects. The algorithm takes as input the outline of the buildings (the building’s footprint) together with a height value. Additionally, an arbitrary ‘external’ convex boundary is defined which acts to constrain the creation of the 3D axial lines (so they are developed only within that boundary). The algorithm firstly develops two sets of vertices representing the corners of the buildings (Figure 2).

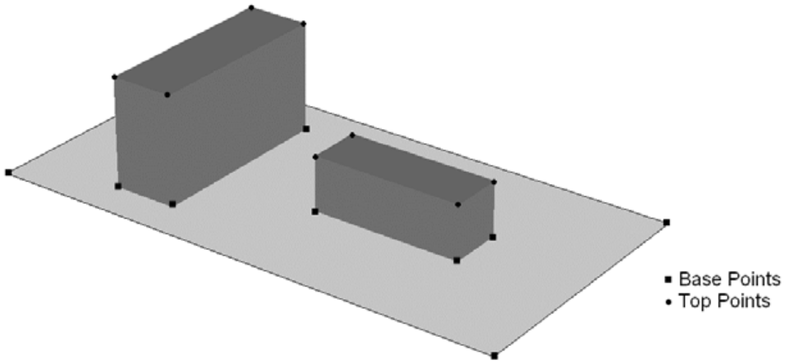


Figure 2. An example of both the base and top point collections.

The first collection (base) represents the base of the buildings with every corner point assigned a z value of zero. The base collection also contains the corner points for the boundary box which are also assigned a z value of zero (assuming the world to be a flat Euclidean surface). The second collection (top) of points represents the top of the buildings - each point is assigned a z value relating to the height of that building. The next step is to develop a line collection that connects each point in the base collection to every point in the building top collection. Each line is tested to see if it crosses any of the building footprints. If it does, then the line is removed from the collection. The algorithm then extends the lines until they intersect either a building or the boundary box (Figure 3).

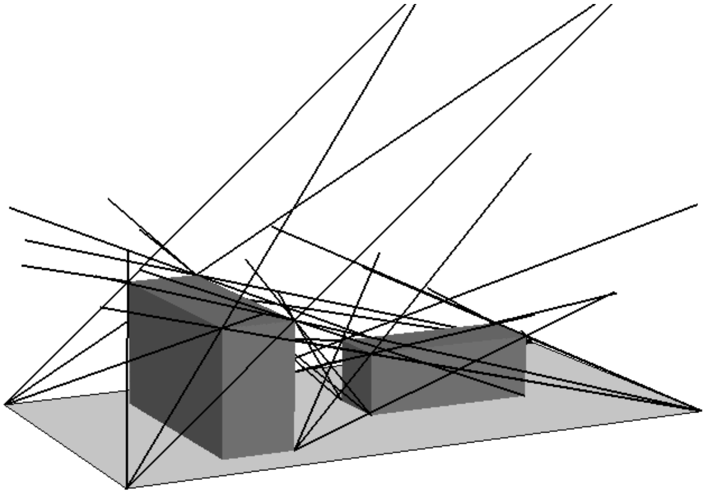


Figure 3. The complete set of lines constituting the 3D all line axial map

From this set of lines a visibility surface is created. This surface is constructed based on the slope of the 3D axial lines. The slope of each line is, therefore, calculated. A 3D axial line with a gentle slope would mean that an individual would have a ‘plaza like’ view of the space whilst an axial line with a much steeper slope which reflect a ‘canyon like’ view of the space. The algorithm also generates the set of intersection points among the 3D axial lines (Figure 4). The average slope value of the two intersecting lines is assigned to that intersection point (for any pair of intersecting lines) (Figure 5).

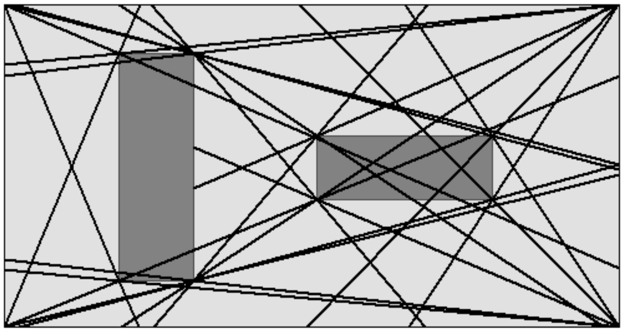


Figure 4. Finding points of intersection (The 3D all axial line map from Figure 3 represented in 2D).

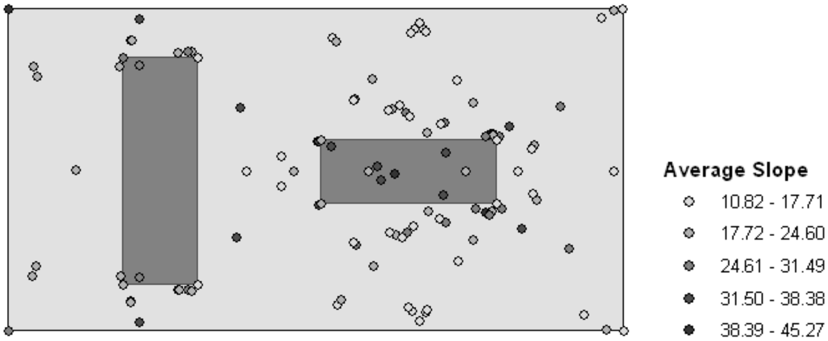


Figure 5. The set of intersection points coded by the average slope.

These points are then interpolated to create a visibility surface using Kriging (Figure 6). Kriging was selected as it allows for the points to be interpolated while taking into account the spatial correlation between the average slopes of the points. The example visibility surface, (Figure 6), shows that there is an area of poor or very limited visibility between the two buildings. Additionally, to the top and bottom of the smaller horizontal building there are large areas of high visibility.

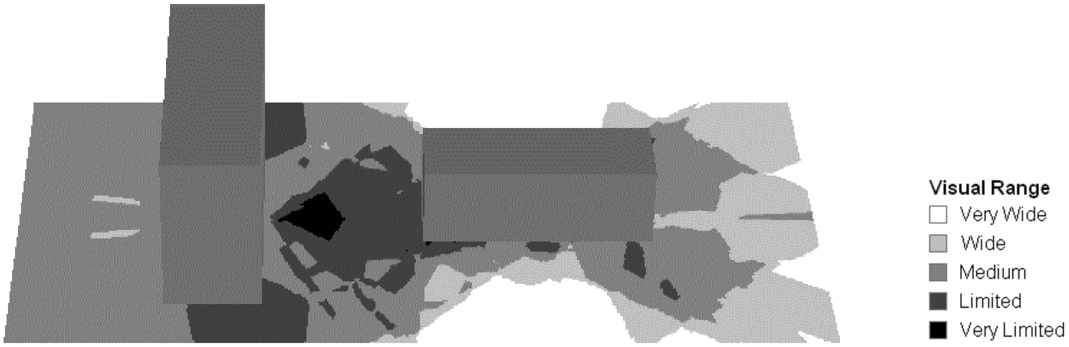


Figure 6. The visibility surface for the 3D all line axial map in Figure 3.

3.1 Limitations

The best solution in creating this visibility surface is to calculate the intersection points for all the 3D axial lines and construct the visibility surface using the complete set of intersection points. For large collections of buildings this proved difficult as ArcGIS, was unable to process the complete set (Schroder, 2006). For performance reasons the best approach was to take a random subset of the 3D axial lines and generate the intersection points and visibility surface from those lines. It was also noted from trial tests that there was a 'boundary edge effect' – whereby the algorithm could not take account of anything outside the boundary box (in effect assuming that no buildings lay outside the boundary box). One way to reduce the edge effect of the boundary box is to develop the visibility surface for an area larger than the one interested in and then disregard the visibility surface close to the edge of the boundary box.

4. Case Study Application

The algorithms described in sections 3 and 4 have been applied to a sample set of buildings from central Wellington, New Zealand (Figure 7). The buildings ranged from shorter buildings nearer the wharf and harbour area with the taller buildings being more prominent the further away one gets from the harbour. The sample dataset included 39 buildings ranging in height from 6.7 metres to 93.5 metres.

Figure 7. Map of the sample Wellington building set.

Once the sample buildings dataset had been created and simplified, the 3D all line axial map algorithm was calculated. In total, 2214 lines were developed by the algorithm. The slope of these 3D axial lines varied dramatically, ranging from 1.85 degrees to 89.8

degrees. Once the 3D all line axial map was calculated, a random subset of 400 lines were used to calculate the intersection points and the visibility surface (Figure 8).

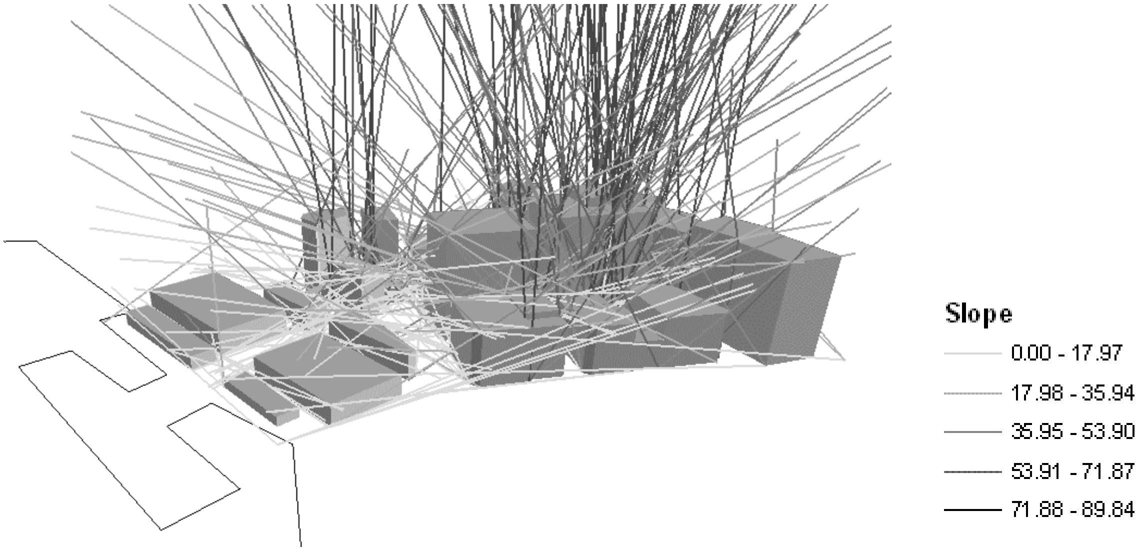


Figure 8. The subset of 400 3D axial lines illustrated in 3D.

The resulting surface is shown in Figure 9, in which the darker the area the more limited the visual range is from that position, whilst the lighter the area the wider the visual range is from that position. The surface can be compared to images of the space (Figure 10).

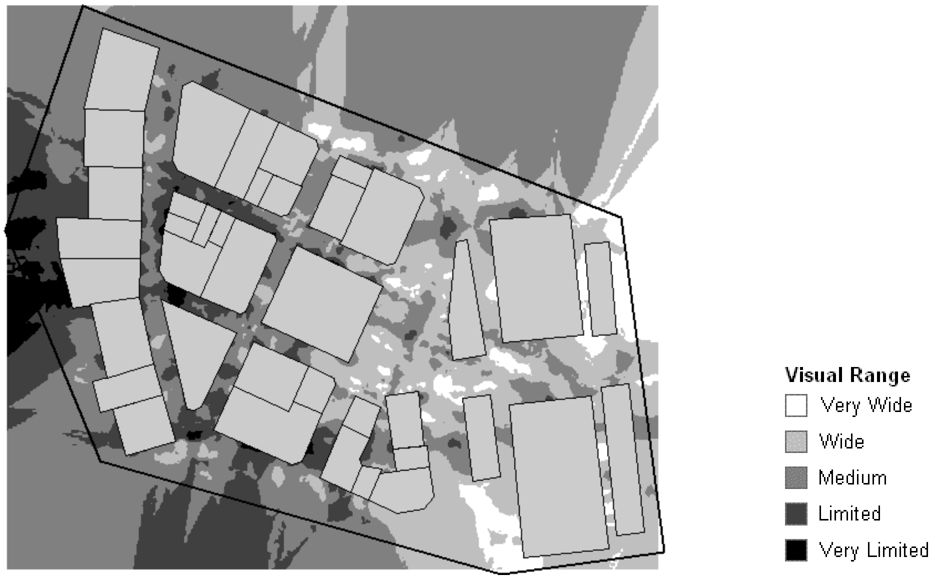
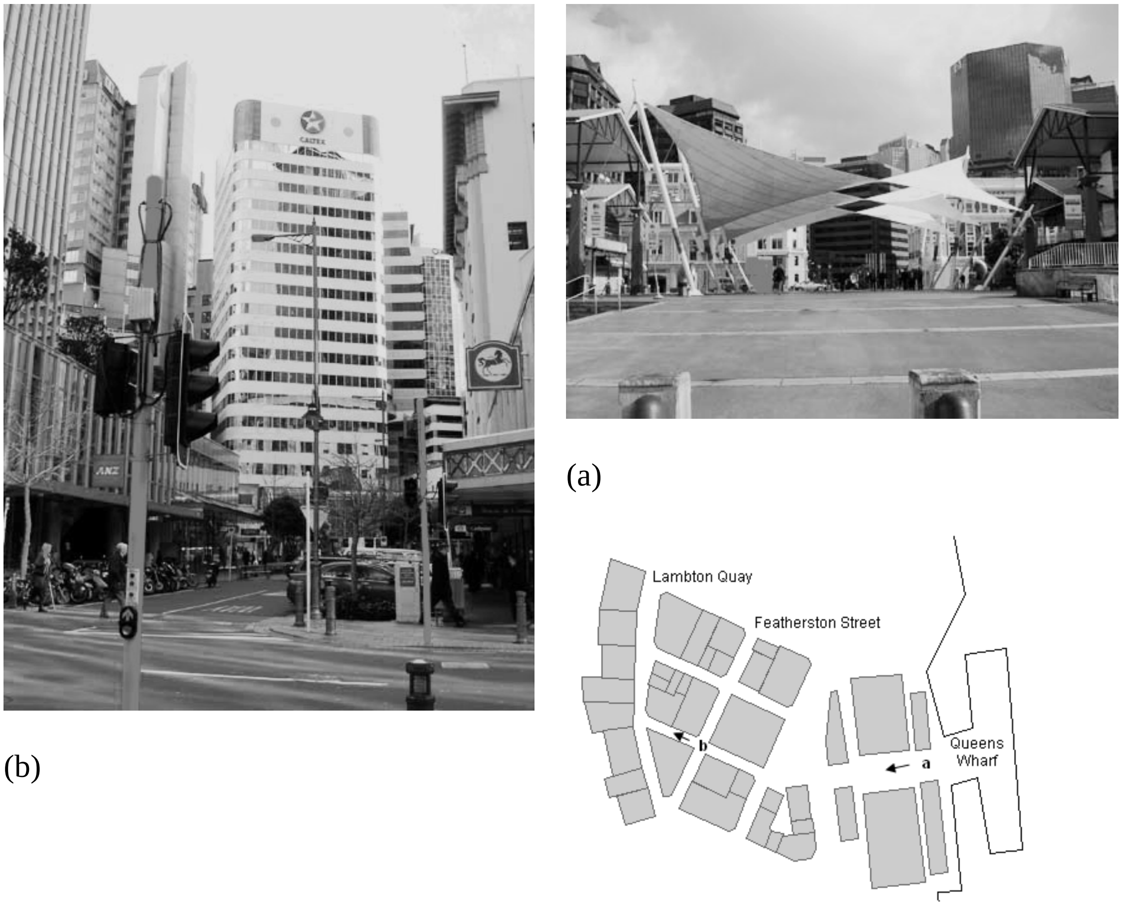


Figure 9. The visibility surface with the sample building set from Wellington superimposed.



(a)

(b)

(c)

Figure 10. (a) Photo looking towards the sample set of buildings from Queens Wharf. (b) Photo looking towards the Lambton Quay area. (c) Map showing the location of where the photos were taken and in which direction.

5. Conclusion

The use of the third dimension within space syntax has only begun to be recently explored. This paper has demonstrated ways of extending the current concept of the axial map to the third dimension. This extension of the axial map and the development of the visibility surface provide a richer picture and compliment the information being gathered from 2D analysis. This application illustrated the appropriateness of the results with the algorithms correctly identifying areas that are fairly open with a wide visual range and also identifying the areas that are quite closed in. Incorporating the third dimension into space syntax and representing the space in the way that the individual sees it, will allow researchers to gain a better understanding of the urban environment and improve the understanding of how social processes operate within these 3D spaces.

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Confidence and Groundwater Flood Susceptibility Mapping

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1. Background

Groundwater flooding is increasingly being recognised as a hazard (Bloomfield and McKenzie 2005, Jacobs 2004). Local knowledge of historic groundwater flooding events has generally been the only guide to an area's vulnerability to flooding. Unfortunately, local knowledge of groundwater flooding is patchy and can be unreliable, and often groundwater flooding is not recognised as a distinct event, being masked by surface water floods. (Marsh, and Dale 2002) There is clearly a need to assess areas susceptible to groundwater flooding.

Work was undertaken to produce a national map of groundwater flooding susceptibility for the UK (ver.1.0). Two main types of flooding were considered:

> "Alluvial (or permeable superficial deposits – PSD) flooding" associated with rivers hydraulically connected to alluvial material). In PSD groundwater flooding the conceptual model is a cross-section through a river valley filled with permeable deposits overlying impermeable rocks. Water moves through the permeable deposits from the river and floods the low-lying land either side of the river (Figure 1).
>
> "Clearwater flooding" resulting from groundwater rising and outcropping at the surface. The clearwater flooding conceptual model, considers a permeable aquifer with a groundwater-supported river flowing down a valley. As the regional groundwater level rises groundwater emerges either side of the river in the valley. The higher the groundwater level rises, the larger the area that is inundated by groundwater (Figure 2).

Based primarily on geological criteria (geological controls), the map identifies areas where groundwater is close to the surface and where geological conditions suggest that an area is susceptible to groundwater flooding. This work has concentrated on the geological 'vulnerability' or susceptibility to groundwater flooding rather than mapping the risk of groundwater flooding events.

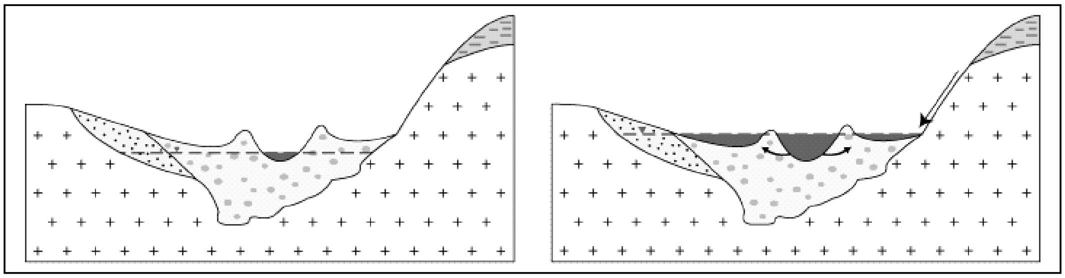


Figure 1. Illustration of the PSD groundwater flooding conceptual model, showing a cross-section through a river valley filled with permeable deposits overlying impermeable rocks. Water moves through the permeable deposits from the river and floods the low-lying land either side of the river.

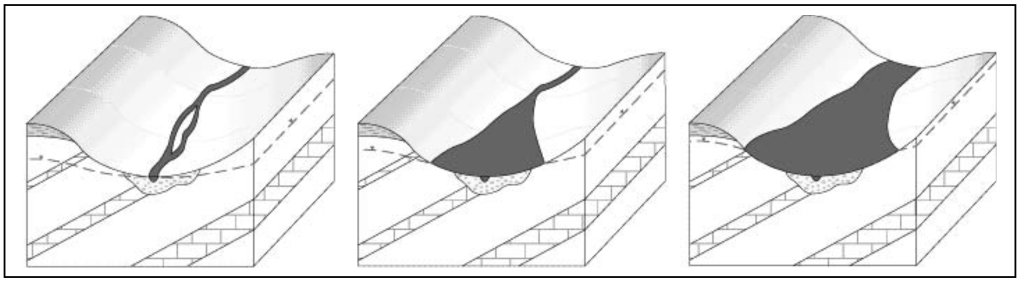


Figure 2. Illustration of the clearwater flooding conceptual model, showing a permeable aquifer with a groundwater-supported river flowing down a valley. As the regional groundwater level rises groundwater emerges either side of the river in the valley. The higher the groundwater level rises, the larger the area that is inundated by groundwater.

As there are a considerable number of factors associated with the development of the dataset, it was necessary also to consider the issue of uncertainty, or confidence. This paper focuses on the development of a confidence map for use with this dataset. A description of the principal factors controlling confidence is described for both conceptual models of flooding, and is discussed in more detail for the clearwater flooding scenario. It was recognised that many aspects of geological and hydrogeological modelling are subject to expert opinion, and confidence can be difficult to quantify.

2. Methodology

Production of the confidence map was a three-stage process:

> Stage 1 – identification of areas of confidence (and uncertainty) in the preparation of the flood susceptibility map. This was carried out using a semi-formal process to produce a cause and effect or 'fish diagram' (Cave and Wood, 2002) that relates primary areas of confidence with underlying factors, then describing each of these factors.
>
> Stage 2 – translation of the 'fish' diagram into semi-quantitative estimates of relative confidence using a simple rule-based scoring process
>
> Stage 3 – using the rule-based scoring process in step 2 in a GIS to produce a map of confidence in the flood susceptibility map

Throughout the three-stage process the procedure adopted combined estimates of uncertainty in the input datasets with a review of available ‘ground truth’ observations.

This three-stage process was undertaken separately for each of the two groundwater flooding scenarios and then the resulting confidence maps were combined.

For both the scenarios five principal contributing factors to the confidence model were identified as follows;

- confidence in the permeability index
- confidence in the conceptual model
- confidence in the digital elevation model (DEM)
- confidence in the rest water level
- availability on information to validate the susceptibility classification

These factors were developed by the preparation of a cause and effect or ‘fish’ diagram for each conceptual model. The diagram was used within a collaborative team discussion to ensure that all aspects of the confidence model had been considered.

1.1 Confidence estimates for PSD flood susceptbility

Figure 3 shows the fish diagram for the PSD confidence model and illustrates the relationship between these primary and secondary factors that influence confidence in estimates of PSD flood susceptibility. It was possible to quantify to some extent some, but not all, of these factors and sub-factors.

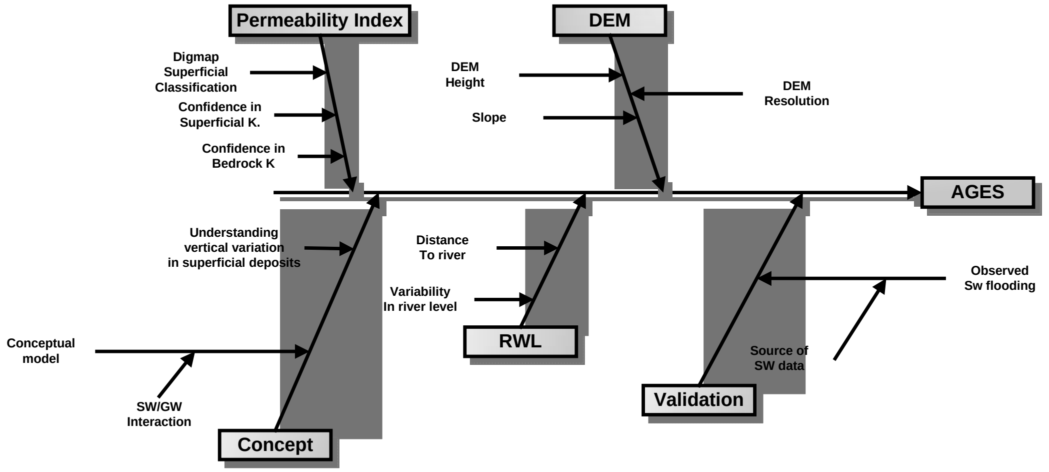


Figure 3. ‘Fish’ diagram used as the basis of the estimation of confidence for PSD flooding (where ‘AGES’ is the total confidence score for PSD flooding).

1.2 Confidence estimates for Clearwater flood susceptibility

Figure 4 shows the fish diagram for the clearwater flooding confidence model, and illustrates the relationship between these primary and secondary factors that influence confidence in estimates of clearwater flood susceptibility. Table 1 is used as an example to briefly describe each of the factors and sub-factors in the ‘fish’ diagram and whether they are quantifiable.

Using Table 1, each of the factors that effect confidence was then used to produce rule-based numerical scores that could be implemented within a GIS.

A combined confidence map was produced by combining the PSD and clearwater flooding confidence files in the GIS. Where there was overlap between the two datasets, the approach was to take the lowest confidence.

Figure 4. ‘Fish’ diagram used as the basis of the estimation of confidence for clearwater flooding (where ‘CGES’ is the total confidence score for clearwater flooding).

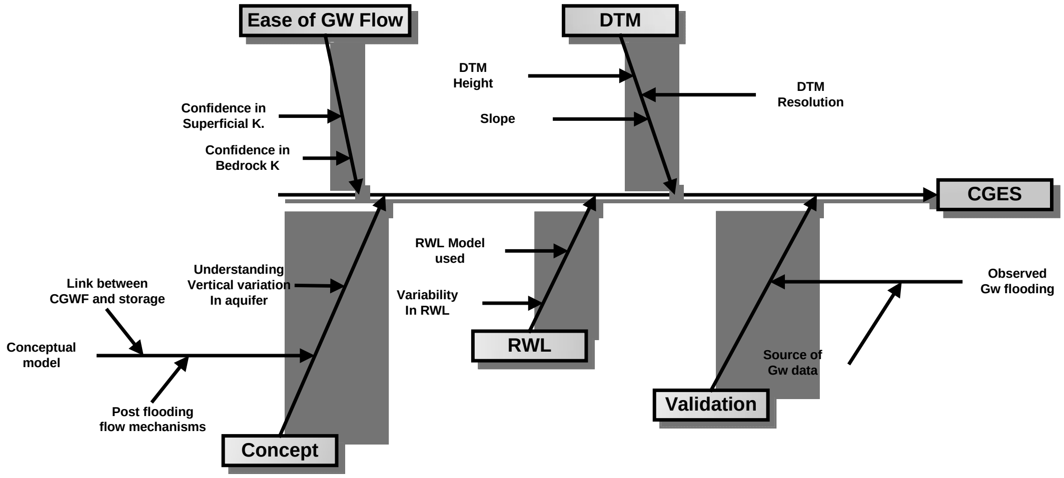


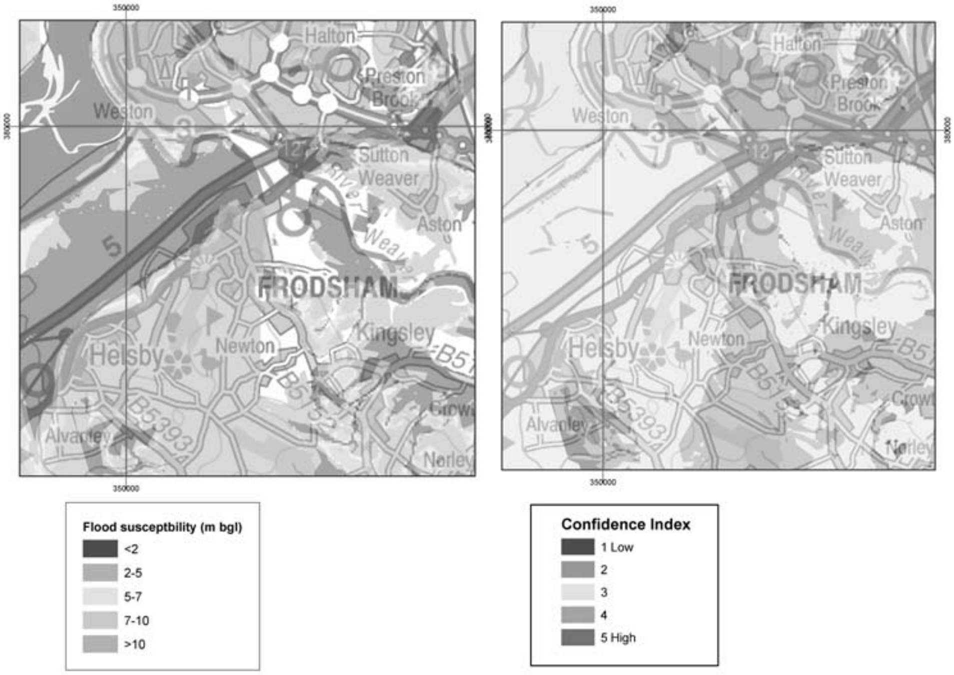
Table 1 Description of confidence factors for clearwater flooding

Factor	**Sub factor**	**Quantification**	**Notes**
Permeability Index	PI of superficial deposits	Available as part of the PI dataset.	Simplified PI confidence used
	PI of bedrock deposits	Available as part of the PI dataset.	Simplified PI confidence used
Concept	Conceptual model	Not quantifiable	Concept of clearwater used is assumed to be valid
	Post flooding flow mechanisms	Not possible with current information	Once flooding occurs water flows away from the flooded area down surface water courses, consequently zones of emergence may not be zones where floods cause economic impact

	Vertical variation in aquifer	Consistent over all units	DigMap only records deposits at surface, and these may not be an accurate representation of the full thickness of saturated deposits
	Link between flooding and aquifer storage	Not quantifiable	The rate at which water level will vary in response to recharge will depend on aquifer storage. PI data is a poor surrogate for storage
DEM	DEM Height	Fixed for a particular DEM	The better the elevation model, the better the accuracy of depth to groundwater estimates, although in practice as relative heights between river and groundwater are used the influence of this factor will be limited.
	DEM Resolution	Fixed for a particular DEM	As for DEM Height
	Slope	Derived from DEM	Flooding from groundwater is assumed to be less likely on steep slopes for the alluvial flooding conceptual model
RWL	RWL Model used	Derived from RWL dataset	Three water level models, with differing degrees of accuracy have been used.
	Variability in river level	Not possible with current information	River level variability, while an important driver for groundwater surface water interaction has not been quantified, and is assumed constant in this release of the dataset.
Validation	Observed groundwater flooding	Comparison with observations	Observed flooding in areas of high or moderate risk validates map in that area
	Source of GW data	Not used	The validation dataset is based on limited observations only

3. Results

A sample of the resulting clearwater flooding and associated confidence map are shown in Figure 5.



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4. Discussion

For any point on the groundwater flooding susceptibility map a ‘confidence’ value can be read off the accompanying confidence map. The confidence value is based on a number of different factors, and may vary across a polygon that has a single susceptibility value. For example, a polygon may be highly susceptible to flooding, but as one of the inputs to the confidence value may be the confidence of water levels, which is highest in close proximity to rivers, part of the polygon near a river havea different confidence value from those parts further away from the river.

Where only point values are required these variations within a polygon are not an issue. However where prognoses are made on the basis of values within a radius of a given point then it is harder to select an appropriate value for confidence. Generally the highest value of susceptibility within the search radius will be chosen. The options for confidence are then (in order of complexity) to:

a. take the lowest value of confidence within the search area;
b. take the lowest value of confidence within the search area that relates to the susceptibility value selected;
c. take an average or area weighted average value of confidence within the search area that relates to the susceptibility value selected.

In all of these cases, as a precautionary approach, the lowest value of confidence should be used, even if this means that an area shown as having high susceptibility and generally high confidence is reported as high susceptibility low confidence. An indication of low confidence is an indication that further investigation may be warranted.

5. Conclusions

The confidence maps provide a valuable resource in guiding the user as to the level of uncertainty in the groundwater flood susceptibility datasets. One of the main limitations in the approach is that its accuracy depends to a large extent on estimations of the accuracy of the contributing datasets. In some cases, these datasets are themselves provided without confidence data. Thus the estimates made suggest a degree of certainty in the resulting confidence estimate that is not, in reality, justified. Not withstanding the limitations, the confidence maps provide a valuable resource in guiding the user as to the level of uncertainty in the groundwater flooding datasets.

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Spatiotemporal Data Model for Managing Volumetric Surface Movement Data in Virtual Geographical Information Systems

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1. Introduction

In Virtual Geographical Information Systems (VGIS), a data model is the abstraction of real world phenomena according to a formalized, conceptual scheme, which is usually implemented using the geographical primitives of points, lines, and polygons or discretized continuous fields (Nadi, S., et. al. 2003). Data model should define data types, relationships, operations, and rules in order to maintain database integrity (Nadi, S., et. al. 2003). In VGIS, a data model is also used to enhance the focus on 3D data. Thus, a spatiotemporal data model in VGIS is an abstraction of managing 3D spatial with temporal elements. Spatiotemporal data model is very important in creating a good database system for VGIS which deals with space and time as main factors in the system (Rahim M.S.M, et. al, 2005).

A variety of spatiotemporal data model has been developed previously. For the purpose of this research, we have collected and analyzed 9 data models namely, GEN-STGIS (Narciso, F.E, 1999), Cell Tuple-based Spatiotemporal Data Model (Ale,R., and Wolfgang, K,1999), Cube Data Model (Moris, K, et. al. 2000), Activity-based Data Model (Donggen, W and Tao,C. 2001), Object-based Data Model, Data Model for Zoning (Philip, J.U, 2001), Object Oriented Spatial Temporal Data Model (Bonan, L., and Guoray, C.2002), Multigranular Spatiotemporal Data Model (Commossi, E. et. al. 2003) and Feature-Based Temporal Data Model (Yanfen, L. 2004).

Several issues were addressed by these researchers and through our observation, the main criteria lacking in spatiotemporal data modeling is the foundation of understanding real world phenomena. In near future, a strong foundation of spatiotemporal data model will become a very crucial factor in developing real-time processes in GIS (Rahim M.S.M, et. al, 2005). We agree that in order to create a VGIS with a realistic process, a spatiotemporal data model should focus on the volumetric data and geographical movement behavior.

Other issue related to the capability of spatiotemporal data model is 3D visualization of volumetric spatiotemporal object. This is vital for increasing user understanding of geographic phenomena in creating simulations or future predictions. Therefore, a VGIS data model must have the capability of user query to visualize information in the form of 3D with movements. This is indeed a very challenging issue. It has also been addressed by Roddick , J. et. al. (2004) that the current development of techniques and tools are simply unable to cope when expanded to handle additional dimensions.

In this extended abstract, the discussion focuses on the volumetric surface movement in the real world, where we have developed a spatiotemporal data model suitable in managing volumetric surface movement data called the Volumetric Surface Movement Spatiotemporal Data Model.

2. Volumetric Surface Movement Data Model and Implementation

The first step in developing a volumetric surface movement data model is to obtain the required definition and parameters by focusing on the volumetric movement in the real world. Real world objects are in volumetric form where we can only see its surface. The surface is constructed by a combination of points that create lines, and lines that are joined together to create a surface. Each change that occurs in an object can only be seen on its surface. Thus, a surface (s) is an important component in presenting a volumetric object which makes it one of the parameters needed in defining volumetric surface movement.

A change is defined as a movement from one state to another where time is the main reference of the change. When an object *(v)* goes through a change where it moves from one state to another, from each movement, we can determine the duration of the occurring event, the starting point of the event and also its ending point. For example, based on Figure 1, the surface for object (v) occur changes where it is recorded at state t_1, t_2, and t_3. Thus, its starting point can be defined as start time (t_1) and the ending point as end time (t_3).

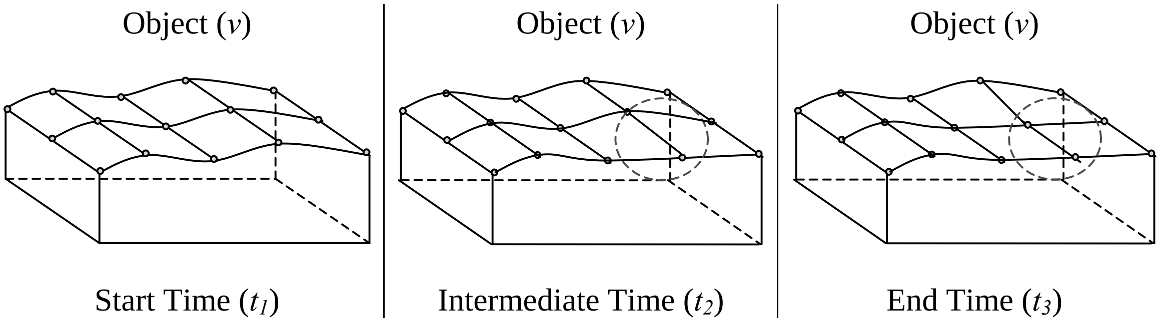


Figure 1: Movement Process in Volumetric Surface

Time and object is linked semantically and is a natural association that is tightly connected. A change that occurs on a surface of an object is in fact a change that occurs on the points that forms the object surface. The changes of these points allow changes to take place on the object surface. At which points and at what time these changes occur have to be clearly identified. Therefore, in general, time belongs to an object, or more specifically, the points that form the surface of an object.

A Volumetric Surface Movement is a combination of data sets where changes that occur are recorded under one object. These data sets contains points and lines that forms the surface, and each of the points and lines is accompanied by the time element that represents the change that occurred. These data will be stored and retrieved by using the equation (1) and (2) below, a combination of the surface set that is classified as a volumetric surface movement object. These equations will be the base in building a data model that manages surface movements data. It will also be the foundation in managing volumetric surface movement object in the real world.

$$f(mv)t_1, t_2, \ldots, t_m \rightarrow f(v, t_1)\ U\ f(v, t_2)\ U \ldots\ U\ f(v, t_m) \qquad (1)$$

$$f(mv)t_1, t_2, \ldots, t_m \rightarrow [\ \{ <x_1,y_1,z_1, t_1>, <x_2,y_2,z_2, t_1>, \ldots <x_n,y_n,z_n, t_1>, \}\ U\ \{ <x_1,y_1,z_1, t_2>, <x_2,y_2,z_2, t_2>, \ldots <x_n,y_n,z_n, t_2>, \}\ U \ldots U\ \{ <x_1,y_1,z_1, t_m>, <x_2,y_2,z_2, t_m>, \ldots <x_n,y_n,z_n, t_m>, \}\ ] \qquad (2)$$

In real process though, not all of the points in the volumetric surface moves or changes. This raises the question as whether it is necessary to store all of the points which will increase the storage usage in the implementation. Therefore, in order to reduce storage and avoid data redundancy, the data model must be able to identify which point that has changed. To identify these points, data model must have the capability to check every point among the versions of data and capture the changing point. The conceptual identification is as follows:

If $<x_1,y_1,z_1,t_n> - <x_1,y_1,z_1,t_{n+1}> = 0$*, data at* t_{n+1} *equal to data at* t_n *,*
else If $<x_1,y_1,z_1,t_n> - <x_1,y_1,z_1,t_{n+1}> \neq 0$ *, data for* t_{n+1} *is* $<x_1,y_1,z_1,t_{n+1}>$

The developed data model can be translated in a table form shown in Table 1 below.

v / t	P_1	P_2	P_3
t_n	(x_1,y_1,z_1)	(x_2,y_2,z_2)	(x_3,y_3,z_3)
t_{n+1}	$(x_1,y_1,z_1) \parallel (x_1,y_1,z_1)'$	$(x_1,y_1,z_1) \parallel (x_1,y_1,z_1)'$	$(x_1,y_1,z_1) \parallel (x_1,y_1,z_1)'$
.	.	.	.
.	.	.	.
t_{n+m}	$(x_1,y_1,z_1)'' \parallel (x_1,y_1,z_1)'''$	$(x_1,y_1,z_1)'' \parallel (x_1,y_1,z_1)'''$	$(x_1,y_1,z_1)'' \parallel (x_1,y_1,z_1)'''$

Table 1 Conceptual Data Model

As stated, not all of the points that form the surface changes. Therefore to store data at time *t*, a comparison will be done to determine which points did change. The algorithm below will be used to identify redundancy in the database during implementation.

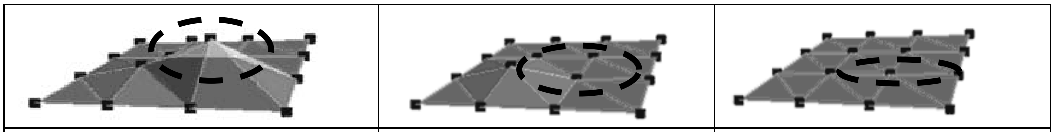
$$P1\ (x_1,y_1,z_1,t_n)\ \text{move} \rightarrow P1'\ (x_1,y_1,z_1,t_{n+1})\ \text{move} \rightarrow \ldots\ldots \rightarrow P1'\ (x_1,y_1,z_1,t_{n+m})$$

```
If $(x_1,y_1,z_1,t_{n+1}) - (x_1,y_1,z_1,t_n) = 0$
        $(x_1,y_1,z_1,t_{n+1}) = (x_1,y_1,z_1,t_n)$
Else if $( (x_1,y_1,z_1,t_{n+1}) - (x_1,y_1,z_1,t_n) > 0 ) || ( (x_1,y_1,z_1,t_{n+1}) - (x_1,y_1,z_1,t_n) < 0 )$
        $(x_1,y_1,z_1,t_{n+1}) = (x_1,y_1,z_1,t_{n+1})$
```

Thus, the next point will be stored in the storage for every point after movement occurs

from t_n *until* t_{n+1} ➔ $(x_1,y_1,z_1) || (x_1,y_1,z_1)'$

By executing this process, movement data can be stored more easily and point which not involve with a change does not store again. Therefore, the data model developed will be less redundant and can manage changes on a volumetric surface more efficiently. Figure 2 bellow show visualization of the conceptual testing has been done to prove that data model has been tested.



Start (t_s) Intermediate (t_i) End (t_s)

Figure 2: Visualization of the Volumetric Surface Movement Data from Spatiotemporal Database

3. Conclusion

The main highlight in this discussion is the capability of a data model in managing surface movement spatiotemporal data. Spatiotemporal systems consist of parameter *x, y, z* (space element) and *t* (temporal element). In summary, our main contribution in this research is the proposed Spatiotemporal Data Model. This data model has been tested and proved of its capability by using a VGIS prototype to simulate the volumetric surface movement. Test result show that by using this model, data redundancy is avoided whenever changes of data in the same area is stored in the database.

However, there are several areas that can still be improved such as data indexing to improve retrieval time, capability to manage and visualize volumetric surface with uncertainty data. Nonetheless, this technique did manage to present ideas in improving VGIS applications.

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First Steps Towards the Automated Production of Intelligent Incident Cordon Zones: Developing a Conceptual Model of Incident Scene Management

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1 Introduction

The emergency services response to large life-threatening CBRN (Chemical, Biological, Radiological or Nuclear) emergencies, which are mainly associated with terrorist attacks, is a very complex process. It requires the co-operation of a vast amount of people representing several agencies with different sets of priorities. Moreover, very little is known about the actual incident in the first stages of the response. This high level of uncertainty coupled with the fact that the response teams are often formed ad-hoc enormously challenge the management of the response.

Before any decision is made, incident commanders, who manage the incident response, have to ensure that they possess all essential information. In accordance with the Civil Contingencies Act (Civil Contingencies Act, 2005) the emergency responders are obliged to share information with each other. Much of this information is of a geospatial nature. The recent Open Geospatial Consortium Web Services, Phase 4 (OWS-4) interoperability testbed has demonstrated that the standards and technology exist to provide access to multiple sources of real-time geospatial information over the Internet (Open Geospatial Consortium, 2006).

However, essential geospatial information at the right time does not yet guarantee a successful response. This information has to be carefully analysed. Subsequently, crucial decisions about the incident response are made based on those analyses. Several research projects have looked at techniques which can automate part of the decision making process to help support the work of incident commanders (Turoff *et al.*, 2004; Batty *et al.*, 2003; Kitano *et al.*, 1999; de Silva, 2000; van Borkulo *et al.*, 2005). However, to date, there are no formalised nor automated decision making processes which can support the work of the incident commanders in the matter of securing the incident site. This research specifically concentrates on delivering a methodology which provides an enhance solution

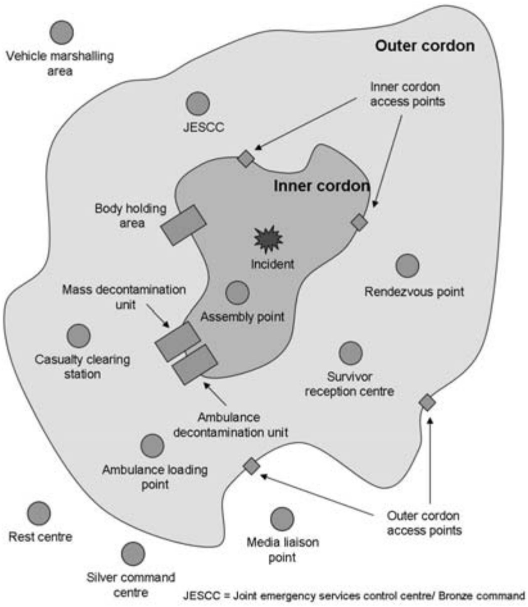


Figure 1: One of the two rich pictures depicting CBRN incident scene management.

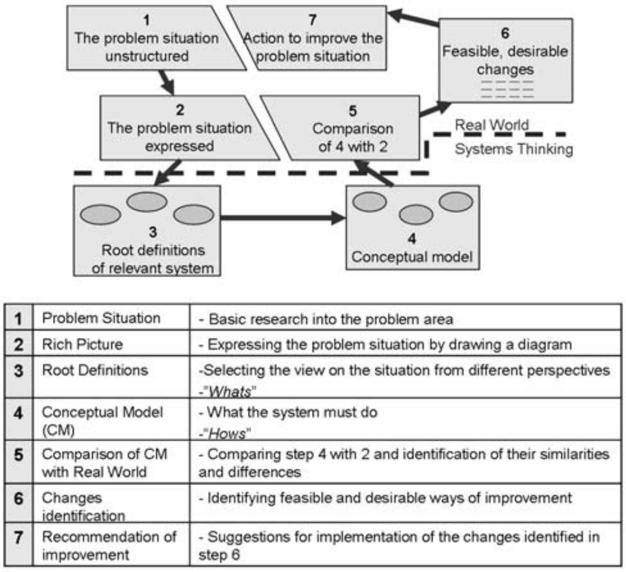
for modelling and optimising size, shape and position of inner and outer cordon zones by developing a tool for the automated demarcation of Intelligent Incident Cordon Zones.

This paper presents the first steps in developing such a tool by identification of management of the incident scene using a rich picture approach (Monk and Howard, 1998). Subsequently, a conceptual model is developed based on that information. This work has been undertaken within a soft systems methodology framework (Checkland and Scholes, 1990).

2 CBRN incident scene management

One of the first decisions incident commanders have to deal with, when managing the response to the large CBRN incidents, is the appropriate demarcation of the affected area into inner and outer cordon zones. Each cordon zone has a distinct function. The inner cordon zone directly secures the incident site and its proximate neighbourhood which is contaminated by the aggressive CBRN agents. The purpose of this cordon is to protect the public and to preserve evidence of the crime for police investigation. People involved in the rescue operations within the inner cordon are allowed to access that area only through designated cordon access point and must be appropriately dressed and equipped.

To support the operations of the emergency services the outer cordon zone is set-up di-



1	Problem Situation	- Basic research into the problem area
2	Rich Picture	- Expressing the problem situation by drawing a diagram
3	Root Definitions	-Selecting the view on the situation from different perspectives -"*Whats*"
4	Conceptual Model (CM)	- What the system must do -"*Hows*"
5	Comparison of CM with Real World	- Comparing step 4 with 2 and identification of their similarities and differences
6	Changes identification	- Identifying feasible and desirable ways of improvement
7	Recommendation of improvement	- Suggestions for implementation of the changes identified in step 6

Figure 2: SSM: conventional seven-stage model (Checkland and Scholes, 1990).

rectly around the inner cordon. The main function of the outer cordon is to provide sufficient space for the location of key off-site functions and facilities. Since the emergence of a CBRN incident is difficult to predict the outer cordon also serves as an additional safety zone which will protect the public if the contamination unexpectedly expands outwards from the incident. Figure 1 depicts core facilities for the inner and outer cordon zones. (HM Government, 2005).

3 Knowledge extraction process

The Civil Contingencies Act (Civil Contingencies Act, 2005) establishes a general framework to assist with selection of suitable locations and extents for both cordon zones. However, the actual decision making process is not a trivial task due to its complexity. Currently, the decisions are based purely on the experience and knowledge of the incident commanders in charge. The decisions are supported by geospatial information about the exposed area, standard operating procedures, information about the dangerous substance involved in the incident and regular reports from the incident site. The decisions are also limited by number of available resources for the actual cordons placement. Since the incident commanders represent different organisations with different concerns over the cordons, the final decision results from several iterations based on timely negotiation of compromises.

Extensive research into the cordon placement problem has to be accomplished before any changes to the current incident scene management system can be suggested. Therefore, a close collaboration with Nottinghamshire Fire and Rescue Services (NFRS) and Nottinghamshire Police (NP) has been established in the initial stages of this research project. Experienced incident commanders have been interviewed to describe the function of the CBRN incident scene management system, responsibilities and priorities of every emergency services. Soft Systems Methodology (SSM) has been used to perform a detailed analysis of complex situations with divergent views about the exact definition of the problem. The rich picture technique has been selected as a tool for capturing and formalising the 'problem situation' in term of extracted knowledge about the current system (Couprie *et al.*, 2006; Wilson, 2001; Checkland and Scholes, 1990).

SSM places emphasis on people's perception of reality, their experience and knowledge of the environment. In general, SSM is divided into seven stages depicted in Figure 2. The stages can be divided into two distinct groups based on the different perceptions of the problem; the real world view and the system thinking view. Each step of the SSM represents an iterative process where every iteration is discussed with people involved in the system (Checkland and Scholes, 1990).

4 Results

4.1 Step 1: Building rich pictures

To capture and organise all possible views of the problem two rich pictures has been compiled from the information that was obtained from the interviews. Since the creation of the inner cordon zone is dependent on different factors to those which influence the location of the outer cordon, two separate rich pictures were drawn to depict the decision processes. To produce the final rich pictures required three iterations. Figure 3 is a rich picture depicting the process of inner cordon zone creation. The rich picture representing the outer cordon zone creation is similar but expresses a number of different concerns. The results of every iteration were discussed with incident commanders.

The picture represents the primary stakeholders in the decision making process. These are the main category one responders as defined under the Civil Contingencies Act (2005) i.e., FRS, Police, Ambulance and Local authorities. Each stakeholder's concerns and desires that are relevant to the CBRN incident scene management system are represented by thought bubbles. Finally, the interrelationships and information flows are expressed by oriented arrows with action labels. Pictorial symbols are used to emphasise the main components involved.

4.2 Step 2: Developing a root definition

The process of establishing an essential perception of the system that is to be modelled involves the construction of a 'root definition'. The root definition provides a succinct encapsulation of the problem from a particular perspective and forms the backbone of the

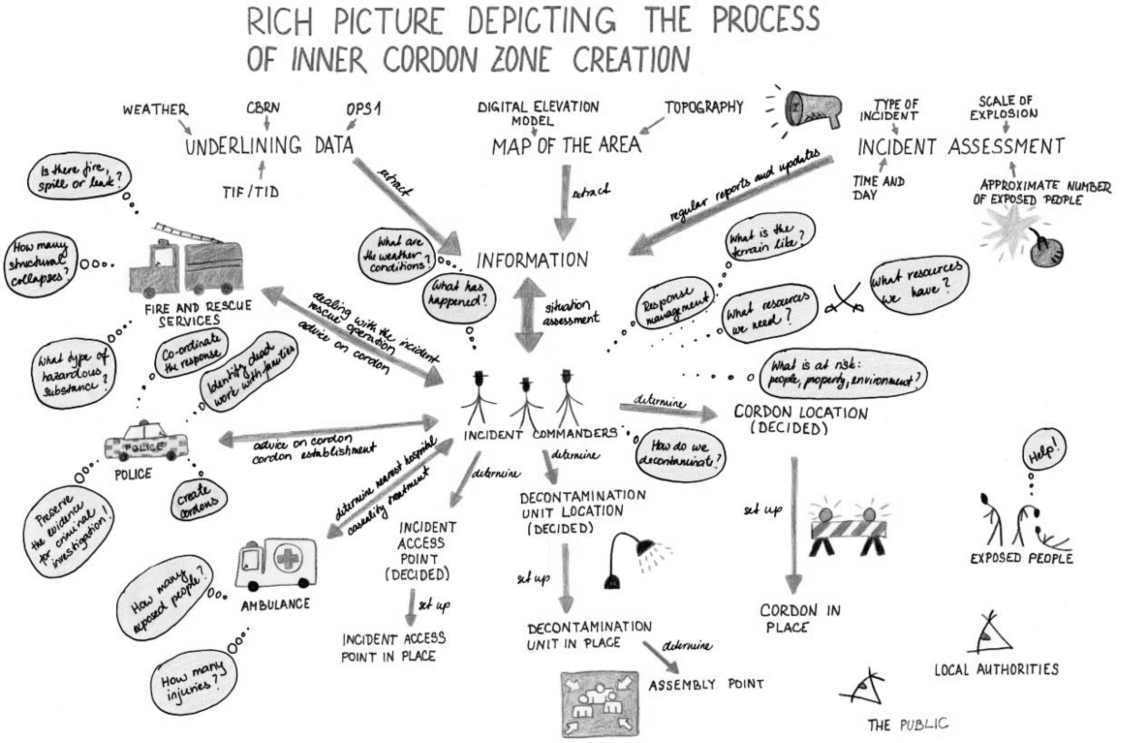
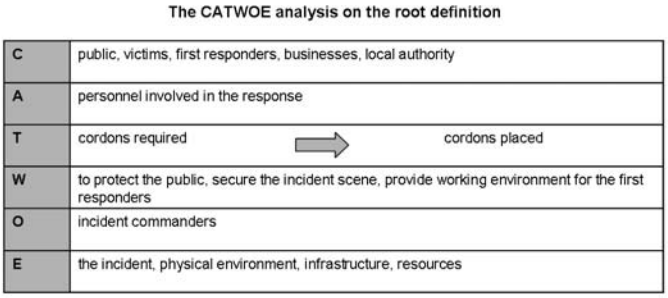


Figure 3: CBRN incident scene management of inner cordon placement.

activity system that is depicted in the rich picture. The core of the root definition is expressed as a transformation process that takes some entity as input, and changes that entity, to produce a new form of that entity as output. The input for the root definition is selected from issues or tasks represented in the rich picture. The actual root definition is written as a sentence of strictly defined structure. Six elements that are summed up in the mnemonic CATWOE were used to check the formulation of a root definition and to question the words that were used within (Wilson, 2001);

C (Customers) - everyone who gain benefits or drawbacks from the system;
A (Actors) - those who would perform the activities defined in the system;
T (Transformation processes) - the conversion of input to output;
W (*Weltanschauung*) - the German expression for world view which makes this transformation process meaningful in context;
O (Owner/s) - those who have proprietary right to start or shut down the system;
E (Environmental constraints) - elements outside the system which it takes as given.

In the CBRN incident scene management system only one root definition is derived based on both pictures: the first one depicting the process of inner and the second one of outer



The CATWOE analysis on the root definition

C	public, victims, first responders, businesses, local authority
A	personnel involved in the response
T	cordons required → cordons placed
W	to protect the public, secure the incident scene, provide working environment for the first responders
O	incident commanders
E	the incident, physical environment, infrastructure, resources

Figure 4: CATWOE analysis of the root definition.

cordon zone creation. Although the processes of creating inner and outer cordon differs, they share the same aim which is to secure the incident scene and protect the public. The final root definition reads:

An incident commanders owned system, operated by incident response officers, to place incident cordon zones, in order to protect the public, treat the victims, secure the incident scene, provide a working environment for the first responders and limit disruption of business activities to a minimum while considering the incident, physical environment, infrastructure and available resources.

The CATWOE elements underlaying the root definition are depicted in Figure 4.

4.3 Step 3: Developing a conceptual model

The general aim of the conceptual model is to capture the essential concepts of the system and to organise initial thoughts and ideas. The modelling process consists of assembling and structuring the minimum necessary activities to carry out the transformation process specified in the root definition (Checkland and Scholes, 1990; Wilson, 2001). The configuration of the model is based upon logical dependencies where the relationships are shown by linking the activities with an arrow directed from the antecedent to the consequent. The creation of the conceptual model is based on three questions related to the transformation where answers to each question may become subsystems of the general system:

What has to be done to acquire the input?
What must then be done to reach the output?
What must then be done to make the output available?

The conceptual model displayed in Figure 5 illustrates all activities of the CBRN incident scene management system which is divided into three subsystems. The first subsystem depicts information acquisition processes. The information about the actual incident is supplemented in form of regularly updated reports from the incident scene. This information

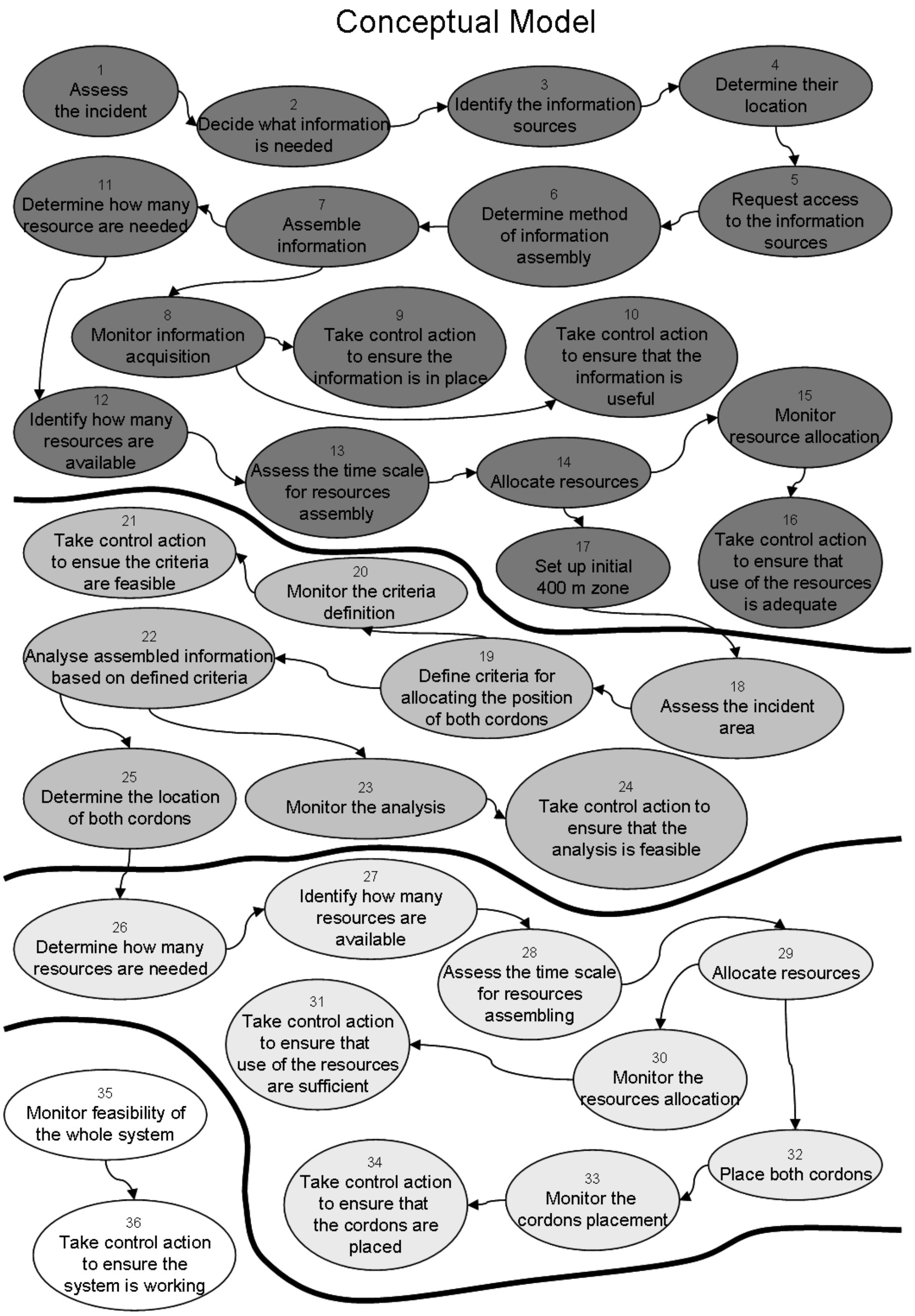


Figure 5: Conceptual model of CBRN incident scene management system.

needs to be then fused with information extracted from underlining data sources: database containing information about behaviour of CBRN substances (CHEMDATA), meteorological data, basic topographic map and digital elevation model of the area. The general function of the first subsystem is to deliver all necessary information for the decision making processes and analyses. These are the core activities of the conceptual model and are represented in the second subsystem. The third subsystem corresponds to the actual placement of the inner and outer cordon zones around the incident scene and is based on the outputs of the second subsystem.

To ensure coherence of the model each of the activities needs to be monitored to determine whether it is performing at acceptable levels. Beside, control actions have to be specified to guarantee the achievement of the purpose defined by the root definition (Wilson, 2001).

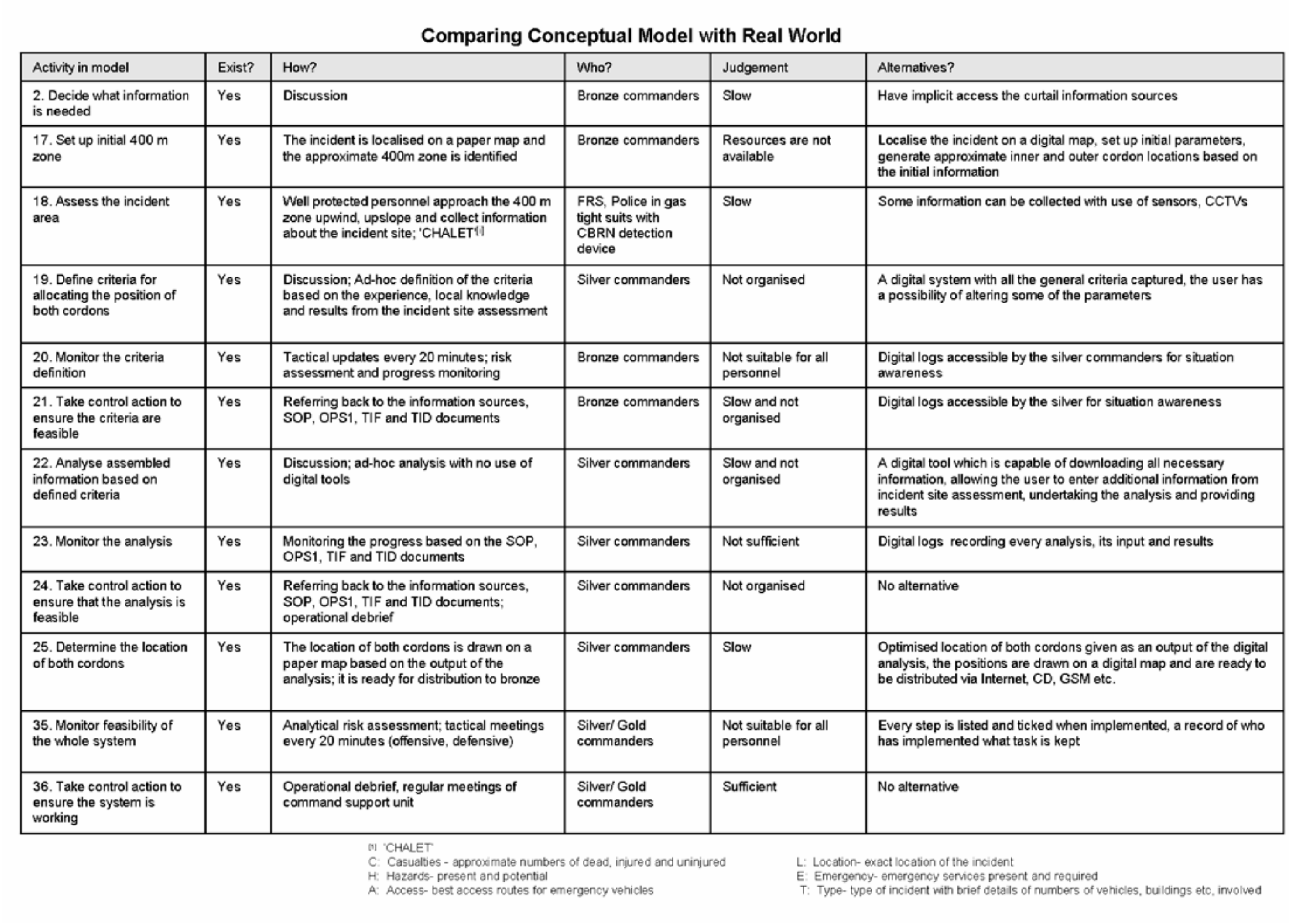
4.4 Step 4: Comparison of conceptual model with real world

The conceptual model is compared with the real world as expressed in the rich picture. Checkland and Scholes (1990) argue that the most common way of comparison in SSM is formal questioning where the conceptual model is used as a source of questions that should be asked of the real world. In general, each activity identified in the conceptual model is evaluated. A description of how the activity is currently realised is recorded. Subsequently, an investigation of potential changes is undertaken together with the system stakeholders and one or more alternative solutions is suggested.

The produced conceptual model of the CBRN incident scene management system demonstrates the complexity of the whole process. Since this research project concentrates on automation of the decision processes only the most relevant activities have been selected for the analysis. Therefore, only activities related to the second subsystem are evaluated. However, having produced the conceptual model of the whole system, any additional activity can be analysed in later stage of the research if needed. A table demonstrating the comparison process is displayed in Figure 6. The "How" column depicts how are the activities currently managed. The last column "Alternatives" summarises the possible changes to the system to improve its functionality.

5 Further work

The aim of this research project is to capture, formalise, and if possible improve the current decision making process that first responders use when searching for the best location in which to place inner and outer cordons delimitating large CBRN incidents. The next step will be to compile a set of generic rules related to the second subsystem of the conceptual model i.e., information analyses and decision making processes of the incident commanders. The implementation of such rules will be tested using a number of different computational methodologies e.g. cost surface analysis, simulated annealing, agent-based



Comparing Conceptual Model with Real World

Activity in model	Exist?	How?	Who?	Judgement	Alternatives?
2. Decide what information is needed	Yes	Discussion	Bronze commanders	Slow	Have implicit access the curtail information sources
17. Set up initial 400 m zone	Yes	The incident is localised on a paper map and the approximate 400m zone is identified	Bronze commanders	Resources are not available	Localise the incident on a digital map, set up initial parameters, generate approximate inner and outer cordon locations based on the initial information
18. Assess the incident area	Yes	Well protected personnel approach the 400 m zone upwind, upslope and collect information about the incident site; 'CHALET'[1]	FRS, Police in gas tight suits with CBRN detection device	Slow	Some information can be collected with use of sensors, CCTVs
19. Define criteria for allocating the position of both cordons	Yes	Discussion; Ad-hoc definition of the criteria based on the experience, local knowledge and results from the incident site assessment	Silver commanders	Not organised	A digital system with all the general criteria captured, the user has a possibility of altering some of the parameters
20. Monitor the criteria definition	Yes	Tactical updates every 20 minutes; risk assessment and progress monitoring	Bronze commanders	Not suitable for all personnel	Digital logs accessible by the silver commanders for situation awareness
21. Take control action to ensure the criteria are feasible	Yes	Referring back to the information sources, SOP, OPS1, TIF and TID documents	Bronze commanders	Slow and not organised	Digital logs accessible by the silver for situation awareness
22. Analyse assembled information based on defined criteria	Yes	Discussion; ad-hoc analysis with no use of digital tools	Silver commanders	Slow and not organised	A digital tool which is capable of downloading all necessary information, allowing the user to enter additional information from incident site assessment, undertaking the analysis and providing results
23. Monitor the analysis	Yes	Monitoring the progress based on the SOP, OPS1, TIF and TID documents	Silver commanders	Not sufficient	Digital logs recording every analysis, its input and results
24. Take control action to ensure that the analysis is feasible	Yes	Referring back to the information sources, SOP, OPS1, TIF and TID documents; operational debrief	Silver commanders	Not organised	No alternative
25. Determine the location of both cordons	Yes	The location of both cordons is drawn on a paper map based on the output of the analysis; it is ready for distribution to bronze	Silver commanders	Slow	Optimised location of both cordons given as an output of the digital analysis, the positions are drawn on a digital map and are ready to be distributed via Internet, CD, GSM etc.
35. Monitor feasibility of the whole system	Yes	Analytical risk assessment; tactical meetings every 20 minutes (offensive, defensive)	Silver/ Gold commanders	Not suitable for all personnel	Every step is listed and ticked when implemented, a record of who has implemented what task is kept
36. Take control action to ensure the system is working	Yes	Operational debrief, regular meetings of command support unit	Silver/ Gold commanders	Sufficient	No alternative

[1] 'CHALET'

C: Casualties - approximate numbers of dead, injured and uninjured
H: Hazards- present and potential
A: Access- best access routes for emergency vehicles
L: Location- exact location of the incident
E: Emergency- emergency services present and required
T: Type- type of incident with brief details of numbers of vehicles, buildings etc, involved

Figure 6: Comparing the conceptual model with real world.

modelling, etc. Hypothetical scenarios will then be simulated for a major CBRN incident within Nottingham city centre.

6 Acknowledgements

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Biography

Věra Karasová is a PhD student at the Centre for Geospatial Science, University of Nottingham. Her research focuses on formalisation of decision processes of incident commanders during a response to large CBRN emergencies in an urban area. She started her university studies in Geodesy and Cartography at the Czech Technical University in Prague, Czech Republic, and obtained her M.Sc. degree in Geomatics at the Institute of Cartography and Geoinformatics, Helsinki University of Technology, Finland.

Morphing Polygonal Lines: A Step Towards Continuous Generalization

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1 Introduction

Visualization of geographic information in the form of maps has been established for centuries. Depending on the scale of the map the level of detail of displayed objects must be adapted in a *generalization* process. Be it done manually or (semi-)automatically, generalization methods usually produce a map at a single target scale. This is a well-studied field, surveyed, for example, by Weibel and Dutton (1999).

In current, often web-based (Jones and Ware, 2005), geographic information systems users can interactively zoom in and out of the map, ideally at arbitrary scales and with smooth, continuous changes. However, current approaches are often characterized by a fixed set of scales or by simply zooming graphically without modifying map objects. To overcome these deficiencies *continuous* generalization methods are needed.

This paper studies an algorithm for continuously generalizing linear features like rivers or roads between their representations at two scales. Instead of line-simplification methods with a single target scale, we consider interpolating between a source and a target scale in a way that keeps the maps at intermediate scales meaningful. In computer graphics and computational geometry this interpolation process is known as *morphing* (Gomes *et al.*, 1999). Of specific interest are morphings that can deal with a certain amount of exaggeration and schematization such as reducing the number but increasing the size of road serpentines at the smaller scale. Our method first partitions the input polygonal line (polyline, for short) into characteristic segments and then defines distances between these segments. Based on those distances we compute an optimum morphing of the polyline segments at the two input scales using dynamic programming. We have implemented a prototype of the algorithm and compare its output with that of a simple linear morph.

2 Related work

Cecconi and Galanda (2002) study adaptive zooming for web applications with a focus on the technical implementation. They use the standard Douglas-Peucker line-simplification method to generalize linear features. While maps can be produced at arbitrary scales there is no smooth animation of the zooming. A set of continuous generalization operators is presented by van Kreveld (2001), including two simple algorithms for morphing a polyline to a straight-line segment. Continuous generalization for building ground plans and typification of buildings is described by Sester and Brenner (2004).

Existing algorithms for the geometric problem of finding an optimal intersection-free geodesic morphing between two simple, non-intersecting polylines (Efrat *et al.*, 2001; Bespamyatnikh, 2002) cannot be applied here because the two input polylines intersect in general. Surazhsky and Gotsman (2001a,b) compute trajectories for intersection-free morphings of plane polygonal networks using compatible triangulations. Similarly, Erten *et al.* (2004) give an algorithm for intersection-free morphing of plane networks using a combination of rigid motion and compatible triangulations. However, those approaches require a given correspondence between network nodes. In the field of computer graphics, Cohen *et al.* (1997) match point pairs sampled uniformly along two (or more) parametric freeform curves. They compute an optimal correspondence of the points w.r.t. a similarity measure based on the tangents of the curves. The algorithm is similar to ours in that it also uses dynamic programming to optimize the matching, but it does not take into account the characteristic points of geographic polylines. Samoilov and Elber (1998) extend the method of Cohen *et al.* (1997) by eliminating possible self-intersections during the morphing.

3 Model and algorithm

In this paper, we consider the problem of morphing between two given polylines, each generalized at a different scale. Our algorithms to solve the problem can be extended in a straightforward manner to finding a series of morphs across many scales, by solving each pair of polylines in the problem independently. The same approach can be applied to two networks with identical topology.

The problem of morphing between two polylines is two-fold. Firstly, a correspondence must be found between points on the two lines. Secondly, trajectories that connect pairs of corresponding points must be specified. Here we focus on the correspondence problem and assume straight-line trajectories.

In addressing the correspondence problem, our goal is to match parts of each polyline that have the same semantics, e.g., represent the same series of hairpin bends in a road at two levels of detail. We wish to do this in a way that allows the *mental map* to be retained as much as possible. The mental map is the mental image a person builds of a diagram. Retention of the mental map is believed to be important in continuous understanding of animated diagrams; see for example Misue *et al.* (1995). One important aspect of retaining the mental map is to ensure that points that are initially close together do not move too far apart. We therefore wish to minimize the movement of points from one polyline to another. To create a morph with these desired properties, we first detect characteristic points of a polyline (Section 3.1) and use these to find an optimum correspondence (Section 3.2).

Formally, we are given two polylines f and g in the plane $\mathbb{R}^2$. In the correspondence problem we need to find two continuous, monotone parameterizations $\alpha : [0,1] \to f$ and $\beta : [0,1] \to g$, such that $\alpha(0)$ and $\beta(0)$ map to the first points of f and g and $\alpha(1)$ and $\beta(1)$ map to the last points, respectively. These two parameterizations induce the correspondence between f and g: for each $u \in [0,1]$ the point $\alpha(u)$ is matched with $\beta(u)$.

3.1 Detection of characteristic points

In order to solve the correspondence problem, we first need to divide each polyline into subpolylines to be matched up. We do this by locating points on each line that are considered to be characteristic of the line; each of these characteristic points then defines the end of one subpolyline and the start of another.

Previous work on generalization notes the importance of inflection points, bend points, and start and end points in defining the character of a line (Plazanet *et al.*, 1995). To find such points, we process each of the vertices in a polyline in order, checking at each if the sign of curvature has changed (an inflection point) or if the vertex is a point of locally maximal curvature (a bend point). We also apply thresholding and Gaussian filtering techniques to minimize error on noisy or poorly sampled polylines, as detailed in Algorithm 1. Gaussian filtering is a method of smoothing curves often used to assist in analyzing noisy curves; Lowe (1989) gives further details and an efficient algorithm.

Algorithm 1: Characteristic point detection

```
Input: Polyline $f$, number of sample points $n'$, Gaussian smoothing factor $\sigma$,
       threshold angles $\theta_i, \theta_b$ and $\theta_c$.
Output: Set of characteristic points $C$.
Resample $f$ using $n'$ equally-spaced points to create a new polyline $f'$.
Apply an in-place Gaussian filter with factor $\sigma$ to smooth $f'$.
Mark inflection vertices with inflection angle $\geq \theta_i$.
Mark bend vertices with bend angle between adjacent edges $\geq \theta_b$ and change in
  curvature $\geq \theta_c$ from last point of locally minimal curvature.
Mark first and last vertices.
Proceed through the smoothed polyline $f'$ and store the distance of each marked
  vertex from the start of $f'$ as a percentage of the length of $f'$.
Return the set $C$ of points at the stored percentage distances along the original
  polyline $f$.
```

Algorithm 1 requires $O(|f|+n')$ time and space, where $|f|$ is the number of vertices on the polyline f and n' is the number of sample points. All input parameters are user-defined. Their values influence the number of characteristic points that will be detected. See the results in Section 4 for sample values.

3.2 Finding an optimum correspondence

We detect the characteristic points of f and g independently of each other. Assume that there are $n+1$ such points on f and $m+1$ points on g, which divide the polylines into two sequences of subpolylines $(f_1, \ldots, f_n)$ and $(g_1, \ldots, g_m)$. Next, we approach the correspondence problem. Basically, there are five possibilities to match a subpolyline f_i:

(a) f_i is mapped to the last characteristic point g_j^{last} of a subpolyline g_j (i.e., f_i disappears),

(b) a subpolyline g_j is mapped to the last point f_i^{last} of f_i (i.e., g_j disappears),

(c) f_i is mapped to a subpolyline g_j,

(d) f_i is mapped to a merged polyline $g_{j\ldots(j+k)}$, and

(e) f_i is part of a merged polyline $f_{\ell\ldots i\ldots(\ell+k)}$ that is mapped to a subpolyline g_j.

Clearly, the linear order of the subpolylines along f and g has to be respected by the assignment.

Now assume that there is a *morphing cost* δ associated with the morph between two polylines. We suggest a morphing distance in the next section, but Algorithm 2 is independent of the concrete distance. It is based on dynamic programming and computes a minimum-cost correspondence. Algorithm 2 recursively fills an $n \times m$ table T, where the entry $T[i, j]$ stores the minimal cost of morphing $f_{1\ldots i}$ to $g_{1\ldots j}$. Consequently, we can obtain the optimum correspondence from $T[n, m]$.

The required storage space and running time of Algorithm 2 is $O(nm)$ provided that the *look-back parameter* K is constant. Otherwise the running time increases to $O(nm(n+m))$. The parameter K determines the maximum number of subpolyline segments that can be merged in order to match them with another segment in cases (d) and (e).

Distance measure. Algorithm 2 relies on a distance function δ that represents the morphing cost of a pair of polylines. Distance functions for polylines can be defined in many ways, e.g., *morphing width* (Efrat *et al.*, 2001) and *Fréchet distance* (Alt and Godau, 1995).

We define a new distance measure that takes into account how far *all* points move during the morphing by integrating over the trajectory lengths. Assume that two subpolylines f_i and g_j with uniform parameterizations α and β are given. Each point $\alpha(u)$ on f_i will move

Algorithm 2: Optimum correspondence

```
Input: polylines $f = (f_1, \dots, f_n)$ and $g = (g_1, \dots, g_m)$, distance matrix $\delta$.
Output: optimum correspondence for $f$ and $g$.
Initialize $T[0, \cdot]$ and $T[\cdot, 0]$
for $i = 1$ to $n$ do
    for $j = 1$ to $m$ do
        $T[i,j] = \min \begin{cases} T[i-1,j] + \delta(f_i, g_j^{\text{last}}) & \text{case (a)} \\ T[i,j-1] + \delta(f_i^{\text{last}}, g_j) & \text{case (b)} \\ T[i-1,j-1] + \delta(f_i, g_j) & \text{case (c)} \\ T[i-1,j-k] + \delta(f_i, g_{(j-k+1)\dots j}),\ k = 2,\dots,K & \text{case (d)} \\ T[i-k,j-1] + \delta(f_{(i-k+1)\dots i}, g_j),\ k = 2,\dots,K & \text{case (e)} \end{cases}$
        Store pointer to predecessor, i.e., to the table entry that yielded the minimum.
    end
end
Generate optimum correspondence from $T[n,m]$ using backtracking along pointers.
```

to $\beta(u)$ on g_j along the connecting segment of length $||\alpha(u) - \beta(u)||$. Then the morphing distance is defined as

$$\delta(f_i, g_j) = \int_0^1 ||\alpha(u) - \beta(u)||du \tag{1}$$

and can be computed in time linear in the complexity of f_i and g_j.

Optionally, we can add further terms to the base distance δ. Adding the length difference of f_i and g_j, or alternatively the length of the polyline $\gamma(u) := \alpha(u) - \beta(u)$ favors pairs of polylines that are roughly the same length or orientation. We can also multiply δ by the ratio of the subpolylines' length with the total length of the containing polylines f and g, to account for their relative visual importance.

Finally, we wish to avoid self-intersections in the morph. We do this locally by setting the effective morphing distance to ∞ if matching two subpolylines causes a self-intersection in the morph between them. However, in rare cases intersections between two non-corresponding subpolylines may still occur.

4 Results

We ran our implementations on a small set of French roads from the BD Carto® and the TOP100 series maps produced by the IGN Carto2001 project (Lecordix *et al.*, 2005). For each road, we used a polyline from BD Carto® at scale 1:50,000, and a generalized version at scale 1:100,000 from the Carto2001 TOP100 maps. Figures 1(a) and 1(b) show two examples of the roads in the dataset, at the two respective scales. The characteristic

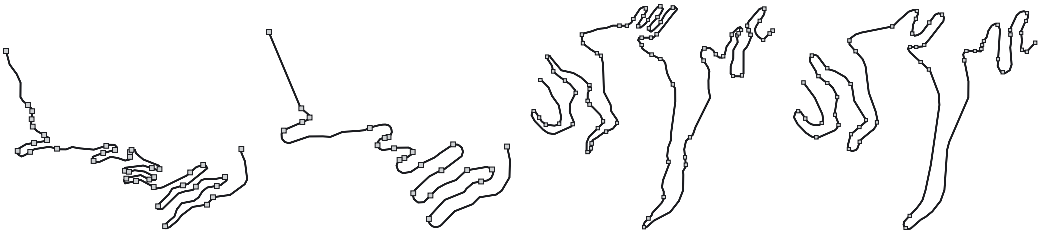
(a) Road 1 (1:50,000) (b) Road 1 (1:100,000) (c) Road 2 (1:50,000) (d) Road 2 (1:100,000)

Figure 1: Example roads at two scales with detected characteristic points marked.

Polyline	$\mathbf{n}$	$\mathbf{n'}$	σ	$\theta_\mathbf{i}$	$\theta_\mathbf{b}$	$\theta_\mathbf{c}$
Road 1 (1:50,000)	135	600	line length / 400	$45°$	$8°$	$10°$
Road 1 (1:100,000)	118	600	line length / 400	$45°$	$5°$	$6°$
Road 2 (1:50,000)	255	600	line length / 800	$55°$	$10°$	$15°$
Road 2 (1:100,000)	202	600	line length / 800	$55°$	$6°$	$11°$

Table 1: Number of vertices n in each polyline and parameter values used to detect characteristic points.

points that Algorithm 1 detected are marked by little squares. The parameter values used to obtain these results are listed in Table 1. Currently, these parameters must be set by trial and error, starting from base values of zero for $\sigma, \theta_i, \theta_b$ and θ_c and manually increasing them until the number and placement of characteristic points is acceptable to the user.

A sequence of snapshots[1] of the final morphs, after applying Algorithm 2, are shown in Figures 2(b) and 2(d), for Road 1 and Road 2 respectively. A look-back parameter K of 5 was used. For the purpose of comparison, Figures 2(a) and 2(c) show a simple linear morphing between the same polylines, where both polylines were uniformly parameterized to establish the correspondence between points. On a 3.0GHz Pentium 4 with 1GB RAM, the entire processing time was under 3 seconds for each example.

The optimum-correspondence morphing (henceforth referred to as OPTCOR) shows some clear improvements over the naïve linear morphing. The linear morphing in Figure 2(a) shows one of the large serpentine sections on the right being flipped "inside-out" during the morph. In contrast, the OPTCOR morphing in Figure 2(b) simply expands the bends. It is evident that the total movement overall is much higher for the linear morphing than for OPTCOR.

A similar situation occurs in the Road 2 example in Figures 2(c) and 2(d): the linear morphing collapses two bends before reforming a single bend, whereas OPTCOR simply collapses one of the bends and expands another to become the final bend. A close-up view of the cir-

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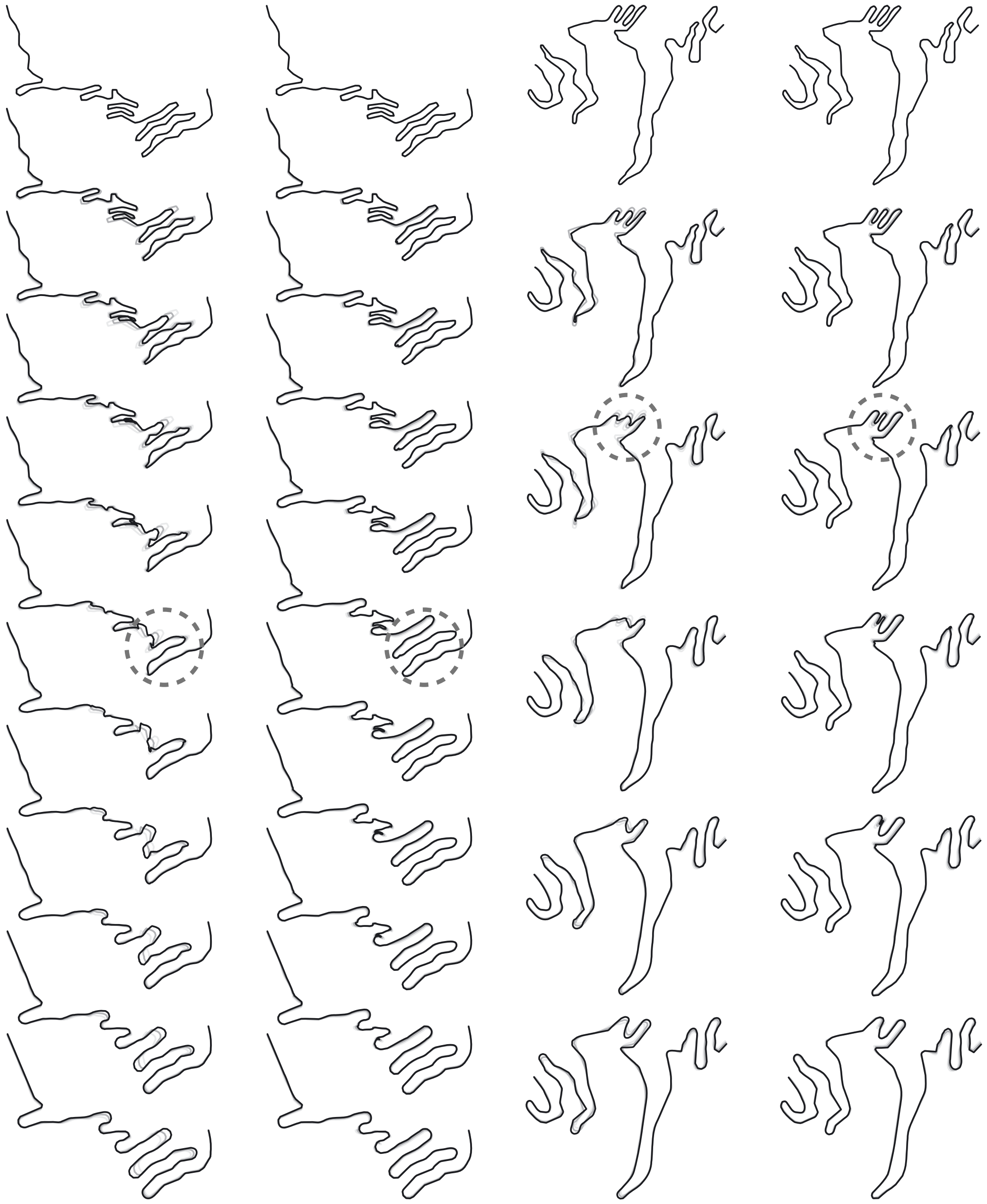
[1] The full animations are available at http://i11www.iti.uni-karlsruhe.de/morphingmovies



(a) Road 1 (Linear) (b) Road 1 (OPTCOR) (c) Road 2 (Linear) (d) Road 2 (OPTCOR)

Figure 2: A comparison between simple linear morphing and the optimum-correspondence morphing (OPTCOR) for the two example roads. In each snapshot, the previous two frames are drawn in successively lighter shades of grey. Areas of particular interest are marked with dashed circles.

cled region in Road 2 for the four central frames of the animation is shown in Figure 3. Note that while the result produced by OPTCOR is clearly better than the linear morphing, it is perhaps still not ideal. It is unclear whether collapsing one bend like this could be considered the best way of morphing from two bends to one. Further research may consider human factors in order to determine what type of morphing is perceptually optimal. In addition, our results indicate that there is a trade-off to be considered. On the one hand, we want to make an animation that is as smooth as possible and retains the mental map, but on the other hand we may also want to ensure that each individual frame is optimal at its scale if viewed without the temporal context of the animation.

(a) Linear

(b) OPTCOR

Figure 3: A close-up of collapsing bends in the Road 2 example.

5 Concluding remarks

The algorithms in this paper should be improved in two ways. Ensuring that self-intersections do not occur during a morph could potentially be accomplished by utilizing the algorithm of Surazhsky and Gotsman (2001b) to compute non-linear trajectories for points. Additionally, the detection of appropriate characteristic points with little or no user interaction requires further investigation.

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Comparison of region approximation techniques based on Delaunay Triangulations and Voronoi Diagrams

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1 Introduction

Region approximation techniques based on constructions from sample data points, i.e., points whose position is known and which are known to be inside or outside the region of interest, can be advantageous in a variety of applications. The technique is introduced in Alani et al (2001) and examples of its use are given in Arampatzis et al (2006) and Tatalovich (2005).

The techniques are attractive because they will typically require less storage and less computing power to generate representations of regions and answer related queries of the form 'what is the area of X?' and 'what is the length of boundary of X?' than techniques based on arbitrary polygons ('exact' vector representations). They are however far more accurate than simplistic region representations such as bounding boxes.

In the application where map data is being transmitted to mobile devices these methods are particularly attractive because the boundary (e.g., of a county) in effect comes free with the transmission of the point locations of (say) towns and villages.

While techniques of this nature are in use as described to approximate boundaries it is not thought that any comparative work on the different possible constructions has been carried out. Also no analysis of the likely errors (as opposed to actual errors for specific cases) exists, so it is not yet possible to say for a real data set that the error is better or worse than expected, or, if the error cannot be calculated, what it is likely to be. The results in this paper should enable the likely degree of uncertainty to be taken into account in future work using these techniques.

In approximating a region the area error is made up of areas modelled as inside the region which are in fact outside (+ve areas) and areas modelled as outside which are in fact inside ($-$ve areas). A related measure, the RMS (Root Mean Squared) distance between the constructed approximation line and the region boundary, is considered to be more informative.

2 Constructions considered

This paper compares the following constructions:

1. Voronoi diagram method. The approximator line is formed from the edges in a Voronoi diagram which separate cells around pairs of points one of which is inside and the other outside the region of interest.
2. Delaunay triangulation mid-points method. This method is illustrated in figure 1. The approximator line (dark gray) is formed by joining the mid-points of edges (mid gray) in the triangulation which cross the line to be approximated (in black) (i.e., they join points inside and outside the region of interest).

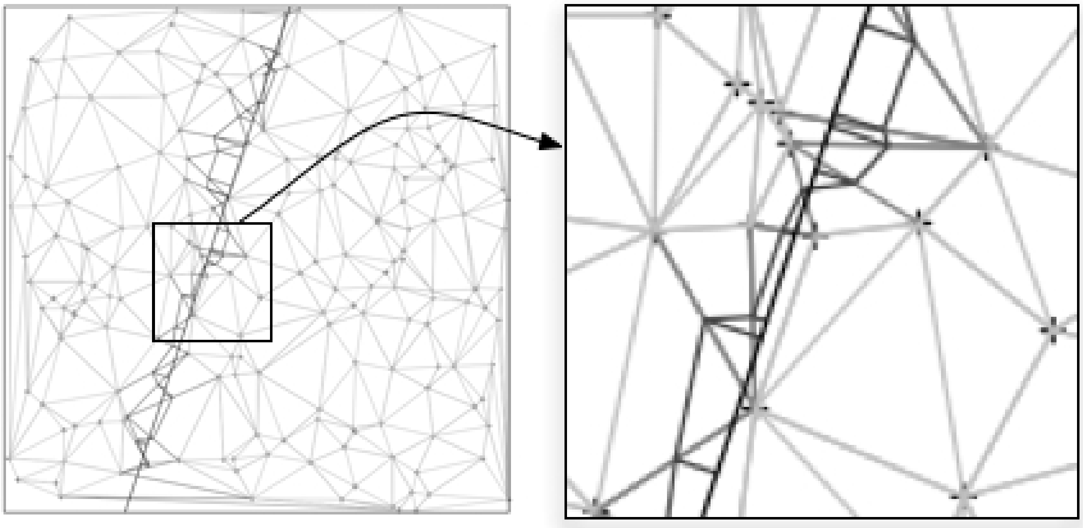

Figure 1: Delaunay mid-point approximation to a region boundary line

3. Further constructions. Various other possibilities for forming the approximator line and limitations on the use of filtering (smoothing) are briefly considered.

3 Results

Results are presented from a Monte Carlo model of the different constructions. 800 random point distributions each with 5 randomly placed lines were used for each point density. A Delaunay triangulation and Voronoi diagram were produced for each random point distribution and line. The results show that the construction based on mid-points of edges in a Delaunay triangulation produces the lowest errors, some 10% less than those produced by the Voronoi diagram construction which appears to be more widely used at present. The results for the different constructions for differing sample point densities in RMS length units are given in table 1. The sample point density is the stated number of points in a square of unit length.

The consistency of the standard deviation would appear to be due to this being a function of the point distribution, not the construction used. The two constructions produce related, though different, area errors, as discussed below.

The results from the model in the case of approximating to a circle of fixed radius with varying point density are given in table 2 and table 3. The imbalance between the +ve and −ve area errors is discussed below.

4 Discussion

A consideration of the basic geometries of the two constructions suggests an explanation for the difference between them based on the length of the generated approximation line. The geometrically based predictions agree closely with the results from the Monte Carlo model.

Consider the 'canonical' case in figure 2. Here a line segment for each construction is shown along with a segment (L(average)) of the line to be approximated. The average length of line crossing the triangle can be derived for the special case of an equilateral triangle grid by considering the diagram in figure 3. From symmetry it is clear that all

	Delaunay mid-points		**Voronoi diagram**	
No. Points	RMS Error	Std. Dev.	RMS Error	Std. Dev.
50	0.03783	0.01438	0.04046	0.01487
100	0.02763	0.00878	0.03025	0.00897
200	0.01949	0.00483	0.02204	0.00474
400	0.01380	0.00281	0.01584	0.00280
800	0.00976	0.00169	0.01122	0.00169

Table 1: Approximation error with varying sample point density

Delaunay mid-points errors				
No. points	+ve rms error	-ve rms error.	total rms error	std. dev.
50	0.01749	0.02266	0.04020	0.00956
100	0.01273	0.01541	0.02814	0.00576
200	0.00956	0.01018	0.01975	0.00324
400	0.00668	0.00728	0.01395	0.00205
800	0.00475	0.00504	0.00979	0.00118

Table 2: Radius of curvature effect on Delaunay mid-points approximation error

Voronoi diagram errors				
No. points	+ve rms error	-ve rms error.	total rms error	std. dev.
50	0.02232	0.02266	0.04496	0.00952
100	0.01583	0.01615	0.03198	0.00586
200	0.01082	0.01132	0.02214	0.00313
400	0.00797	0.00790	0.01588	0.00199
800	0.00567	0.00561	0.01128	0.00117

Table 3: Radius of curvature effect on Voronoi diagram approximation error

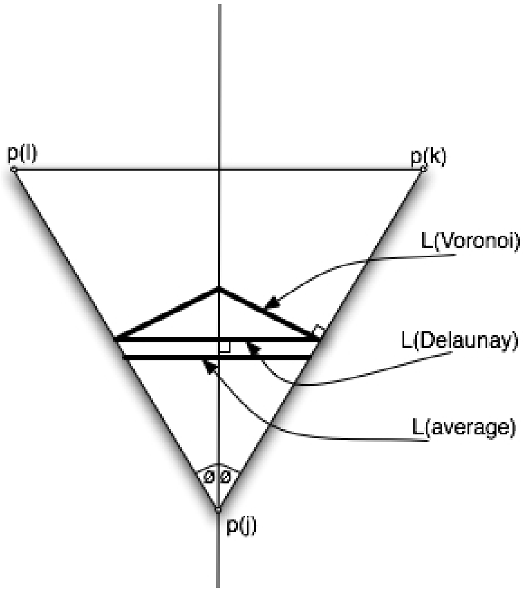

Figure 2: Canonical case of approximation lines constructed

lines P can be considered as being between angle 0 and $\frac{\pi}{6}$ of some arbitrary orientation. For lines in general position (i.e.,not passing through vertices) the number of triangles, N, crossed traversing the hexagon is constant $N = 2n$ (figure 3) and the average length of line, $L(average)$, per triangle of side length d, can be easily calculated as:

$$L(average) = \frac{P(average)}{N} = \frac{3}{\pi}\int_0^{\frac{\pi}{6}}(d\cos(\alpha))d\alpha = 0.477d \tag{1}$$

assuming all angles α to be equally likely. The extra line length generated by the two constructions ($L(Delaunay) = 0.5d$, $L(Voronoi) = 0.577d$) necessarily leads to an extra area error. This is greater for the Voronoi diagram as shown in the Monte Carlo results. A construction which generated the correct line length would still exhibit area errors.

Generalising from this special case requires consideration of the distribution of angles ϕ but it is worth noting that the Delaunay triangulation by its nature tends to minimise variation of ϕ from the equilateral case. Cases where the Voronoi construction does not conform to figure 2 would also need to be considered.

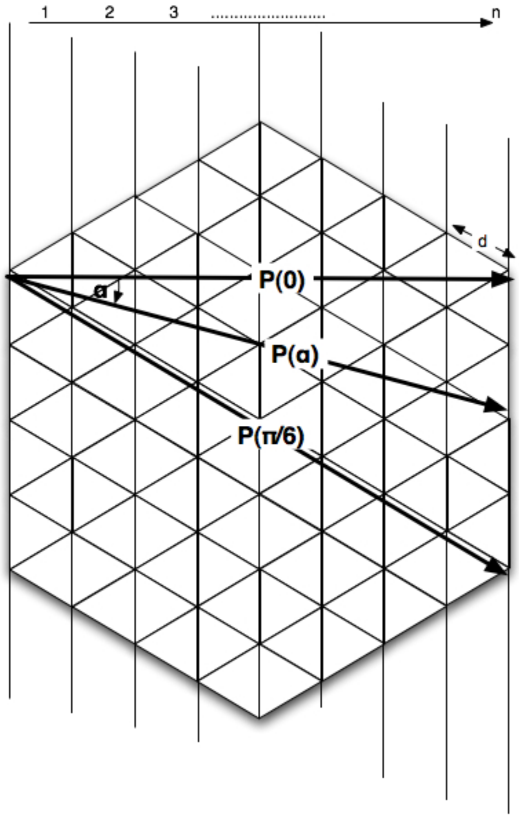

Figure 3: Construction for calculating L(average)

The geometry of the constructions when approximating boundaries with finite radius of curvature is illustrated in figure 4. The effect of the curvature will depend on whether P(j) is inside or outside of the region, however for a closed convex region there will be more cases where it is inside than out (6 more for the equilateral grid special case). Thus we would expect the reduction in positive area error shown in the Monte Carlo results (table 2) for the Delaunay mid-points approximation to a circle. Also as expected the Voronoi diagram approximation to a circle does not exhibit the effect to the same extent (table 3)

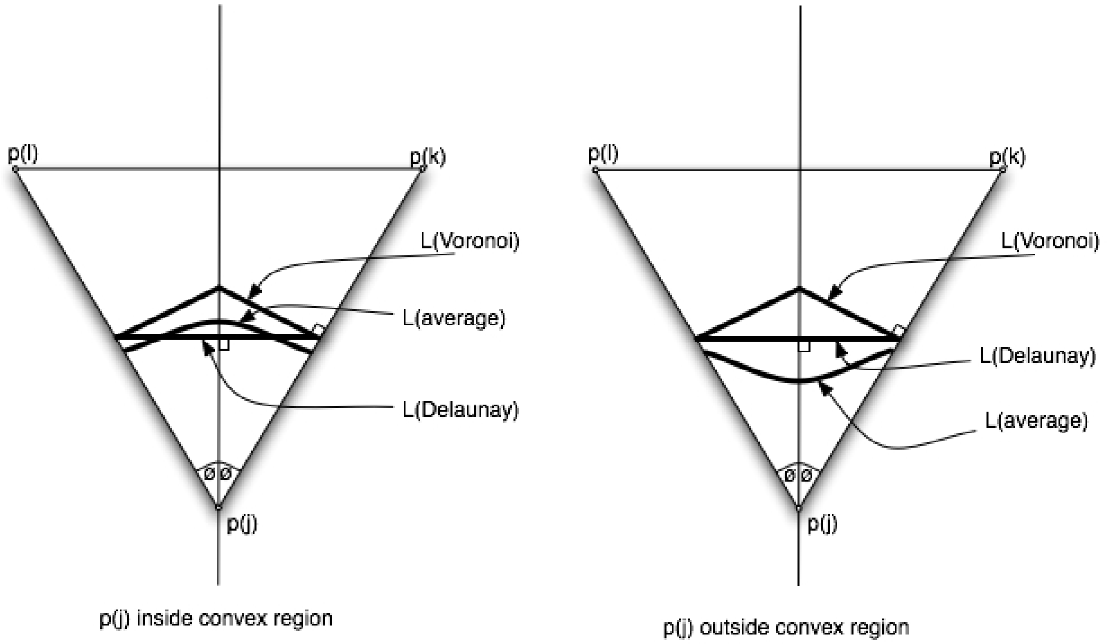

Figure 4: Approximation to curved line segments

Some discrepancies in the size of the errors between the Monte Carlo model and those predicted from consideration of the geometry remain unresolved and are noted as topics for further work.

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Representing Forested Regions at Small Scales: Automatic Derivation from the Very Large Scale.

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1. Context

Being able to view geographic regions at multiple levels of detail is essential to geographic inquiry (Sheppard and McMaster 2004). It affords meaning through the identification of pattern, and interpretation of a palimpsest of processes that operate at various scales (in both time and space). One class of feature commonly found on topographic maps is forest. At the finest scale it can involve the representation of individual trees. And at very coarse scale (say 1:250 000 scale) forests are shown in a way that enables broad classifications of land use, that 'map' to our conceptual understandings of what constitutes (prototypically speaking) 'forest' – such that we are able to conceptualise what is meant by the 'Amazonian Forest', or 'Sherwood Forest' (one of the largest forests in the UK). Rather than the redundancy of multiple databases (each recording forests at these different conceptual scales), surely it is more efficient to maintain a single, highly detailed database, that acts as single point of update? Then to apply generalisation algorithms that, metaphorically speaking, aggregate the detail of the tree, in order to see the forest? The creation of such a system can support integration/conflation of data at different scales (Weibel 1995), 'intelligent zoom' in interactive environments (seeing more detail as you zoom in to the map), scale dependent spatial analysis (analysis of data at a scale appropriate to the task) and exploratory data analysis. This paper presents a technique that automatically creates forested regions for visualisation at a scale of 1:250 000 from very detailed mapping – the Ordnance Survey's (OS) MasterMap (1:1 250/1:10 000) Forestry layer (a vector-based topography layer).

2. Methodology

The input data was OS MasterMap data of forest regions around Peebles, in the Scottish Borders (Figure 1). Some regions were used to parameterise the algorithm as part of the initial pilot study, whilst other regions were used to assess the success of that parameterisation process. In this research we used two types of forests: Coniferous and Non Coniferous trees.

2.1 Rich get Richer – Poor get Poorer

Initial work drew upon the work of Muller and Wang (1992) who developed an algorithm to generalise groups of lakes. The essence of their methodology was to rank the lakes in order of size, to define a midpoint in the ranking, and for those lakes greater than a certain area, they were further enlarged (by buffering), and those beneath the midpoint, for their areas to be reduced in size. Then any lakes falling beneath some prescribed visual tolerance (the size at which they were no longer discernable to the human eye for a given scale) were removed. Their ‘area patch’ methodology is analogous to the idea that ‘the rich get richer, and the poor get poorer’. Their algorithm was re-implemented and applied to forest patches, but produced disappointing results (Figure 2). Though the algorithm presented here retains the idea that “the rich get richer and the poor get poorer” it was extended to additionally support aggregation of polygons and the elimination of unwanted detail.

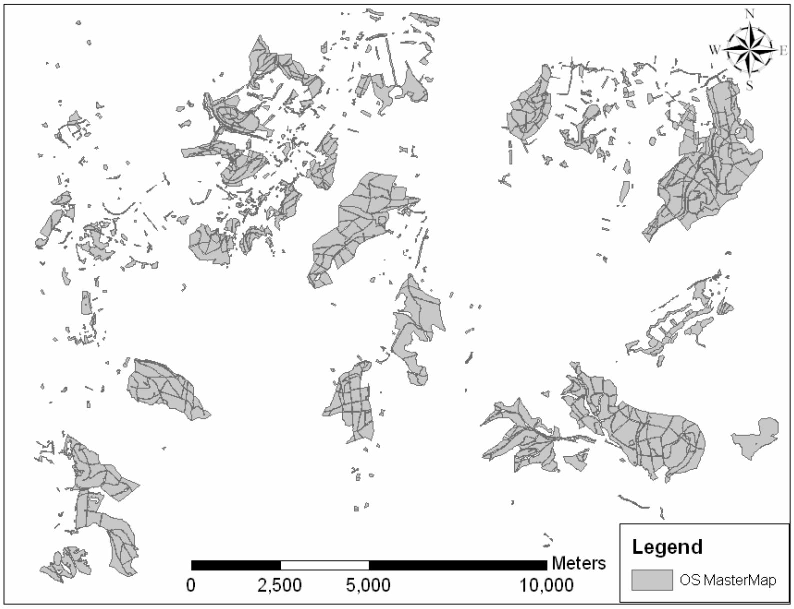

Figure 1: Example of Input Data (Woodland) from OS MasterMap (OS MasterMap© Crown Copyright Ordnance Survey. All rights reserved)

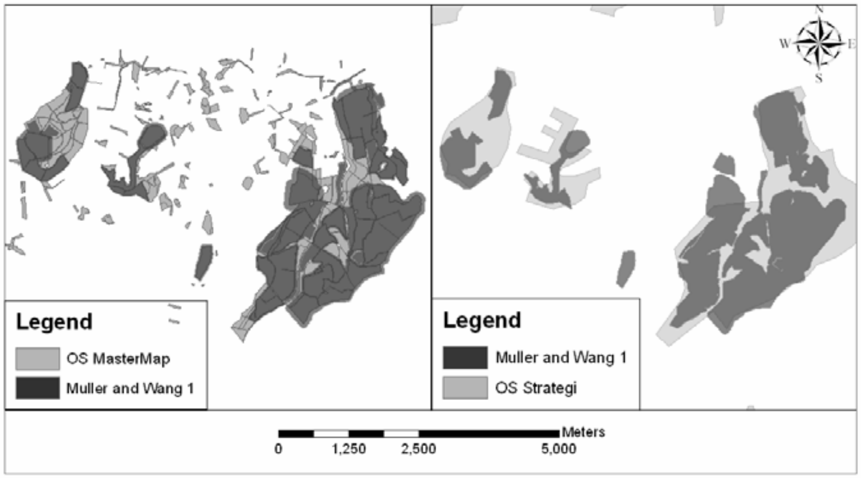

Figure 2: Unsatisfactory results from Muller and Wang’s Methodology (OS MasterMap© Crown Copyright Ordnance Survey. All rights reserved)

The methodology presented here works by buffering (either enlarging or shrinking) the size of forest patches. When resulting patches overlap, they are joined (union'ed). Small holes within regions are 'patched' and reclassified to that of the surrounding patch. The algorithm takes into account groups of small patches. Where there is sufficient density of small patches, these are union'ed. As a final step, the areas are significantly shrunk, and then re-enlarged. The selection of various tolerances (how much to enlarge by, what size of hole is deemed to be too small, what is the tipping point at which some grow larger, and some grow smaller), was done by empirical analysis. In other words, various output was examined using different tolerances until the desired output was consistently produced. The key stages are visually summarized in Figure 3.

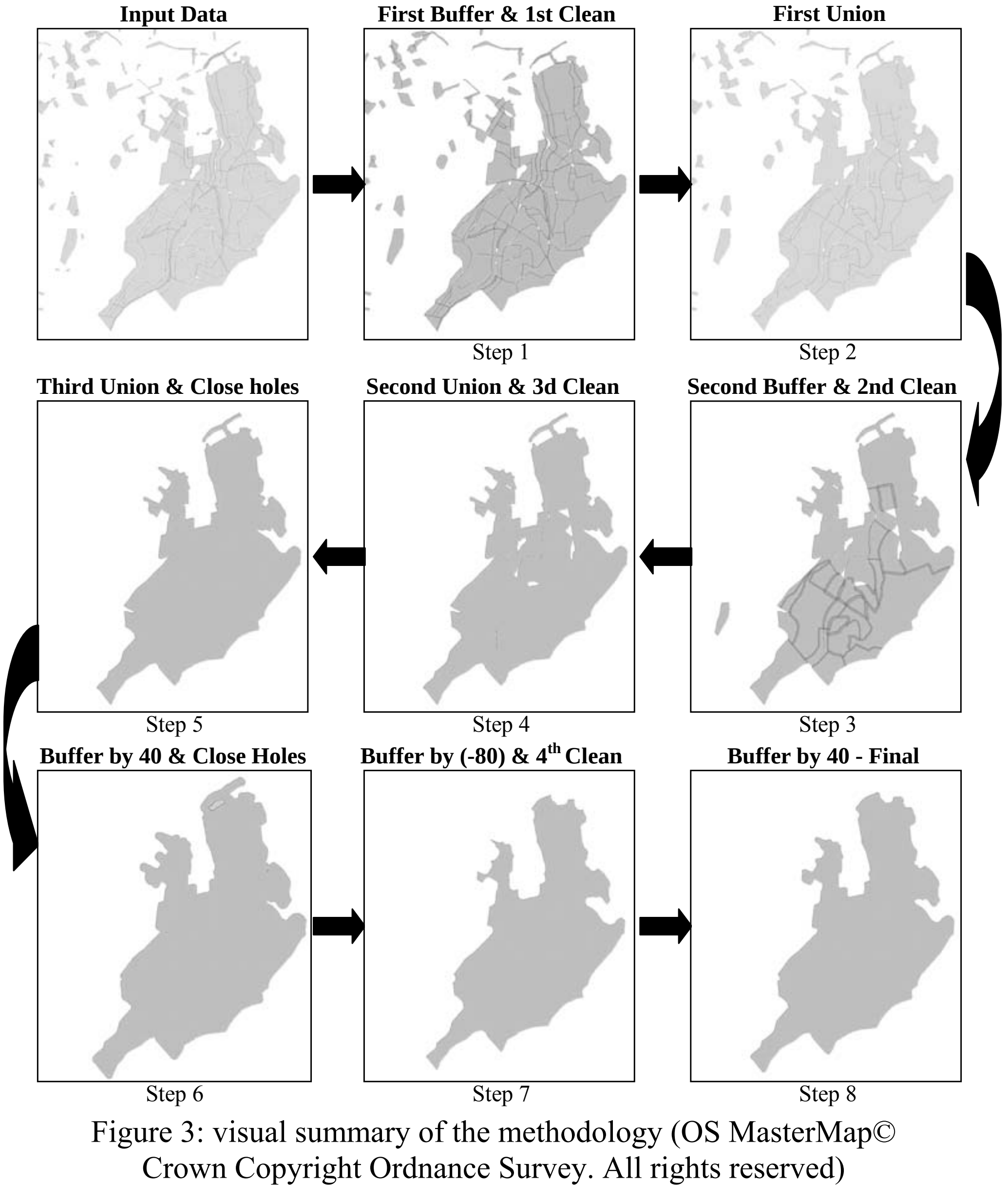

Figure 3: visual summary of the methodology (OS MasterMap© Crown Copyright Ordnance Survey. All rights reserved)

2.2 Pre selection and union

Original forest polygons provided by OS included very small patches which are not useful to a generalized solution but create high processing overheads. Therefore those patches had to be eliminated before starting any calculations, and patches within a certain distance threshold were aggregated. This reduced the number of patches by up to 90% depending on the amount of fragmentation and the density of patches.

The thresholds (used either for selecting or buffering) were empirically derived after numerous tests with small test data sets. For example inspection of the dataset revealed that there were many patches with an area less than 5000 m2(T 1) a size that is practically invisible to the human eye at 1: 250 000 scale. The buffering threshold (T 2) (used in step 1 and 2) was derived by inspection of dense collections of small areas and was set roughly to half the width of the roads. This threshold was trying to merge patches separated by narrow roads. The most important threshold, (T 4), was the size above which patches were expanded (Step 3). The threshold for elimination (Ws) was originally set by calculating the smallest visible patch found at 1:250 000 scale. The remaining threshold values where identified empirically.

2.3 Promotion and Elimination

All the important data selection was done in steps 3-5 (Figure 3). Its effectiveness in choosing and creating the final woodland patches was crucial to the success of the overall process. Any patch larger than T4 was expanded by a blanket width defined by equation 1 (Muller and Wang ,1992).

$$\text{Blanket Width: } ti = (ci)(K)/\sqrt{|a_i - T4|} \qquad (1)$$

where K is the constant for scaling the blanket width

$K = t^*/\sqrt{(Max - T4)}$

t* = threshold provided by user(larger scale reduction = larger value of t*)
Max = Maximum patch area of the input data
T 4 = Threshold for expansion or contraction provided by user
and ci is the compactness index of patch ai
ci = ai/(pi/4π)
ai = Area of patch i
pi = Perimeter of area ai
π = Mathematical pi = (3.142)

Equation 1: Muller and Wang's equation for defining the amount of expansion.

The objective of the next step was to 'promote' small areas if they were part of a dense region. This was done by checking the remaining patches of the first filter to see if they were larger than 3Ws/4 (Threshold extra) (where Ws is the elimination threshold), and at the same time "close" to at least two other patches (Threshold close).Ordinarily, small isolated patches would be removed. But this intermediate threshold (T extra) meant that clusters of small patches were retained. The key idea was that if a patch contains two or more patches within a certain threshold distance (i.e., close) it is considered important and therefore is expanded to increase its chance of surviving the elimination filter that follows. The 'close' threshold was defined empirically and surviving patches were buffered (expanded) by a blanket width equal to ti (Blanket Width). All other patches not following this rule were contracted by a blanket width ti. Once this buffering process was completed, all those patches smaller than Ws were eliminated.

The result of these steps is a dataset with only large patches completely unified without holes, unless a hole is larger than threshold (T5). Patches tended to have sharp edges or unwanted cavities. These needed to be simplified. Simplification was achieved by making first a large positive buffering, a union operation, and then an equivalent negative buffering.

3. Model Implementation

The entire model was implemented using Eclipse Java Platform and Java Language programming. The Java Topology Suite's (JTS) libraries provided important methods such as the buffering and polygon union of overlapping and touching patches. JUMP (Java Unified Mapping Platform) was also used to view the input and output results. ESRI ArcGis and MapManager8 was used for initial data processing of OS supplied data, and resulting shapefiles. The algorithm presented here has recently been developed so that it is available as a JAVA generalisation algorithm for the WebGen (Generalisation Web Services) platform, enabling its deployment as a Web Service (http://www.ixserve.de/).

4. Case Studies and Evaluation

Figure 4 shows output from the algorithm for the input shown in Figure 1 (the two are overlaid in order to facilitate comparison). Evaluation was done firstly by a direct visual comparison between the output and the OS Strategi map (Figure 5 shows the results overlaid with OS Strategi data).

5. Evaluation

The algorithm was applied to a second geographic region (completely independent of the first) without any adjustment being made to the parameters. The results were equally encouraging. The results were examined by cartographers at the Ordnance Survey who commented that 'whilst the algorithm has performed well, there are slight question marks concerning the minimum size threshold' and that… 'although the granularity obtained was adequate, the outlines could be simplified slightly more'. It is always important to remember that these results are intended for display at 1: 250 000 (Figure 6). At this scale some of the discrepancies identified at the fine scale are no longer discernible. It is important that the algorithm is attempting to characterise a region.

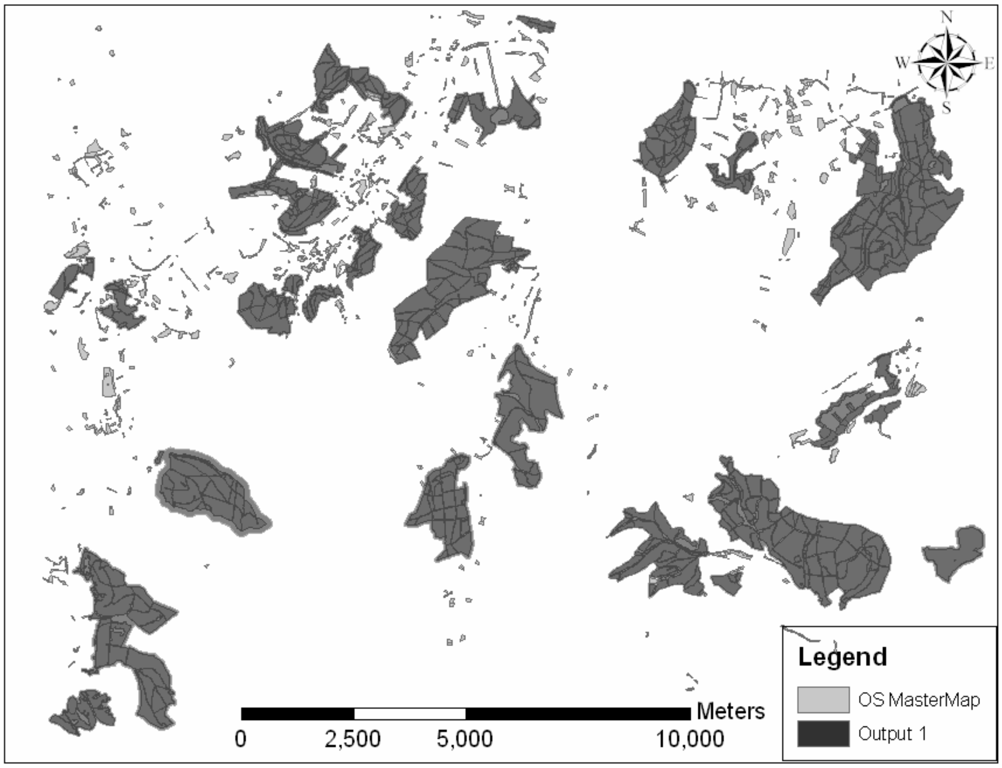

Figure 4: Output produced by the algorithm from input data in Figure 1. (OS MasterMap© Crown Copyright Ordnance Survey. All rights reserved)

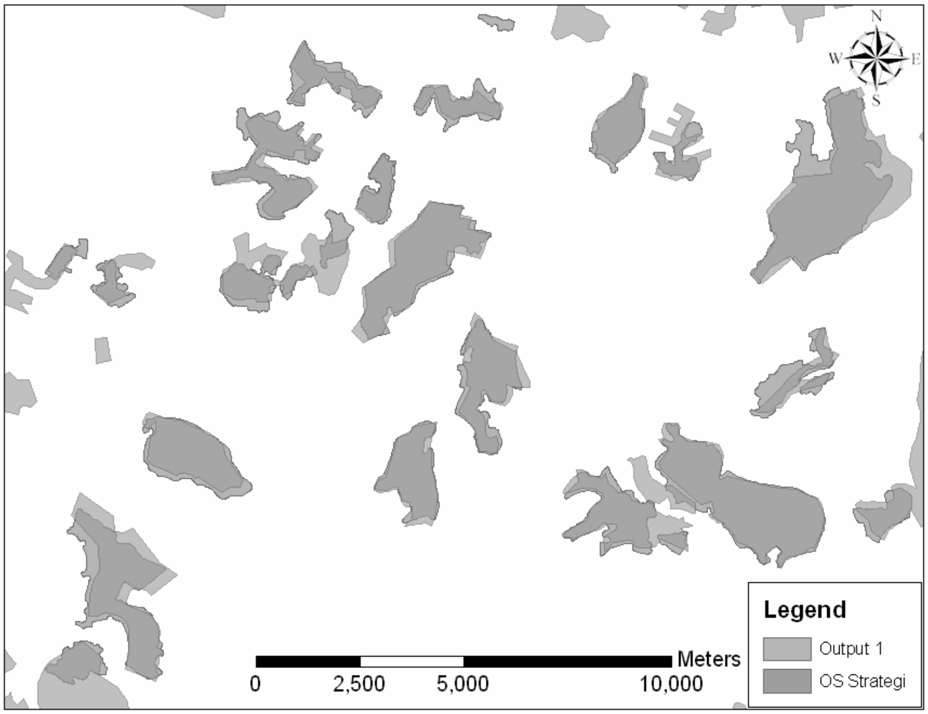

Figure 5: Output from the algorithm overlaid with OS Strategi data. (Mapping is Ordnance Survey ©Crown Copyright. All rights reserved).

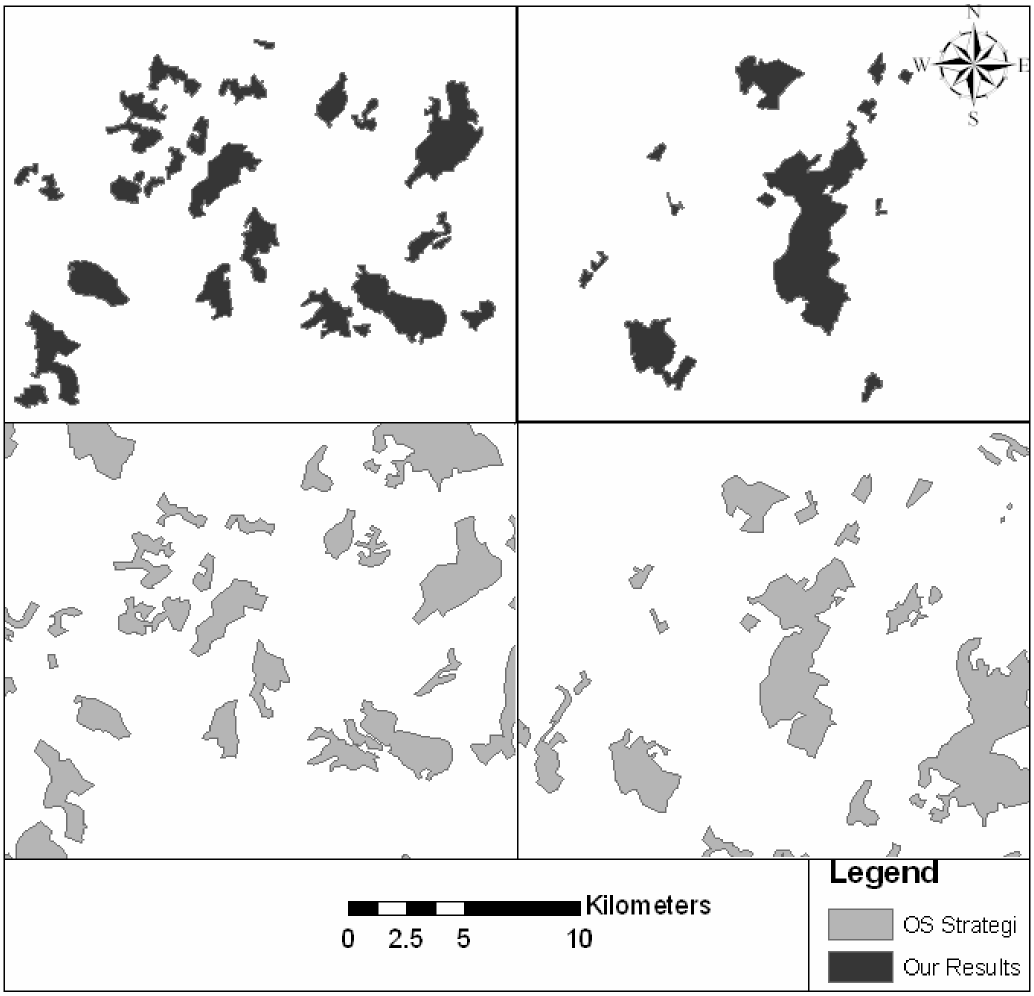

Figure 6: Output and OS Strategi at 1:250 000 scale – spot the difference? (Mapping is Ordnance Survey ©Crown Copyright. All rights reserved).

6. Conclusion

The two case studies confirm the general applicability of the algorithm and point to future work (such as improved smoothing and scalability of the algorithm). By making this algorithm available via the webGen JUMP service, it is hoped that other researchers can utilize and make further improvements to the algorithm.

7. Acknowledgments

Our thanks to the Ordnance Survey in support of this project.

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Automated schematic map production using simulated annealing and gradient descent approaches

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1. Introduction

Generating schematic maps are an effective means of generalization of large scale network datasets. The aim is to enhance visualization at line networks and also make them user friendly for interpretation. The basic steps for generating schematic maps are to eliminate all features and networks (or portions of networks) that are not functionally relevant to the network system chosen for mapping. All geometric invariants of the network's structure are relaxed except topological accuracy. Routes and junctions are represented diagrammatically.

The schematization process was initially refined by Elroi (1988) as three main graphic manipulations. First, lines are simplified to their most elementary shapes. Next, lines are re-oriented to conform to a regular grid, such that they all run horizontally, vertically or at a forty-five degree diagonal. Third, congested areas are increased in scale at the expense of scale in areas of lesser node density. Topological errors can occur in the final network, but this was not treated. Implementation details as well as results were not given.

Steps one and two are the key components of the schematization process and their automation has been the focus of previous work by several researchers. The step of line simplification can be achieved using an algorithm such as that of Douglas and Peucker (1973). Care must be taken when performing simplification to avoid the introduction of topological errors. This can be achieved most easily by making use of topology preserving variants of the Douglas-Peucker algorithm, for example that presented by Saalfeld (1999), or other simplification approaches.

Avelar and Muller (2000) present an algorithm for the automatic generation of schematic maps from vector-based information of road networks. They make use of gradient-descent based optimization in an attempt to force the network to conform to specified constraints, such as orientation and minimum separating distance. Map modifications are achieved by the iterative displacement of network vertices. At each iteration vertex displacements are calculated and, provided topological consistency is maintained, are applied.

This paper introduces the concepts of schematic maps generation and looks into two optimisation approaches used for the automated generation of schematic maps: simulated annealing and gradient descent. The details of the experiments carried out using the two approaches on a test dataset and a comparison study of the performance on the dataset is presented.

2. Constraints for automated schematic map production

The schematic map production presented here considers five primary constraints (Anand et al 2006, Avelar 2002):

- Topological: The original network and derived schematic map must be topologically consistent;
- Orientation: If possible, network edges should lie in a horizontal, vertical or diagonal direction;
- Length: If possible, all network edges should have length greater than or equal to some minimum length (to ensure clarity);
- Clearance: If possible, the distance between disjoint features should be greater than or equal to some minimum distance (to ensure clarity);
- Angle: If possible, the angle between a pair of connected edges should be greater than or equal to some minimum angle (to ensure clarity).

Two secondary constraints are included in the simulated annealing approach (Anand 2006). Their purpose is to minimize unnecessary changes to the input network that are likely to occur due to the random nature of simulated annealing.

- Rotation: An edge's orientation should remain as close to its starting orientation as possible;
- Displacement: Vertices should remain as close to their starting positions as possible.

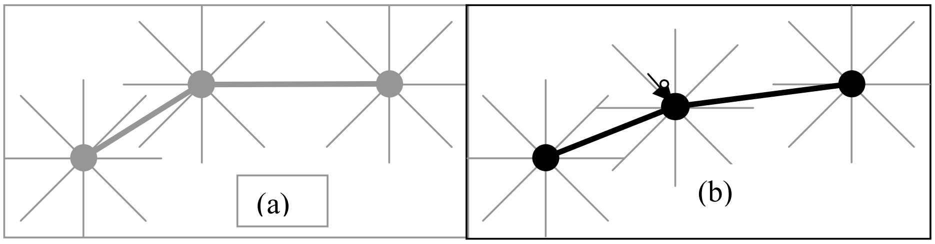
Each of these constraints can be evaluated using straightforward computational geometry functions, e.g. edge/edge intersection test and vertex to edge distance calculation. In order to work efficiently, certain of these functions require the use of a spatial index to avoid sequential scanning of the whole workspace. A simple regular two-dimensional indexing scheme was used in the implementation of the two optimization approaches.

3. A simulated annealing approach to generate schematic maps

The simulated annealing (SA) based schematization algorithm used in this work is similar to that used by Agrawala and Stolte (2001) to render easy-to-read non-schematic route maps. At the start of the optimization process SA is presented with an initial approximate solution (or state). The simulated annealing based algorithm is given below.

In the case of the schematic map production, the input is the initial network: line features made up of edges, which in turn are made up of vertices. The initial state is evaluated using a cost function C; this function assigns to the input state a score that reflects how well it measures up against a set of given constraints. If the initial cost is greater than some user defined threshold (i.e. the constraints are not met adequately) then the algorithm steps into its optimisation phase. This part of the process is iterative. At each iteration the current state (i.e. the current network) is modified to make a new, alternative approximate solution. The current and new states are said to be neighbours. In simulated annealing algorithms the neighbours of any given state are generated usually in an application-specific way. In the algorithm presented here, a new state is generated by the function RandomSuccessor, which works by selecting a vertex at random in the current state and subjecting it to a small random displacement, subject to some maximum displacement distance (Figure 1). This compares to the random displacement methods favoured by Agrawala and Stolte (2001) and is in keeping with the random approach inherent to most simulated annealing based solutions. The new state is also evaluated using C**.** A decision is then taken as to whether to switch to the new state or to stick with the current. Essentially, an improved new state is always chosen, whereas a poorer new state is rejected with some probability p, with p increasing over time. The iterative process continues until stopping criteria are met (i.e. a suitably good solution is found or a certain amount of time has passed or a certain number of iterations have taken place without improvement).

```
Procedure SA_SchematicMap(Initial, Annealing_Schedule, Stop_Conditions)
input: initial state, annealing schedule, stop conditions
output: $Cost_{current}$
begin
Current←Initial
t←GetInitialTemperature(Annealing_Schedule)
$Cost_{current}$=C(Current)
while NotMet(Stop_Conditions) do
    New←RandomSuccessor(Current)
    $Cost_{new}$=C(New)
    $\Delta E \leftarrow Cost_{current} - Cost_{new}$
    if $\Delta E > 0$ then
        Current←New
        $Cost_{current}$=$Cost_{new}$
    else
        $p = e^{-\Delta E / t}$
        r = Random(0,1)
        if (r<p) then
            Current←New
            $Cost_{current}$=$Cost_{new}$
        end if
    end if
    t←UpdateTemperature(t, Annealing_Schedule)
end while
end
```



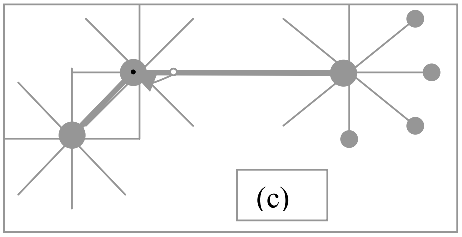


Figure 1: Two new states generated using random displacement of vertex. (a) Current state; (b) Displacement of randomly chosen vertex resulting in poorer solution due to orientation constraint being violated; (c) Displacement of randomly chosen vertex resulting in better solution.

As with other simulated annealing solutions, at each iteration the probability p is dependant on two variables: ΔE (the difference in cost between the current and new states) and t (the current temperature). p is defined as:

$$p = e^{-\Delta E / T}.$$

The variable t is assigned a relatively high initial value; its value is decreased in stages throughout the running of the algorithm. At high values of t higher cost new states (large negative ΔE) will have a relatively high chance of being retained, whereas at low values of t higher cost new states will tend to be rejected. The acceptance of some higher cost new states is permitted so as to allow escape from locally optimal solutions. In practice, the probability p is tested against a random number r ($0 \leq r \leq 1$). If $r < p$ then the new state is accepted. For example, if $p = {}^{1}/_{3}$, then it would be expected that, on average, every third higher cost new state is accepted. The initial value of t and the rate by which it decreases is governed by what is called the annealing schedule. Generally, the higher the initial value of t and the slower the rate of change, the better the result (in cost reduction terms); however, the processing overheads associated with the algorithm will increase as the rate of change in t becomes more gradual.

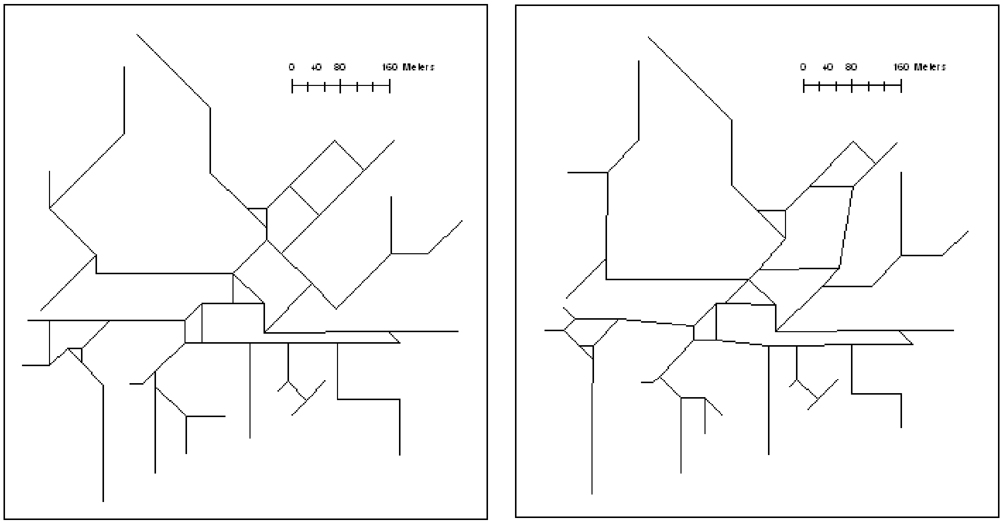
The viability of any SA algorithm depends heavily on it having an efficient cost function, the purpose of which is to determine for any given element of the search space a value that represents the relative quality of that element. The cost function used here, C, is called repeatedly and works by assessing the extent to which a given state meets the set of constraints of the map.

When invoked initially, C evaluates a cost for each vertex in the network. This cost represents the extent to which each vertex meets the set of constraints. The overall cost is found by summing the individual vertex costs. A record of the individual vertex costs is maintained for future reference, meaning that, in any further call, C has to consider only vertices with costs affected by the most recent vertex displacement (Ware et al, 2006).

4. Comparison with gradient descent approach

A gradient descent version of the schematic software was implemented, in order to gain understanding of how the simulated annealing application compares to a gradient descent (GD) based optimization. The gradient descent algorithm differs mainly in the way a new solution is selected for comparison with the current candidate solution. It attempts to proceed toward an optimal solution by finding a sequence of solutions, each of which is better than the previous one. This involved modifying the code in the simulated annealing version to ensure that all negative moves are rejected. If a neighbourhood search does not find any new state better than the current one, GD becomes stuck in the local minima.

The two implementations were compared by generating schematic maps from a road network for 100 seconds. The input parameters were the same for both techniques. The experiment was repeated 10 times for the same dataset and results averaged to take account of randomness. In each of the 10 experiments for the example dataset simulated annealing produced better results than gradient descent.



(a) (b)

Figure 2: Comparison between the highest costs simulated annealing result and the lowest cost gradient descent result to show the variation. (a) SA final cost = 115. (b) GD final cost = 132. (Oscar dataset, Ordnance Survey, UK)

Starting with an initial schematic map cost of 764, the summary of simulated annealing final costs were: 112 (average), 109 (lowest), and 115 (highest). Gradient descent costs were: 138 (average), 132 (lowest), and 147 (highest). A sample output of both techniques is shown in Figure 2. The superior performance of simulated annealing can be explained by its occasional acceptance of negative moves and hence ability to escape local minima. Notice that some schematic edges in the gradient descent network for the stopping time are not yet oriented correctly (Figure 2.b); this is most likely due to the fact that neighboring edges all have low cost and so constituent vertices have very little incentive to move. It could also happen that oscillation between a current state and a new one occurs, such that the network is not any more improved or takes a long time to improve, looking like local minima.

5. Conclusions

This paper has introduced two possible ways of producing schematic maps, the simulated annealing and gradient descent approaches respectively, and shows the comparison of results generated by both approaches. Both simulated annealing and gradient descent based methods have shown good results. In both approaches a stopping criterion enables the system to decide when to stop the iterations, even though it has not reached the perfect answer and can in fact never know when and if it actually will.

Gradient descent can only provide locally optimal solutions and these solutions depend on the starting state. This can be considered restrictive in some situations; however in the production of schematic maps it is advantageous, because a given initial state will always produce the same result. Simulated annealing can avoid suboptimal results, because it will not get stuck every time a locally optimal solution is encountered, but it can produce very different results each time it is run.

Further work is still necessary to find data characteristics and costs to decide for the specific optimization strategy to be applied. We expect to repeat the experiment for various datasets and observe outputs and errors for small and large datasets. We should also investigate if the input network can be preprocessed or additional modifications made to the gradient descent so that it can keep moving towards the required criteria.

6. Acknowledgements

The authors express thanks for the Ordnance Survey, UK for the data used in this work.

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Biography

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Characterising Linear Point Patterns

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1. Introduction

Point pattern analysis often involves delineating the areal region occupied by a set of sample points (Galton and Duckham, 2006). These areal boundaries are generally derived using either polygon, or hull-based, methods or statistical techniques. Kernel density estimation (KDE), which produces continuous estimates of the spatial intensity of a point pattern (Silverman, 1986), is widely used in many applications, including crime hot spot analysis (Bailey and Gatrell, 1995) and wildlife home range estimation (Worton, 1987).

While KDE is widely used to characterise point patterns, the technique has received recent criticism in the literature, particularly when applied to wildlife tracking data. KDE is sensitive to selection of the bandwidth (Seaman and Powell, 1996; Gitzen and Millspaugh, 2003), which is generally chosen using a least-squares cross validation procedure (LSCV; Silverman, 1986). Several authors have argued that KDE using LSCV bandwidth selection fails to accurately delineate point pattern boundaries, particularly when sample sizes are small (Seaman et al., 1999; Girard et al., 2002), when sample points are spatially or serially autocorrelated (de Solla et al., 1999), or when the distribution of points is linear or contains a large amount empty space (Blundell et al., 2001; Hemson et al., 2005). While sample size and autocorrelation can be addressed by choice of sampling design (Borger et al., 2006; Katajisto and Moilanen, 2006), impact of the shape of the distribution has not been adequately considered in the literature.

Examination of a fundamental assumption of KDE can explain why the overall shape of a point distribution can impact the accuracy of the estimates. Namely, KDE generates continuous measures of spatial intensity using a weighted distance function, typically a Gaussian kernel, where distances are measured in Euclidean space. Many processes, however, operate in network space (Miller, 2005), resulting in linear or irregularly shaped spatial distributions. If a set of points is generated by a network-related phenomenon, then using KDE based on Euclidean distances cannot be expected to yield accurate results, regardless of the method used to select the bandwidth. Rather, in these cases, we suggest an approach where KDE is performed using network distances. Borruso (2005) used a similar approach to identify clusters of node intersections in a street network, although he did not apply a distance weighting function as is used in KDE. Additionally, the use of network distances has been recently applied to *K*-functions (Yamada and Thill, 2004). This paper describes a preliminary implementation of network-based kernel density estimation (NKDE).

2. Methodology

The kernel density estimate (f) at the point x is formulated as:

$$\hat{f}_h(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right), \qquad (1)$$

where sample size n contains points X_1, X_2,…, X_n, h is the bandwidth, and $K(y)$ is the kernel (Silverman, 1986). NKDE is implemented in a GIS environment similar to KDE, except distances between the grid points where the spatial intensity is to be evaluated and the individual event points are calculated along a specified network. Network distances are calculated by first connecting each evaluation grid point to the nearest node in the network and then computing the distance to each sample point. A distance weighting kernel is then applied to the network distances and substituted into the density function f. Any distance weighting function can be used, although we selected the Gaussian kernel. For comparison, we computed both KDE and NKDE estimates for two scenarios, one where a known network could be specified and another where the network was unknown. We calculated the density estimates using TransCAD GIS and mapped the results using ArcGIS 9.1.

First, we characterised the pattern of traffic accidents in a portion of Orleans County, Vermont, USA, which contained 27 unique traffic accident sites during 1998-2001. We obtained digital traffic accident and road data from the Vermont Center for Geographic Information. We applied NKDE using road network distances and specified a bandwidth of 4 km for both the NKDE and KDE analyses.

Next, we applied KDE and NKDE to characterise the area occupied by an individual animal, termed the home range. We used a hypothetical dataset of 50 sample points, similar to what would be obtained during a radio-tracking study (Amstrup et al., 2004). Since the exact paths travelled by wildlife are not known from typical tracking studies, we estimated a travel network by creating a two-dimensional triangular irregular network (TIN) from the set of sample points. The TIN approximates paths used by wildlife in their home range, as paths between neighbouring points are represented by straight lines, while paths between more distant points are represented as pathways that connect intermediate points. For illustration, we computed both the KDE and NKDE home ranges using a single arbitrary bandwidth.

3. Results and Analysis

The characterised patterns of traffic accident densities differed markedly between KDE and NKDE applications (Figure 1). Use of Euclidean distances produced a single high-intensity core area, with intensity decreasing radially outward. However, the network analysis produced highest densities along road segments with several accident locations, with intermediate levels corresponding to connecting roads or those with fewer accidents. These results illustrate that NKDE provided a much more realistic characterisation of traffic accident density than Euclidean-based KDE, given that the accidents were associated with the road network.

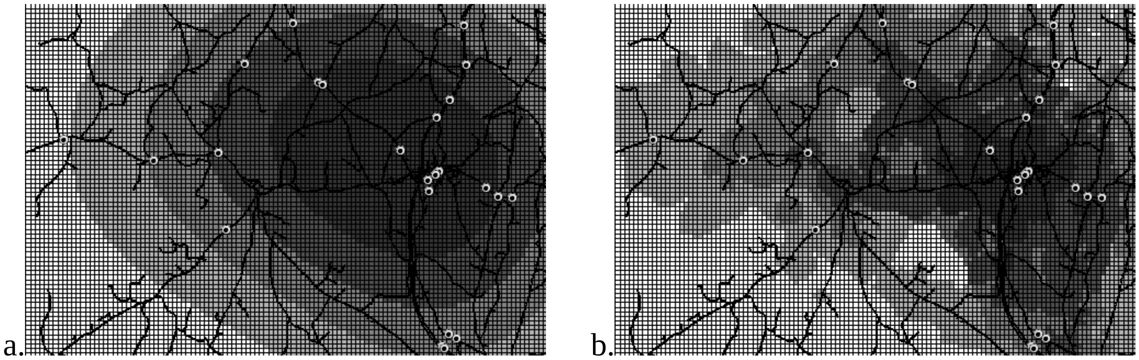

Figure 1. Euclidean (a) and network-based (b) kernel density estimates for 27 traffic accidents in Vermont, USA.

Results of the wildlife home range analysis were similar to the traffic example, although the differences between the KDE and NKDE results were not as dramatic (Figure 2). The NKDE analysis produced two distinct core areas separated by a lower intensity area. Using the same quantile classification, the Euclidean-based analysis did not distinguish between the two clusters of points and the empty space between them. Additionally, the NKDE estimate appeared to generate a better fit to the shape of the point distribution, containing less empty space within the high intensity area.

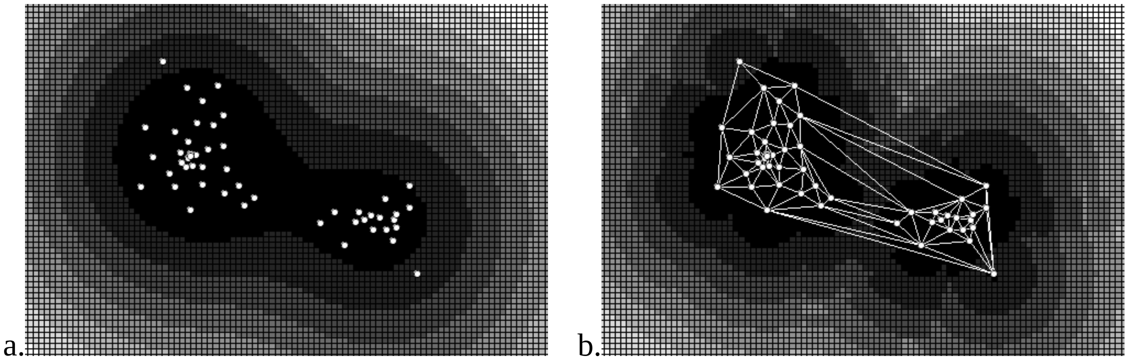

Figure 2. Euclidean (a) and TIN-based (b) kernel density estimates of the home range of an animal from 50 sample locations.

The presented analyses were sensitive to both the specified networks and bandwidths. While the road network was an obvious choice for the accident data, the TIN served as an approximation of the animal's network of travel paths. While the TIN generated will vary with different sets of sample points, we suspect that NKDE estimates will improve as the number of points increases, as the TIN should better represent actual paths travelled. While we did not conduct the analyses using LSCV-selected bandwidths—as we have yet to develop such a procedure—the chosen bandwidths still served to illustrate NKDE. The preliminary results suggest that NKDE provides an improved method for characterising point patterns generated in network space.

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Biography

Joni Downs is currently a second-year Ph.D. student in the FSU Department of

Fuel Poverty in Scotland: refining spatial resolution in the Scottish Fuel Poverty Indicator using a GIS based multiple risk index

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1.Introduction

Fuel poverty describes a complex interaction between households with low income and energy inefficiency, whereby a household is unable to obtain adequate energy services for less than 10% of its income. The Scottish Executive has charged local authorities in Scotland with the task of eradicating fuel poverty by 2016. In order to direct investment and tackle fuel poverty, a local authority must know which areas are more likely to contain fuel poor households. Currently local area fuel poverty indicators, based on small area statistics, are used to identify target areas. Only one local area indicator is freely available to local authorities in Scotland, however its use may be seen as problematic as data is aggregated to an electoral ward level and information on the energy efficiency of local housing is not taken into account. This paper proposes an innovative methodology for refinement of the Scottish fuel poverty indicator using GIS as a framework for integrating census data with georeferenced energy efficiency data on local housing. We concentrate on one local authority, Stirling Council (see Figure 1). The proposed methodology allows a multi-scale mapping of fuel poverty risk at both a census output area level and an individual dwelling level. This approach highlights small areas susceptible to fuel poverty which were previously masked by the aggregation of statistics to large geographic units.

1.1 Background

In order to effectively set out measures to prevent fuel poverty, a local authority must know where to target its efforts. A tool is therefore required to predict areas where fuel poverty is likely to be prevalent, as the issue differs in many respects to general deprivation (Baker *et al* 2002, Shortt & Rugkasa, 2007). An attempt was made to provide such a tool by Energy Action Scotland in 2003 through their Scottish Fuel Poverty Indicator (SFPI), which classifies all Scottish Electoral Wards according to the risk of their containing fuel poor households. With an average population of around 4000 people per ward however, this indicator can be seen as problematic in terms of the ecological fallacy – small areas or houses which may lie in fuel poverty are ‘masked’ by the characteristics of the area in which they are situated.

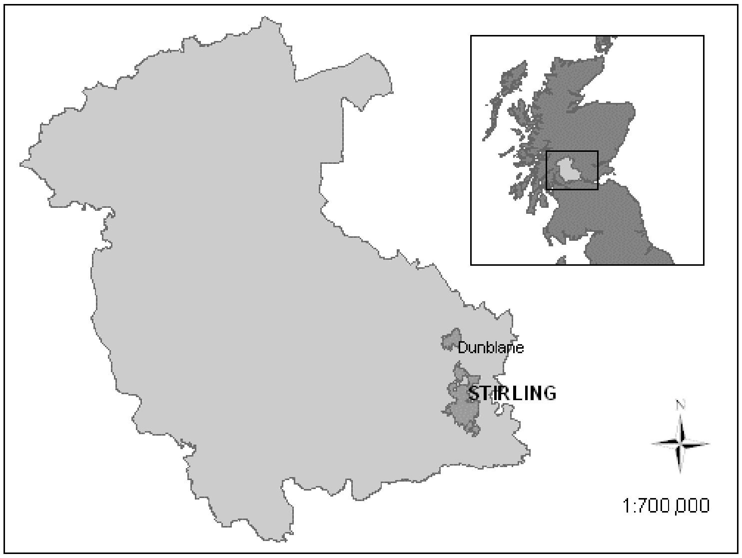

Figure 1. Location of study area

2. Methodology

In light of this, there is a need to look at alternative methodologies for predicting areas susceptible to fuel poverty in Scotland – incorporating both social aspects, in terms of identifying those groups of people most at risk, and physical aspects in terms of those buildings most prone to energy inefficiency. In addition, there is also a need to cost-effectively improve the spatial resolution at which fuel poverty can be predicted so as to ensure all potentially fuel poor households are identified.

In constructing a fuel poverty indicator for Stirling Council it was necessary to ascertain local sources of housing information. Through liaison with Stirling Council, GIS datasets held by Housing Services were made available, opening up the possibility to map the location of almost 30,000 dwellings in the council area in terms of property type and tenure, from a total of almost 38,000. This data was then integrated with a GIS dataset obtained of current and previous local authority housing from the council's intergrated housing management system and referenced geographically using the council's corporate address gazetteer. This dataset offered further variables of energy efficiency (year of construction and type of water heating) for a sample of 9,205 dwellings.

The methodology proposed combines census variables used in the SFPI with the data retrieved on individual dwellings. This methodology is based on the use of Principal Components Analysis (PCA) to obtain fuel poverty risk scores. Working from the approach taken by Rudge (2000) in integrating census and housing energy efficiency data, a methodological framework for developing a fuel poverty indicator is outlined in Figure 2. Central to this methodology is the collection of information on local housing stock energy efficiency in order to, where possible, weight the model toward the characteristics of the local area. A key goal behind this approach was to refine the spatial resolution at which predictions of fuel poverty could be made as far as possible. In light of the ability to map fuel poverty risk onto individual dwellings it was decided the data made available could best be utilised using a two part indicator. The proposed methodology combines the mapping of social factors at the output area scale and energy efficiency characteristics at an individual dwelling scale (Figure 2). PCA was used for both indicators in order to reduce the component variables to a single output score (through the generation of factor scores) for fuel poverty risk. This process showed that for social factors (output area scale) 3 components explained 77% of variance, while for energy efficiency data (individual dwelling scale) 3 components explained 63% of variance. The key benefit of this methodology is centered on the point at which the social and energy efficiency components are brought together. In order to map overall fuel poverty risk at different scales, a final output area fuel poverty ‘score’ is obtained from the social component PCA and attributed as a variable to any dwelling located within that output area, as a measure of the level of risk of potential inhabitants being groups at risk of fuel poverty. This score is then fed into a second PCA conducted for individual dwellings.

The goal of the project was therefore to identify risk of fuel poverty due to the characteristics of those households found in an area, and using this information to identify those households in such an area whose characteristics would suggest they could be considered energy inefficient. The use of GIS in providing a flexible environment in which all relevant information can be brought together and analysed is key to this methodology.

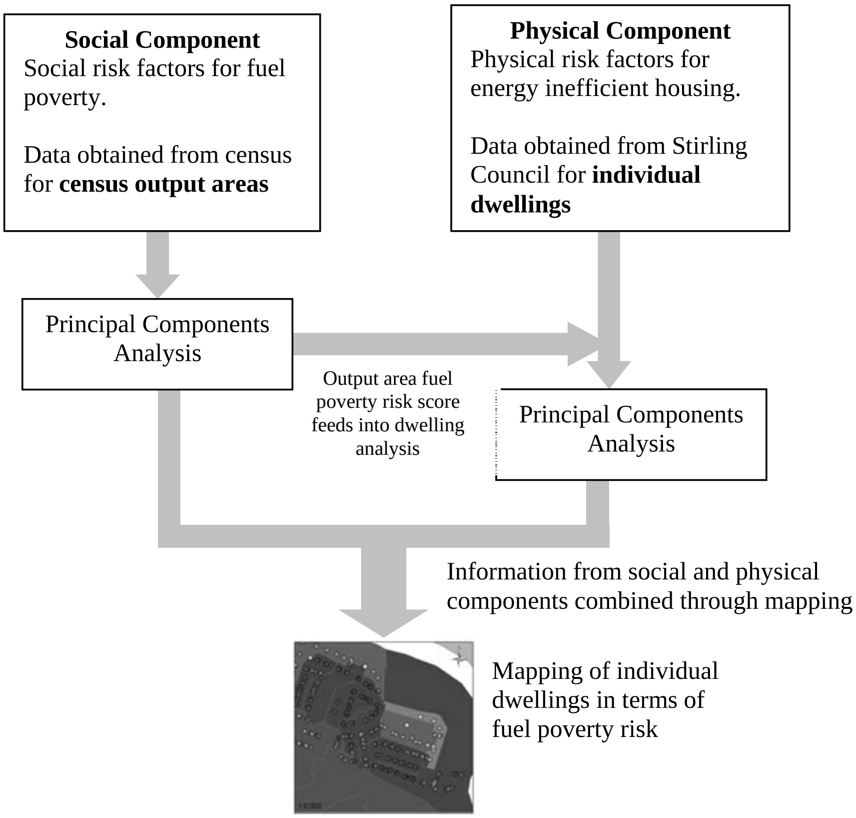

Figure 2. Proposed methodological framework

3. Results and Conclusions

When mapped (see example in Figure 3), 10 of the 139 output areas in the top 2 deciles most at risk from fuel poverty lay within wards classed by the Scottish Fuel

Poverty Indicator as being ‘at least risk from fuel poverty’. A further 53 output areas in the top 2 deciles most at risk from fuel poverty lay in wards classed by the Scottish Fuel Poverty Indicator as having a ‘below average percentage of fuel poor households’. This represents the possibility of around 3,150 households in fuel poverty within wards previously classed as having the least risk of containing fuel poverty.

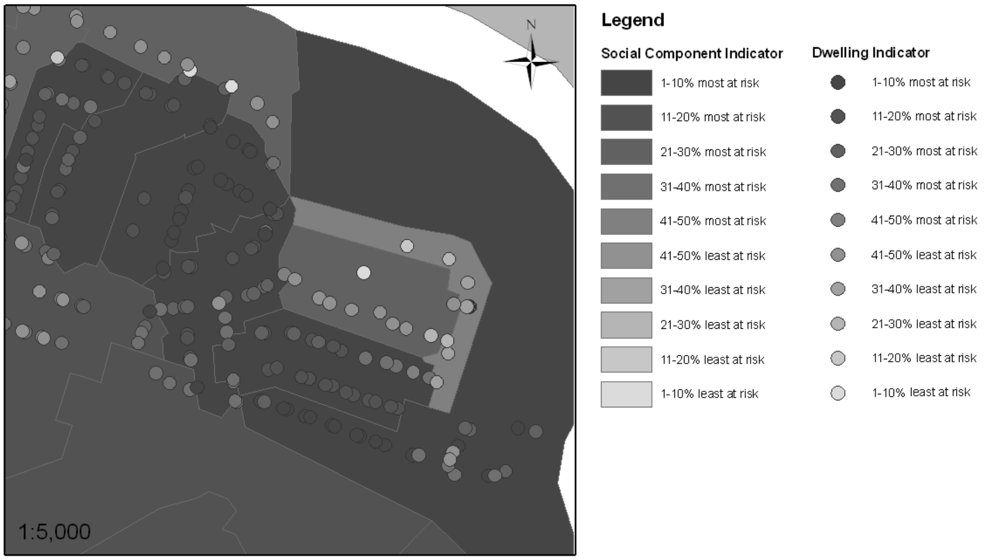

Figure 3. Social component / output area indicator shown with dwelling level indicator superimposed.

When the sample of 9,205 dwellings was mapped as address points, 312 of the 1,871 dwellings in the top 2 deciles most at risk of fuel poverty lay within output areas ranked in the top 2 deciles most at risk of fuel poverty. The remaining 1,559 dwellings in the top 2 deciles most at risk of fuel poverty were therefore spread out in areas which would not have otherwise been highlighted as being at risk from fuel poverty. On inspection of output areas highlighted as most at risk from fuel poverty, a range of different energy efficiency levels were also noticeable in dwellings.

This research has highlighted the dangers of ecological fallacy in the use of local area predictors of fuel poverty, and the generation of fuel poverty risk indices for relatively large spatial units such as electoral wards demonstrated to mask smaller areas at risk of fuel poverty. The problems of ecological fallacy in predicting fuel poverty can therefore be reduced with reduction of the size of the spatial unit to which statistics are aggregated, however this solution is made still more problematic in considering the size of the area for which assumptions about housing can be made (Moore *et al*, 2006). Information on local housing stock energy efficiency is therefore key to the successful identification of such previously masked areas or dwellings susceptible to fuel poverty.

The ability to map fuel poverty risk onto individual dwelling can be seen as important in freeing any subsequent analysis from standard geographical units, thus for example allowing for the identification of individual dwellings likely to be at risk, and complete freedom in building up community profiles at any scale. Such information would not however be available for all local authorities, therefore this highlights the importance of investigating locally available data on housing stock. While providing a useful tool for the identification of dwellings which may be susceptible to fuel poverty however, this indicator is by no means intended to be an absolute measure of whether a dwelling is in fuel poverty or not, as this can only be determined through a detailed household survey (as identified by Moore *et al* 2006).

Given directives from the Scottish Executive for the eradication of fuel poverty in Scotland by 2016, local authorities are under increasing pressure to effectively and efficiently target those areas within their boundaries where this problem is prevalent in order to set about tackling it. This research therefore represents a step towards improving the accuracy with which areas and dwellings can be targeted, thus improving the efficiency of directing further action against fuel poverty.

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Biography

Following the completion of an MSc. in GIS at the University of Edinburgh, Colin Morrison is currently employed within Stirling Council's Corporate Research Team. Here his focus is on the implementation of GIS to add value and understanding to a wide range of social and demographic research. Dr. Niamh Shortt is a lecturer in the Institute of Geography, University of Edinburgh and course director for the MSc (by research) in GIS & Society. Niamh’s primary research interests are in spatial inequalities in health and geographies of exclusion.

Housing stock surveys in GIS systems using pattern recognition

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1. Introduction

The Energy and Environment Prediction (EEP) model (Jones, Williams and Lannon, 2000) has proven valuable to its users. The EEP model is a computer based modelling framework that quantifies energy use and associated emissions for cities to help plan to reduce carbon dioxide and other emissions. This model has shown that it can produce considerable financial, energy, and Carbon savings through the targeting of energy efficiency measures appropriate to certain house types. It also allows the user, e.g. a local authority, to target those areas with the greatest need.

Regional energy models, such as EEP, require an accurate description of the built characteristic of an area (e.g. the profile of housing type, age, etc.). The survey methods developed in the original EEP project to provide this information required a laborious and expensive 'walk by' survey. When this method was applied to the county of Neath Port Talbot in the United Kingdom, where a total of 55,000 dwellings were surveyed (nearly 100% of the population), it required an investment of 18 man-months. Although the survey provided a level of information that was otherwise unobtainable, an investment in manpower and time on this scale has proved to be a barrier to the further uptake of the model.

In order to allow greater access to such modelling methods as EEP, there is a need to explore and develop more efficient methods for acquiring survey data of building stock. Should these become available, feedback from users indicates that EEP type systems would find wide-scale application in local and regional government.

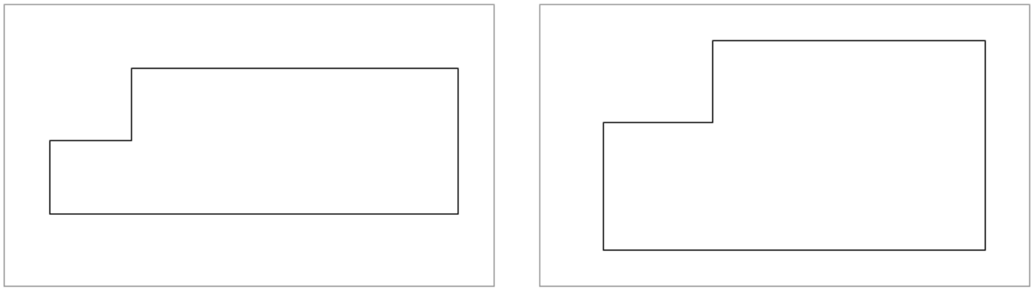
As a first step in this exploration a new method, applying a simple pattern recognition algorithm to the analysis of digital maps, has been developed and tested against the known region surveyed for the EEP programme.

2. Methodology

At a larger urban level the use of pattern recognition has been established; Barr and Barnsley (2004), for instance, used Ordnance Survey (OS) maps to infer urban land use and successfully identified areas with similar built ages by considering street layout patterns. However in order to achieve the level of detail necessary for a model such as EEP, data at the level of an individual dwelling is required, and this aspect is unproven.

In regional energy applications it has been found that it is necessary only to identify a building to an era of construction as this will define basic characteristics such as wall construction type and so define heat loss factors required for energy use calculations. As a result the actual date of construction of each building is not needed; rather the dates can be clustered into the eras: pre-1919; 1919-1945; 1945-1965; 1965-1980; post-1980.

An initial subjective comparison of map data and survey data acquired for the Neath Port Talbot region lead to the hypotheses that a) housing of a common era will exhibit a common form, or rather a range of plan forms, and that b) these “standard” forms will alter with the era of construction. A survey based on an analysis of building plan forms should therefore be able to distinguish approximate building age. For example, figures 1a and 1b show typical plan forms of two ages of housing, extracted from the region studied. Although the two eras show a similar plan form, the pre-1919 houses appear to exhibit a consistently higher aspect ratio and so should be robustly identifiable. Other similar distinctions were seen to exist between other housing eras as well.



a) Pre 1919 housing b) 1919 to 1945 housing

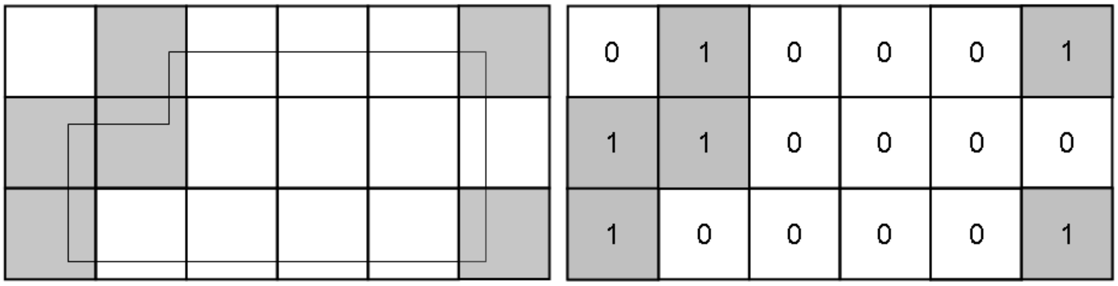
Figure 1. Typical dwelling outline patterns.

The analysis of the building plan forms can be undertaken via software analysis of digital map information. Individual building outlines are now available digitally on OS Master Map™ files as polygons. Using GIS methods and the Ordnance Survey’s Address Point™ system, each polygon can be associated with an individual address and assessed to provide information on, for instance:

- Geometrical plan shape,
- Number of vertices,
- Aspect ratio,
- Floor area,
- Size of ‘garden plot’,
- Density of housing.

In order to extract information to assess building age, the polygon information representing building plan form is first normalised for orientation and for longitudinal dimension. Then, allowing for mirroring and distortions, those polygons are analysed, to identify and cluster “similar” shapes.

In order to do this, in the GIS system a simple fixed grid is laid over the normalized building plan outline, with the building centered in the grid. Internal GIS functions are used to locate corners, or “nodes” of the building shape; where a node lies in a grid cell this is marked as occupied otherwise the cell is empty. Figure 2a shows the building outline with an example 6x3 grid overlaid. The grey cells represent the presence of a building node. The occupied and empty cells are converted into a numerical code which identifies the shape of the building outline. Figure 2b show the code formed using 1 for node cells and 0 for empty cells; in this case the building outline translates the code 010001110000100001.



0	1	0	0	0	1
1	1	0	0	0	0
1	0	0	0	0	1

a) building outline with grid

b) cell codes

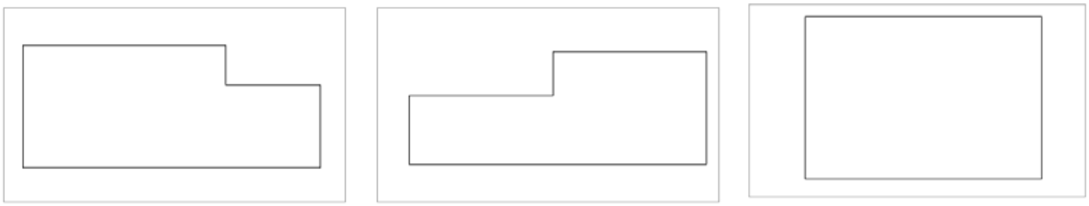
Figure 2. Typical dwelling outline patterns.

This coding method was applied map data for a selection, chosen to contain a wide range of housing age, of over 2,000 domestic buildings from the detailed survey for the Neath Port Talbot region; the actual building characteristics of this sample were therefore known due to the earlier manual survey. The resulting codes that were generated using this method were analyzed to compare the codes to the known building types. The aim of the analysis was to determine level of ability and reliability in the identification of building age, and to determined if further development was worthwhile.

3. Results

The analysis showed that the building “signature”, e.g. the numerical code, could indeed identify building era to a certain degree. The effect of grid density was investigated; form signatures generated by 6x3, 8x4, and 8x8 grids were examined. Of these the 8x4 grid produced the best results; success rates dropped considerably for the others.

Using an 8x4 grid produced 491 signatures from the sample. However many of these were produced by “solo” building plan forms; that is, no others in the sample shared that code. Excluding those, it was found that 83 signatures uniquely matched to a building era, while 49 were seen to contain a mix of eras. Thus over 60% of the buildings in the sample could be placed in an era. Sample result plan form “signatures” are shown in figure 3. The best agreement was found for pre-1919 housing; for this era 69% of the stock in the sample was attributed to unique forms. This was considered highly encouraging as this era marks a crucial housing type often characterised by solid walls with a correspondingly poor energy performance; the “hard to heat” home. There were similar clusters found for other ages but with lower success rates; for instance 36% of post-1980 housing and 26% of 1945-1965 housing were correctly identified, however only 12% of 1965-1980 housing were attributable to unique plan forms.



a) b) c)

Figure 3. Typical plan forms generated by the method; a and b uniquely define an era, while c) covers a number of eras.

These success rates, though too low to be useful in practice, are considered encouraging enough to continue to develop the method. In order to become a useful method, the identification success rate must be increased. This initial attempt used only a very simplistic shape matching algorithm. It is considered that an improved success rate could be achieved through the use of more sophisticated matching algorithms; e.g. using methods and algorithms such as those identified by Jain et al. (1988) and Belongie et al. (2002). Inspection of the unidentified and incorrectly identified properties may show common characteristics which the method used was too coarse to detect. In addition, improvements may be made through the incorporation of data from other sources; this may be contextual data (as supplied, for instance, from the map itself, e.g. the neighbourhood road or estate layout or distance from the road centre, or from the analysis of aerial or high resolution satellite images providing information on e.g. roof forms), or from other databases, for instance census data. There may well be an upper limit of success available from this approach; as only ground plan form is used, data such as number of stories, façade form or fenestration, cannot be derived. Through recently acquired funding from the Engineering and Physical Sciences Research Council, these various aspects are now being explored.

4. Conclusions

A simple pattern matching algorithm has been embedded in a GIS system to analyse the plan form of housing stock. The trial system was able to successfully identify, without further intervention, the age of a high proportion (60%) of dwellings in a sample of 2000. Pre-1919 housing was most readily identified with 69% of that sample being correctly identified. Housing constructed within the era 1965-1980 was the least well recognised, with only 12% being correctly identified.

Higher success rates will be required in a working system. It is considered that improvements in the success rate will require the use of more advanced pattern matching methods and algorithms and the use of supporting information, such as distance from the road centre or roof form (as may be determined from satellite imagery for instance). These aspects are currently being investigated.

5. Acknowledgements

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Biography

Mr S. Lannon is a Senior Research Associate of the Welsh School of Architecture, whose research specialities include GIS, database integration and programming. He is co-author of the Energy and Environment Prediction (EEP) model and was part of the Housing and Neighbourhoods and Health (HANAH) project.

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Professor P.J.Jones is Head of Department of the Welsh School of Architecture and is director of the Centre of Research in the Built Environment (CRiBE). Professor Jones has been active in research on energy and sustainability in the built environment for more than twenty years.

Spatial Trends of unpaid caregiving in Ireland

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1. Introduction

Demographic changes in Europe, otherwise known as increases in the size of the very elderly population, mean that the number and proportion of people in need of assistance with everyday activities is expected to increase considerably in coming decades. Nowadays, most of this assistance is provided by voluntary caregivers, predominantly close relatives. There is an increasing need for statutory authorities to work with and support these caregivers.

In fact, caregivers support not only elderly people but also those with a long-term illness, health problem or disability, regardless of age. The number of elderly people is predicted to increase dramatically in the future due to population ageing. Ireland has a relatively younger population compared to other western European countries due to high birth rates (CSO, 2004). However, it is important to raise these issues (of population ageing) and plan for those days when an aged society will be a fact.

We believe that there is a strong geographical element in the study of voluntary care giving. In this paper we examine the spatial distribution of unpaid care providers, the disabled and the elderly people. We aim to identify areas of high and low probability of provision of voluntary (domestic) care to the people in need. We build on past experience (Young et al., 2005; Foley, 2007) and we attempt to conduct a more advanced geographical analysis on a finer geographical scale.

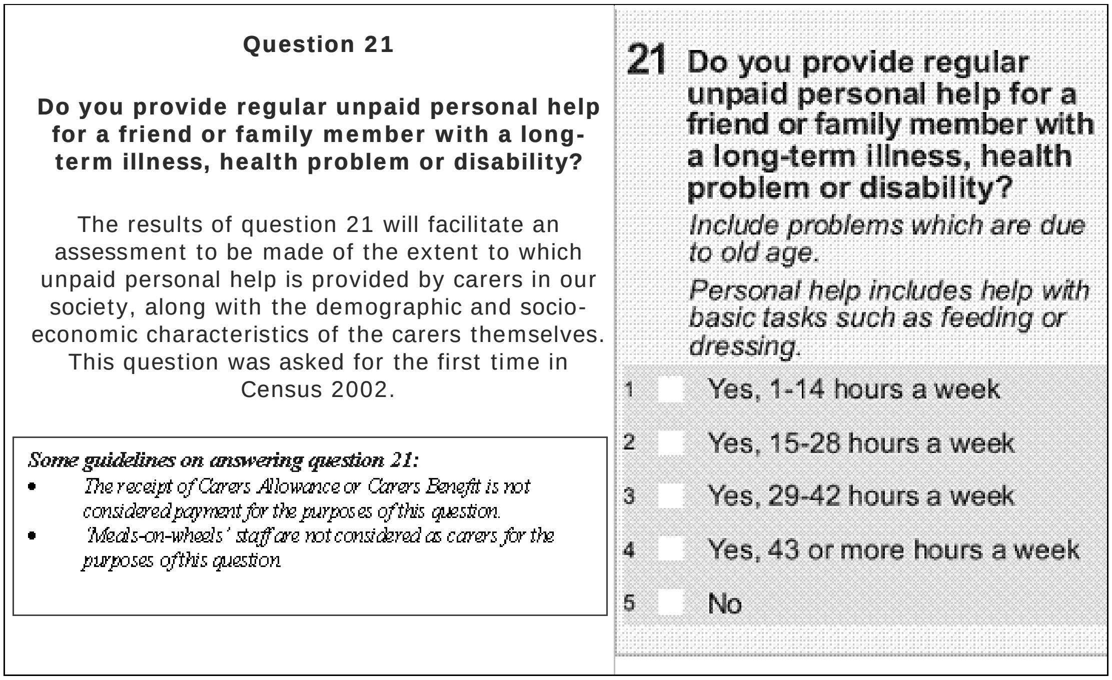
2. Literature Review

Care provision is an important issue in Ireland and for this purpose government funds are provided by means of two schemes, Carer's Allowance (since 1990) and Carer's Benefit (since 2000). As the census question indicates, the financial aim of these schemes does not constitute paid care. Another scheme is the Respite Care Grant. Care provision in Ireland is a crucial issue. There are several social groups of carers as well as umbrella organisations such as the Care Alliance Ireland (CAI). CAI is an NGO that supports Irish carers and conducts research in care giving and issues related to carers.

There is extensive literature on social care, informal care giving and the socio-economic profile of the carers as both Young et al. (2005) and Foley (2007) indicate. There are also several geographical studies looking at those in need of care as well as the availability of care (Foley, 2002; Milligan, 2000; 2001; Power, 2005; Shaw and Dorling, 2004; Wheeler et al ., 2005). Shaw and Dorling (2004) look at the relationship between the need for care (through LLTI) and the domestic as well as state-derived provision of care to discuss the high geographical association between informal care and LLTI. A report of a longitudinal study looking at the characteristics of people who provide unpaid care has been recently published by the Joseph Rowntree Foundation (Young et al., 2006).

3. Methodology and Data

The main source of information is the 2002 Census for Population in Ireland. We use data on population distribution, disability and unpaid care giving. The latter data were collected for the fist time in 2002, making it possible to study in detail the geography on unpaid care giving. The census question is presented in Figure 1 (CSO, 2007). The demographic data used are at the Electoral Division (ED) geographical level.



Question 21

Do you provide regular unpaid personal help for a friend or family member with a long-term illness, health problem or disability?

The results of question 21 will facilitate an assessment to be made of the extent to which unpaid personal help is provided by carers in our society, along with the demographic and socio-economic characteristics of the carers themselves. This question was asked for the first time in Census 2002.

Some guidelines on answering question 21:

- *The receipt of Carers Allowance or Carers Benefit is not considered payment for the purposes of this question.*
- *'Meals-on-wheels' staff are not considered as carers for the purposes of this question*

21 Do you provide regular unpaid personal help for a friend or family member with a long-term illness, health problem or disability?

Include problems which are due to old age.

Personal help includes help with basic tasks such as feeding or dressing.

1 ☐ Yes, 1-14 hours a week
2 ☐ Yes, 15-28 hours a week
3 ☐ Yes, 29-42 hours a week
4 ☐ Yes, 43 or more hours a week
5 ☐ No

Figure 1. Census Question 21 (Source: Central Statistics Office, Ireland)

We employ Exploratory Spatial Data Analysis (ESDA) methodologies to examine the existence of spatial dependence in our data. In order to assess the degree of spatial autocorrelation, we choose to use Local Indicators of Spatial Association (LISA). One such indicator is Moran's I (Moran, 1948), for which we use the formula by Cliff and Ord (1973, 1981) as shown in Equation 1:

$$I = \frac{n\sum_i \sum_j w_{ij} z_i z_j}{M\sum_{i=1}^{n} z_i^2} \qquad (1)$$

where n is the number of data points, $z_i = x_i - \bar{x}$, $\bar{x}$ is the mean value of x, $M = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}$, and w_{ij} are the element of the matrix of spatial proximity M, which show the degree of spatial association between the points i and j. Here we use w_{ij} =1, when j is one of the k nearest neighbours of i, and w_{ij} =0 elsewhere. We use a single order Queen Contiguity weighting, which means that k varies for each data point i. Queen Contiguity includes all common points, namely boundaries and vertices, to define neighbours (Anselin, 2003b). The Moran Scatter Plot and the global value of Moran's I for the mean income analysed here are shown in Figures 2 – 5 for the four variables shown in Table 1.

The local indexes of spatial autocorrelation measure the spatial association for only a small part of the study area. Using the same matrix of spatial proximity, we calculate the values of the local Moran's I and find them to be statistically significant at the 0.05 level. For the calculation of the above indexes (Moran's I, local Moran's I) as well as the scatterplot and the map we used the software GeoDa (Anselin, 2003a, 2004).

Variable	Nominator	Denominator
Proportion of carers providing 15 hours or more unpaid	Carers per ED	Total Population per ED
Proportion of people with long-lasting illness or disability	People with long-lasting illness or disability per ED	Total Population per ED
Ratio of people with long-lasting illness or disability divided by the number of unpaid carers	Total number of carers per ED	People with long-lasting illness or disability per ED
Ratio of people aged 75 and over years old divided by the number of unpaid carers	Total number of carers per ED	Population aged 75 and over per ED

Table 1. Study Variables

4. Results and Discussion

The spatial analysis of the geographical data of the variables the proportion of carers; the proportion of people with long-lasting illness or disability; the ratio of people with long-lasting illness or disability divided by the number of unpaid carers; and the ratio of people aged 75 and over years old divided by the number of unpaid carers show that there is a positive spatial autocorrelation in the data. This suggests that there are areas formed by neighbouring EDs of high or low values.

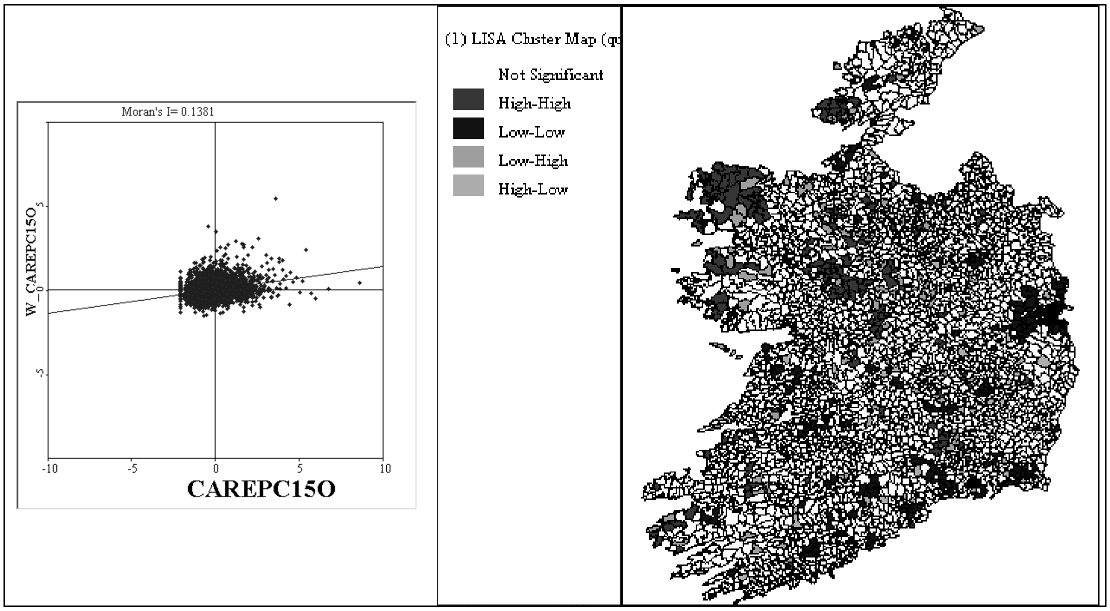


Figure 2. The Moran Scatterplot and Cluster Map for the proportion of carers providing 15 hours or more unpaid care

The Cluster Map for the proportion of carers providing 15 hours or more unpaid care is shown in Figure 2. Clusters of high proportions of carers are located mainly in Western

Ireland (Donegal, Co Mayo, parts of Co. Galway) whereas low proportions of carers are found in the East (Dublin and Kildare, Co Waterford).

Figure 3 shows the Moran Scatterplot and the Cluster Map for the proportion of people with long-lasting illness or disability. There are some outstanding spatial clusters of EDs covering large areas. Low proportions of people with long-lasting illness or disability are found in areas in the conurbations of large cities and surrounding counties (Dublin, Cork, Waterford, and Galway). In the case of Dublin, this conurbation covers three counties (Co Kildare, Co Meath and Co Wicklow). However, there are large clusters of high proportions of people with long-lasting illness or disability in inner cities (Dublin, Cork, Waterford, and Limerick) and in the North and West Ireland (Co Mayo, Co Donegal, and Co Roscommon).

Figure 3. The Moran Scatterplot and Cluster Map for the proportion of people with long-lasting illness or disability

We look at two variables we believe are more important. They are ratios of those in need divided by those providing unpaid care. Thus, the lower the value of the ratio for an ED, the higher the potential availability of care. The opposite is the case when the ratio value is high. Areas with significantly high ratio values require a closer look. In such areas there is little if any informal social support and perhaps local communities or the government should make policies to care for those in need.

Figure 4 shows the ratio of people with long-lasting illness or disability divided by the number of unpaid carers. The picture is now mixed. Several areas with high numbers of those in need are well off due to the high availability of those providing unpaid care. This is more apparent in inner cities (Dublin, Cork, Limerick, and Waterford) and the counties in the west of the country (Mayo). However, there are several areas, such as Co Wicklow and Co Cork where there is a rather low availability of unpaid care providers. The results for the ratio of people aged 75 and over years old divided by the number of unpaid carers (map not shown) are also interesting. There is a clear inner city – suburbs divide favouring those older people living down town to have a larger pool of potential carers.

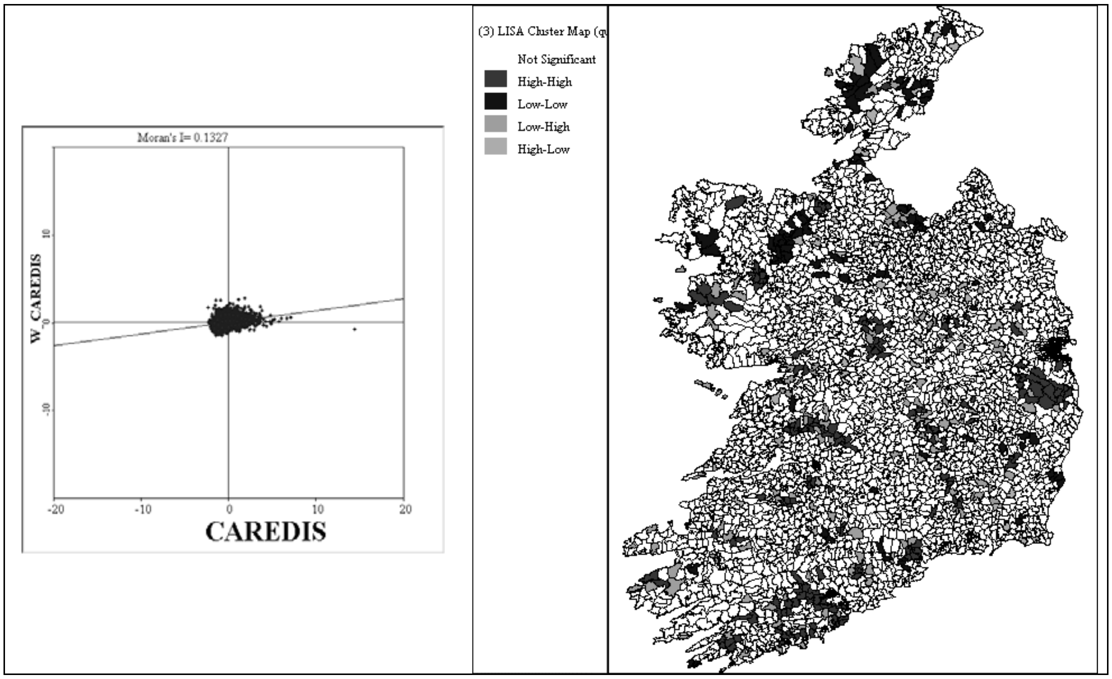


Figure 4. The Moran Scatterplot and Cluster Map for the ratio of people with long-lasting illness or disability to unpaid carers

5. Conclusions

The maps of carers and those in need show some interesting patterns. In many cases there is an apparent urban – rural divide and in others an east – west divide. We should look at these findings and interpret them with care. In the full version of the paper we employ other techniques, such as the Geographically Weighted Local Statistics (Fotheringham et. al., 2002). We also try to interpret our findings and link these findings with the relevant literature.

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Biography

Dr Kalogirou is an affiliate of the National Centre for Geomputation, NUI Maynooth, Ireland. He has a computing and geography background. His research areas are spatial analysis, migration modelling, population ageing and GIS. He is currently working at GeoInformation in Athens developing a geodemographic system for Greece.

The Spatial Disaggregation of GB and European Agricultural Land Use Statistics

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1. Introduction

Spatially and temporally detailed land use data are an increasingly sought, yet generally lacking, environmental data source. Among the many drivers of demand for such data is the requirement to understand how climate change is influencing both global and local patterns of biodiversity. It is understood that human interactions with the distribution of biodiversity, in the form of land use change, need to be taken into account when both modelling the current distribution of biodiversity and future impacts on it (Parmesan & Yohe, 2003; Pearson & Dawson, 2003; Thuiller *et al.*, 2004). Recent snapshots of land cover derived from remotely-sensed data are proving highly valuable for teasing out the importance of climate versus land use change (Termansen *et al.*, 2006). However, longer run time series are required to fully understand changes in biodiversity's spatial distribution over recent climate history. Such data are also required in order to determine how farmers adapt spatially to policy signals. In the past, these signals have included CAP reform and other external factors such as world commodity prices, but an understanding of how farmers adapt may prove invaluable in assessing how land use may change as a response to climate change.

Very good records of major agricultural land use in GB have been collected since the 1860s, including areas of crops grown and livestock reared. For many years this was an agricultural census, in that all farmers returned records. Recently, the June Agricultural Census has become a very large survey. For confidentiality reasons, individual records for farm businesses cannot be released. Results of the survey have been released using a number of different geographies over the years. At the highest spatial resolution data have been released over time at parish level, groups of parishes level, ward level and now super output area level. All of these geographies have been developed with human activities in mind. As a result, these data cannot be integrated easily with data on biodiversity. Furthermore, changes in the units over time do not allow straightforward comparison of agricultural activity across years. Other similar data sets exist for other areas of the world, and suffer from similar limitations. For example, Eurostat release statistics for agricultural land use at a number of different nomenclature of territorial units for statistics (NUTS) levels, in the case of the UK regions reported, these data will be from the agricultural census.

Therefore, there is a need to spatially disaggregate data if they are to be compared through time using some common geography compatible with biodiversity-type data (Howitt and Reynaud, 2003). This need to change geographies has been appreciated by geographers for some time, particularly when dealing with data reported for differing administrative regions (Tobler, 1979; Openshaw, 1984). The work reported here attempts to disaggregate two different scales of such data, both are easily accessible via the internet and other published sources, the GB agricultural census data from reports at the county-level and Eurostat regional agricultural statistics data. The former are disaggregated via a 1 km grid resolution to a 10 x 10 km grid resolution, while the latter are disaggregated via a 5 km grid resolution to a 25 x 25 km grid resolution. Previous work has disaggregated such data (Moxey *et al.* 1995; Howitt and Reynaud, 2003; Huby *et al.*, 2006; You and Wood, 2006), but the approach here demonstrates that a relatively simple and quick method can give results of sufficient quality for many purposes.

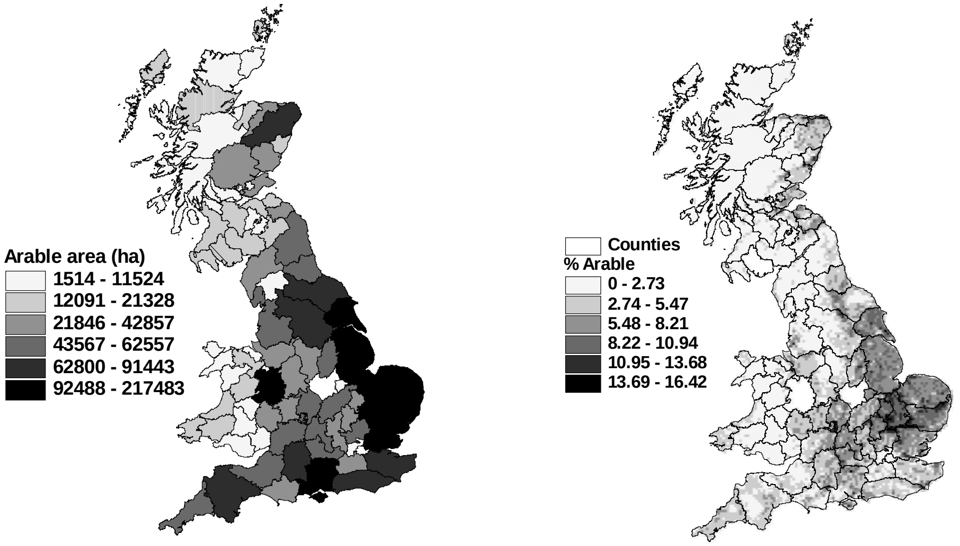
2. Methods

The method used develops from work by Moxey *et al* (1995) and simplifies a more recent approach developed in Huby *et al.* (2006). In the former, a 1 km grid resolution land capability map was used as a key to redistribute parish-level census data using an econometric approach. In the latter, as in the GB part of this work, a 1 km land cover map is used in the place of a specific land capability measure. However, they serve the same purpose in that both are used to guide the allocation of the recorded areas of agricultural land use at the coarser geography to grid cells at a higher resolution. For the GB disaggregation the Centre for Ecology and Hydrology's Land Cover Map of Great Britain 1990 is used. 1 km^2 grid cell records of the percentage cover of the nine most relevant cover types are used: coniferous woodland; deciduous woodland; tilled land; marsh/rough grass; grass shrub heath; dwarf shrub heath; managed grass; heath/moor grass; urban and suburban. For the European data, the equivalent Corine land cover data are used.

The algorithm used to disaggregate the census data has two stages. For each individual land use recorded in the census/Eurostat data, for each year, a simple linear regression model of suitability for that land use is constructed using proportions of land cover types found in the set of administrative boundaries for which the land use data were originally reported. These models are then applied to a finer, 1 km^2 (GB) or 5 km^2 (Europe) representation of the land cover map to produce surfaces of the likely suitability for particular land uses in each grid cell. Given that these are national/regional models based on county/NUTS-level data, it is not necessary that the estimates for each grid cell are particularly accurate, these surfaces are only used as a guide to the second stage of the dissagreation process. The second stage is a simulation process whereby randomly selected units of land use from the census/Eurostat data for a county/NUTS are allocated to 1 km/5 km grid cells on the basis of the suitability scores estimated in the models from the first stage. This simulation stage is run many times to estimate a mean pattern of land use with 10 km/25 km grid cells (summing results for the 1 km/ 5km cell simulations).

3. Results

An example disaggreagation of the GB county-level arable data are illustrated in figure 1. Initial results are visually promising, showing changes in agricultural land use practices across GB that appear sensible for the periods considered. Tests of the stability of estimates and the spatial pattern are made using different simulation



a) b)

Figure 1. a) Areas of arable land reported for counties in 1950 b) disaggregation of data to 5 km grid cells (percentage of 5 km grid cell that is predicted to be arable).

parameters, including the number of iterations of the simulation stage. Tests of the accuracy of the spatial disaggregations are also performed. GB diaggregations are compared to agricultural census data reported at ward level, while European disaggregations are compared to GB county-level data. The approach does not explicitly incorporate spatial dependencies within the data, however spatial patterns in residuals will be interpreted to ascertain whether improvements could be made in the first stage of the method. These will be reported in the full-text of this paper, along with observations about how well disaggregation works at these two varying scales. Potential extensions of the approach to other applications will be considered.

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Biography

Colin McClean is a senior lecturer. He has 20 years experience in applying spatial analysis to research fields including ecology, environmental economics, geomorphology and hydrology. As well as the work presented here, recent research has assessed the potential impacts of climate and land-use changes on the British and African flora.

A combined pycnophylactic-dasymetric method for disaggregating spatial data: the example of agricultural land use

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1. Introduction

In this paper we present a novel method for disaggregating data that for reasons of confidentiality or expediency has been summarised over spatially coarser reporting units. The method combines pycnophylactic approaches with dasymetric ones. We use the June Agricultural Census (JAC) for England and Wales by way of illustration. The JAC has been subject to a number of changes in reporting units[1], for instance:

- 1998-2003 data reported within the NUTS hierarchy:
- From 2004 data reported within ONS super output areas (SOAs).

These agricultural census reporting units are referred to as “parents” and their higher aggregations as “grandparents” in the text below.

The JAC is an annual survey of agricultural activity which collects information from carefully selected agricultural holdings in England relating to land use, crops, livestock, labour, horticulture and glasshouse. However there are a number of issues associated with using the JAC for agri-environmental modelling:

- The survey collects information about individual agricultural holdings (farms) but to preserve farm confidentiality only aggregate data are released;
- The periodic change in reporting units makes comparisons across time difficult;
- Consistent units are needed as input into models (e.g. nutrient leaching) to satisfy EU directives
- Management of the Modifiable Areal Unit Problem (MAUP) as described by Openshaw (1984), where the patterns observed at one scale change at another (this is related to the Ecological Fallacy);
- The unreasonable assumptions of internal homogeneity associated with many areal interpolation techniques;

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[1] http://www.defra.gov.uk/esg/work_htm/publications/cs/farmstats_web/Publications/data_documents/data_notes.htm#nuts

The approach presented in this paper seeks to address these fundamental issues associated with aggregated holdings level data by combining dasymetric techniques with pycnophylactic techniques. *Dasymetric* techniques are those where ancillary information about area under consideration constrains the assumption of homogeneity. *Pycnophylactic* approaches are those which generate a smooth surface from polygon based data whilst preserving the mass or volume property of the original data units.

2. Dasymetric Mapping

Dasymetric mapping provides a method for refining the distribution of land use within a spatial unit parish by incorporating additional data to provide a more realistic estimate of the actual distribution of the process under investigation within the units of analysis. It does this by bringing in additional relevant information to estimate the actual distribution of aggregated data within the unit of analysis. Dasymetric mapping was first described by Wright (1936) in his analysis of population distributions in Cape Cod, Massachusetts. Wright identified unpopulated areas within towns and calculated population densities for the remaining parts of the towns. In this way dasymetric mapping provides a means to statistically represent a more realistic surface than that provided by the aggregated data. It is a form of areal interpolation that incorporates additional knowledge or data relevant to the study area (Flowerdew and Green, 1991) by breaking down the artificial structure imposed by (usually) arbitrary political boundaries. Dasymetric mapping can reveal hidden data distributions and overcomes what Langford and Unwin describe as the "spatial discontinuities" created by the imposition of an artificial boundary and shows a more realistic distribution of the data (Langford and Unwin, 1994). In this way dasymetric mapping spatially refines aggregated data and has been used as an areal interpolation tool by a number of workers (Fisher and Langford 1995; 1996; Martin, et al., 2000; Eicher and Brewer 2001).

3. Pycnophylactic Interpolation

Tobler (1979) developed a procedure to generate a smooth surface from polygon based data which preserves the mass or volume property of the data called "pycnophylactic interpolation". In pycnophylactic interpolation volumes are smoothed iteratively with the weighted average of nearest neighbours. During each iteration the total is adjusted to maintain the population count of the original (parent) polygon. The number of nearest neighbours used and of iterations determines the overall level of smoothing and is subjective. That is, the data totals for the original set of parent areal units are preserved during the transformation to a new set of areal units. Agricultural census data are only published as totals for spatial units of a certain size to ensure the privacy of individuals. Values such as the area of arable crops in each unit may be considered as a volume. Pycnophylactic interpolation computes a continuous surface from polygons-based data in 2 stages:

1) Parents are converted to a regular grid with height values (e.g. the area of agricultural land use) assigned to the grid points;
2) The height values are increased or decreased individually to make the surface smooth whilst simultaneously enforcing parent volume preservation.

The step 2 is repeated until the remaining "roughness" – the deviation from the ideal smoothness – reaches a user-defined threshold or the maximum iterations is reached.

Pycnophylactic interpolation transforms data from one system of units (parent zones) to another. During interpolation parts of the volume are not be distributed to cells within neighbouring parents, only within the original. Tobler presents a verbal overview of the approach[2] which is illustrated in Figure 1.

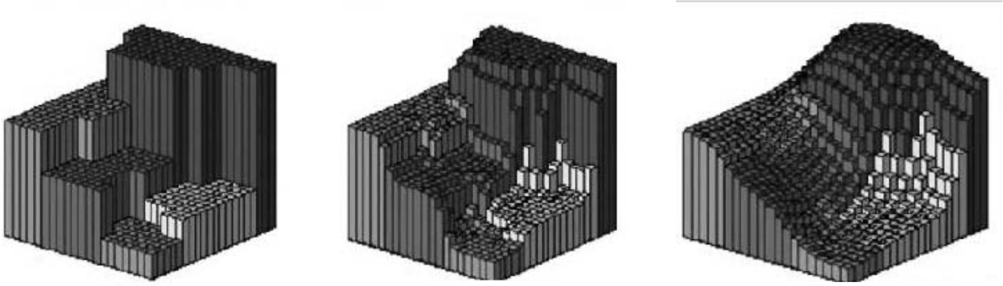
Zero Iterations Five Iterations Twenty-five Iterations

Figure 1. The process of pycnophylactic interpolation from http://www.csiss.org/streaming_video/csiss/tobler_pycno.htm

4. Method

The approach taken was to combine dasymetric techniques with pycnophylactic ones:

- Dasymetric methods to identify areas of non-agricultural land use within each 1km^2;
- Pycnophylactic ones to iteratively sum the various land use areas over groups of 1km^2 squares and then to compare those totals with the reported totals at the higher level geographies (parishes, output areas, etc.).

The objective was to develop a database describing general classes of non-overlapping land use. Data integration was through a series of discrete stages.

Stage 1. Identification of non-agricultural areas

A 1km^2 dataset of non-agricultural areas was produced by combining the vector maps of urban land, woodland (Strategi), common land (Rural Surveys Research Unit, University of Wales), rivers, canals, railways, and roads (Strategi) with a 1km^2 grid. For each cell in the grid this identified the areas of each type of (non-agricultural) land use. All of the linear features used were buffered by an appropriate amount prior to integration so as to fully represent the land area that they occupy. Each buffered vector data set was intersected with the 1km^2 grids.

Stage 2. Comparison with the PAC at the district level

An estimate of the non-agricultural land in each parent was generated from its constituent 1km^2. A comparison (at a grandparent level) showed an under estimation of non-agricultural land area in rural areas due to incomplete vector data particularly woodland areas and small hamlets.

Stage 3. Improvement of the non-agricultural land estimates

Non-agricultural uses were divided into 5 classes for comparison with Land Cover Map of Great Britain (LCMGB) classes: Sea, Inland Water, Woodland, Urban and Rough

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[2] http://www.csiss.org/streaming_video/csiss/tobler_pycno.htm

Grass. A full description of LCMGB can be found in Fuller et al. (2004). For each 1km^2 the initial land use estimates from Stage 1 were treated as being incomplete (i.e. as a lower bound). The amount of each land use was increased by *adding in* equivalent values from the aggregated LCMGB classes until they matched the total amount of non-agricultural land for each grandparent. If at the end of this constrainment the non-agricultural land was still underestimated, the additional land required was added to the Rough Grass category – the category associated with the most uncertainty in the LCMGB classification.

Stage 4. Improvements in the agricultural land estimates

After Stages 1-3 the total crop areas (Arable) for {district areas} were within +/- 5% of those reported by the parent census totals. In order to ensure the total areas for each crop matched those of the census totals completely the crop areas were adjusted in the following fashion:

- Initial crop areas were estimated from the proportions reported in the parent data;
- The total area under each crop from the census data and the 1km^2 was compared at the grandparent level;
- The grandparental differences were used to adjust the parent crop proportions.

The proportions of crops continued to be held on a per-parent basis, but were adjusted to ensure that the totals, when calculated at a grandparent level from the disaggregated 1km^2 data, matched those of the grandparent census totals.

5. Results

We compare the distribution of land use at the level of 1km^2 with aggregated habitat data for Kent, an English county (Table 1 and Figure 2). The important results, Arable and Grass as these are used to model different crop types and livestock distributions, show close correspondences.

Land type	ADAS Land use	Aggregated Habitat
Arable	138175	133069
Grass	65033	85031
Rough grazing	45979	23033
Woodland	37999	60207

Table 1. Areas (in hectares) for Kent of different land types from the aggregated habitat data, the modelled land use (NB not all land types are shown).

The value and relevance of this dataset and this method is demonstrated by the number of applications which have successfully incorporated this data:

- Phosphorous and Sediment Yield, CHaracterisation In Catchments (PSYCHIC)[3];
- NEAP-N - a model developed for modelling N losses at a national scale[4];
- National Ammonia Reduction Strategy Evaluation System (NARSES)[5].

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[3] http://www.psychic-project.org.uk

[4] Silgram et al. 200. Intercomparison of national and IPCC methods for estimating nitrogen loss from agricultural land. Nutr. Cycl. AgroEcosystems, 60, 189-195.

[5] http://www.defra.gov.uk/science/Project_Data/DocumentLibrary/AM0101/AM0101_3668_FRA.doc

Each of these has been developed in response to national and EU policy and has been robustly validated.

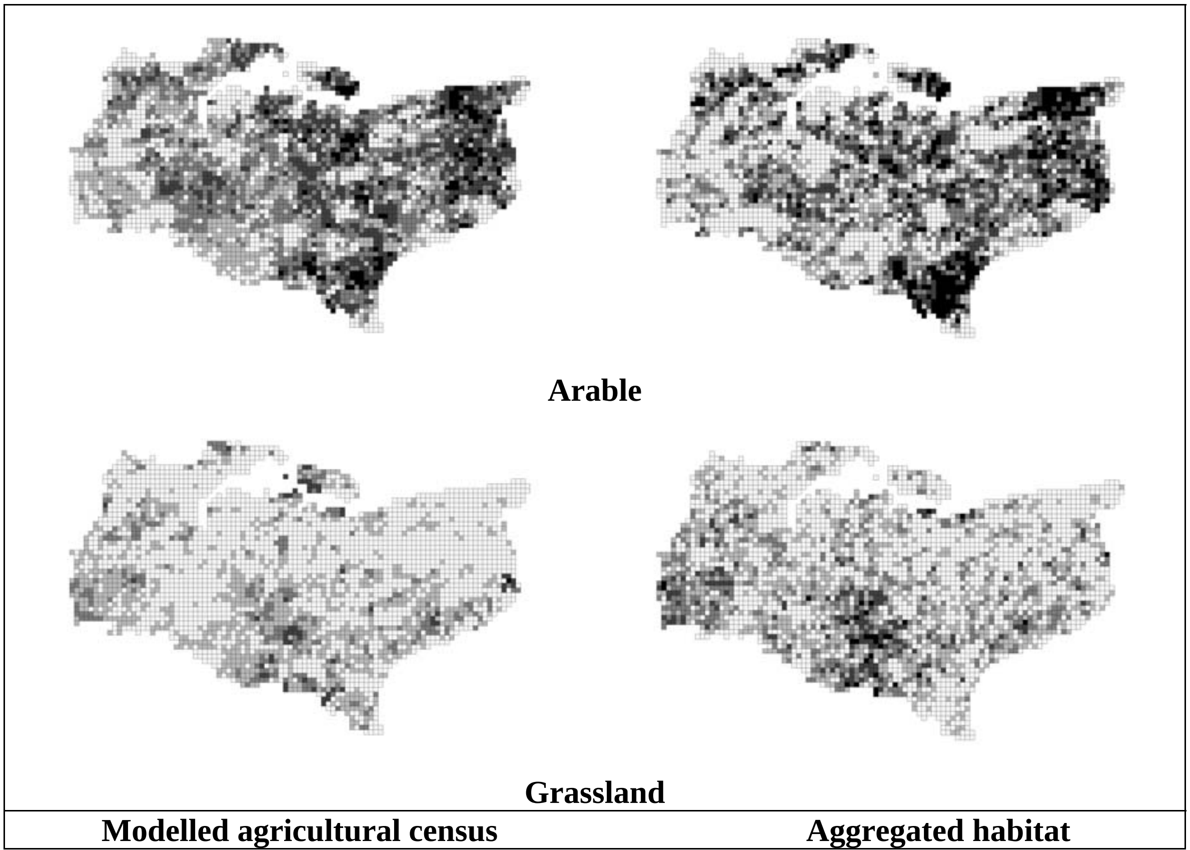

Figure 2 shows the 1km^2 maps of arable and grassland distributions in Kent, classified into quintiles (lightest is < 20%, darkest >80%).

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Biography

Lex Comber gained his PhD from the Macaulay Institute and the University of Aberdeen in 2001. Up to 2003 he worked as an RA on the EU REVIGIS project developing methods for integrating semantically discordant data. After a year in GIS consultancy with ADAS, Lex took up a lectureship at the University of Leicester where he now directs the MSc in GIS.

A New Technique about Selecting Base Points of the Territorial Sea Based on the Principle of Convex Hull Creating

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1. Introduction

The baseline is a line from which the outer limits of a State's territorial sea and certain other outer limits of coastal State jurisdiction are measured. According to the United Nations Convention on the Law of the Sea (UNCLOS), the baseline can be normal baseline, straight baseline or combination baseline based on actual instance of coastal states.

The normal baseline is the basic element from which the territorial sea and other maritime zones are determined. It is defined as the low water line along the coast, as marked on large-scale charts of the coastal state (UNCLOS' Article 5). Straight baselines are defined by straight lines that join points on the coastline which have been selected according to the criteria listed in UNCLOS' Article 7. They delineate internal waters from territorial seas and other maritime zones.

Straight baselines are a system of straight lines joining specified or discrete points on the low-water line, usually known as straight baseline turning points, which may be used only in localities where the coastline is deeply indented and cut into, or if there is a fringe of islands along the coast in its immediate vicinity (UNCLOS' Article 7).

In maritime boundary delimitation practice, in order to manage and maintain the baseline conveniently, and to protect national maritime rights and interests, straight baseline was adopted in most countries including China. When straight baseline scheme adopted, selection of baseline points of the territorial sea, i.e., the number of selected points and their spatial distribution, has an important influence on the result of maritime boundary delimitation. The reason is, once the position of baseline point is determined, the baseline (connecting neighbouring two points), as then the internal water, territorial sea, contiguous zone, exclusive economic zone(EEZ) which are based on the baseline, will be determined, too. Here internal water means the water on the landward side of the baseline of the territorial sea, the sovereignty of this water area belongs absolutely and exclusively to the coastal state. As a result, the first aim of maritime boundary delimitation is to ensure the maximum area of internal water.

UNCLOS has set restrictions on base point selection. For example, the drawing of straight baselines must not depart to any appreciable extent from the general direction of the coast; any baseline of archipelago can not exceed 125 nautical miles, etc. However, in the conventional manual selection of base points, as restricted by technical condition, it is very difficult to set up the mathematic model of base points selection which accord with these prescription, so the selected base points can not ensure optimization (maximum internal water area) in accordance with these prescription. Therefore, this paper brings forward the idea and method to realize the optimized selection of base points using convex hull creating technique. A case study of an archipelago's base point selection is given at the end of this paper.

As China only partly publicized the base points of the territorial sea (baseline) in continental area and Xisha Islands area, and the base points of the territorial sea (or baseline) in many other areas are not determined yet, the research on the best technology of base points selection and confirmation can be of great value to China.

2. Selection of Candidate Base Points

Candidate base points are the points which project towards the sea at the brim of continent, islands or drying reefs, and can help to make the internal water area maximum. In another word, candidate points are the points that may be selected finally as the points of the territorial sea. Candidate points are selected from official charts at largest available scale. Obviously, suitable selection of candidate points is the necessary precondition of the formal points of territorial sea. However, as the spatial distribution of candidate points is usually loose, it is quite difficult and unreasonable to directly select candidate points from the largest scale charts. Therefore, a pre-selection process is usually needed to appropriately determine the places of candidate points on smaller scale charts that cover the entire sea area.

Although this happened mainly in analogy mode, similar process is used even under GIS circumstances. GIS can only help to achieve efficiency, precision and reduction in work intensity. The process with GIS support is:

1) Select the possible candidate points and get the sketchy position by using GIS at a smaller scale;
2) Switch to the largest scale display containing the same point from the database by using direct scale-switch display function;
3) Mark and catch the candidate points precisely, and obtain the coordinates of each point.

For the archipelago shown in Figure1, according to UNCLOS, 22 convex points projecting towards the sea on the outer side of the brim islands of this archipelago are selected as candidate points (marked with +). Segments, each of them connects two neighbouring candidate points, and their lengths (nautical miles) are shown in table 1.

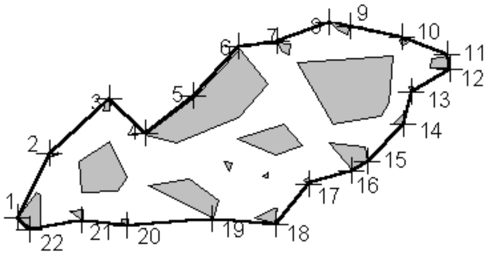

Figure 1. Candidate points of an archipelago

Section	1,2	2,3	3,4	4,5	5,6	6,7	7,8	8,9	9,10	10,11	11,12
Length	63	72	45	56	60	35	49	20	48	4	14
Section	12,13	13,14,	14,15	15,16	16,17	17,18	18,19	19,20	20,21	21,22	22,1
Length	40	30	46	16	41	47	57	78	41	48	16

Table 1. Segments and their lengths of candidate points (unit in nautical mile)

3. Polygon Convex Hull Creating Technique and Ideal Points Selection

3.1 Concept of polygon convex hull

The key problem is how to select, as formally announced point set which will set the maximum internal water, the best point set from the candidate points. By research, we believe the best way is by using polygon convex hull creating technique. Thus the concept of convex hull (also called minimum convex or minimum convex polygon) will be introduced as following.

The convex hull of a finite polygon P is the smallest polygon PC that contains P. That is, there is no other polygon P0 with P⊆P0⊂PC. Also, this convex hull has the smallest area and the smallest perimeter of all polygons containing the set P. Thus, for any polygon, if it is not convex, the area of it will always be less than the area of its convex hull. To obtain maximum area, the candidate point set is not the best choice, for the polygon it forms may not be convex, and the area it surrounds may be less then that of its convex hull. So it is quite obvious now that the point set which forms the convex hull is the ideal set of points, because we can get the maximum internal water area from it. GUO[1997] has introduced in detail the method of creating polygon convex hull.

3.2 Ideal point selecting by convex hull creating technique

In the same case in Figure1, we can use foregoing method to get the only minimum convex polygon (convex hull) from the polygon formed by the 22 candidate points. As shown in Figure2, the points that form the convex hull are candidate point No.1, 2, 3, 6, 8, 9, 10, 11, 12, 14, 15, 18 and 22.

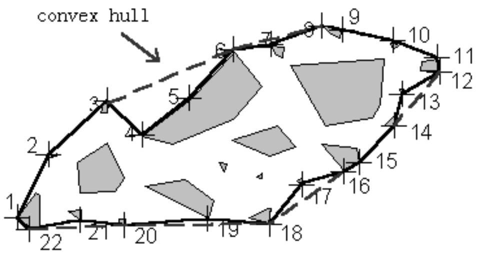

Figure 2. The polygon and convex hull from candidate point set

3.3 Determination of the formal point set

Although the point set chosen by convex hull is ideal, the selection of point must accord with the prescription of the UNCLOS. The set can not be directly applied as the formal point set of territorial sea yet. As shown in Figure 2, some baseline is too long and some departs obviously from general direction of the coast. An improvement is needed as follows.

1) Calculate the geodesic distance between the two nodes of the convex hull, as shown in Figure 2;
2) Divide the long baseline that exceeds 125 nautical miles into two or more segments, by inserting node(s) selected from candidate points which are relatively extruding and good in location. This ensures the point set according with the prescription of the UNCLOS.

It can be seen in table 2 that the baseline between points No.3 and No.6 exceeds 125 nautical miles, one point should be inserted. Two candidate points, No.4 and No.5, may be the inserting point. Polygon area respectively with No.4 and No.5 is calculated to choose the better one (see Tab.3 sequence 1.1 and 1.2). For convenience, the area of the convex hull is set as one unit.

The baseline between points No.18 and No.22 is 221 nm long and exceeds 125 nm, too. At lease one or more point(s) should be inserted. The candidate points are No.19, 20 and 21. No.20 is the most extruding and nearest to the central location, but the distance from it to No.19 is 134nm. So No.19 is necessary. Since No.19 is more than 125nm from No.22, a mid-point is still needed. No 20 is better for this place according to the larger surrounding area. The possible polygons and their areas are shown in Tab.3 sequence 2.1 and 2.2. Therefore, point No.1, 2, 3, 4, 5, 8, 9, 10, 11, 12, 14, 15, 18, 19, 20, 22 are determined as the formal point set (marked by symbol ⌖ in Figure3). It should also be noticed that candidate point No.20 will locate outside the baseline, which is obviously wrong.

Edge	1,2	2,3	3,6	6,8	8,9	9,10	10,11	11,12	12,14	14,15	15,18	18,22	22,1
Length	63	72	126	83	20	48	43	14	64	46	100	221	16

Table 2. Each edge’s length of the convex hull（unit in nautical mile）

Polygon sequence number	The sequence of polygon vertex(candidate point)	Area (compared to the area of convex hull)
1.1	1, 2, 3, 5, 6, 8, 9, 10, 11, 12, 14, 15, 18, 22	0.964
1.2	1, 2, 3, 4, 6, 8, 9, 10, 11, 12, 14, 15, 18, 22	0.942
2.1	1, 2, 3, 6, 8, 9, 10, 11, 12, 14, 15, 18, 19, 20, 22	0.935
2.2	1, 2, 3, 6, 8, 9, 10, 11, 12, 14, 15, 18, 19, 21, 22	0.924

Table 3. Possible polygons and their areas for different point set

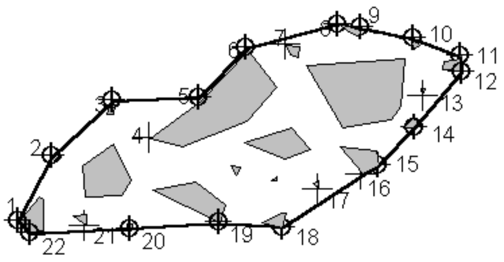

Figure 3. Points and their relevant straight baselines

3.4 Analysis and evaluation of the points selection

The point set for an archipelago was analyzed by using the foregoing scheme and method. Two points were found not ideal, which located inside of the polygon convex hull and the direct distance between its two neighbouring points is less than 100 nautical miles, which results in an area loss of 28 square kilometres. So, these 2 points can be deleted from the point set. The analysis focuses the value and necessity to evaluate the current official point set.

4. Conclusions

Convex hull of the candidate point set determines in fact the maximum possible area of internal water, so it can be considered as the ideal mathematic model of point set selection, and may lead to the ideal solution more scientific than the conventional analogy method on experience. It provides the possibility select point set totally by computer. However, because of the restriction by UNCLOS, adjustment on point set by convex hull is still necessary, on which we have discussed the method and scheme in the former part. For example, when the baseline goes off the main trend of coastline and its length exceeds the limit, when the ratio of water area to land area exceeds the limit, proper candidate point(s) should inserted in order to make it reasonable for the last selection scheme. The quantitative evaluation of whether straight baseline goes off the main trend is very complicated a technique problem. Only part of the question, of whether the distance is too long to cause the departure in direction, was discussed in this paper. The question whether there is other effective quantitative estimation model is also worthy of further research.

The case discussed in this paper is of the archipelago area, but its principle and method are applicable to the base point selection of continental edge territorial sea delimitation on straight baseline scheme. For example, the continent outline can be similar to that of "archipelago" geometrically when a suitable seal line is appended the inner side of the continent; thereby the optimized method above can be applied to the delimitation of territorial sea.

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Biography

PENG Rencan, professor, Ph.D, Ph.D supervisor, majors in the theories and methods of charting, the development and application of military oceanic geographical information system, and the high precision models and methods of oceanic delimitation based on the earth ellipsoid.

Spatio-Temporal Personalized Web Search

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ABSTRACT

With the proliferation of mobile technologies and the advent of GPS enabled personal devices, spatial as well as temporal data related to a user's presence in different places over time are becoming available. Such data can be useful in understanding and building a personal user profile that reflects their behaviour, activities and general interests. Existing applications, such as Location-based services (LBS) normally rely on 'instantaneous' space and time data values representing user's location at a certain point in time. Several approaches have been proposed in the literature that considers the use of multiple/historical data values of user's location information collected over time. However, only simple numerical interpretations of such information have been presented. In this work, it is argued that a rich spatio-temporal data model of Place is needed that incorporates, as well as facilitates, the analysis and discovery of place semantics, such as for example, the type of place, services offered by the place and relationships between places. Ultimately, such a data model will allow for the analysis of collected spatio-temporal data logs to support the development of rich personal user profiles.

Keywords: user models, spatio-temporal data, personalized web search, ontology, semantic Web.

1. INRODUCTION

The problem of information overload is recognized as a chronic feature of the Web. The amount of the data publicly available for search engine crawlers is massive and keeps growing. Also, search query keywords represent a partial view of the user's information need. Various approaches to personalized web search have been proposed to address this problem. Personalisation refers to the use of "some" information about the user to give them a tailored, personalized, set of results that is more suitable to their information needs.

The following is a list of the main approaches in the literature on the topic of personalized web search.

1. Relevance feedback and query modifications: explicit (or implicit) users feedback is used to re-formulate the search query to get more focused results.
2. Contents-based personalized search: the contents of web resources in the search results are analysed against the user's consuming behavior to identify the user's interests.
3. Hyperlinks-based personalized search: different indexes of the web corps are built, each biased towards a specific topic.
4. Community-based search: collaboration of groups of users' profiles.
5. Personalized mobile search: utilizing the location of the mobile users to enhance the search.
6. Other approaches: many other, less common, approaches exist – though some of which are not pure search utilities. These include; goal-oriented search and browsing, adaptive user interface search portals and recommender systems.

Using spatiotemporal user data in the physical space is of interest to many application domains. Context-aware systems such as LBS, personalize their information and services using several types of contextual information including location. There are many systems that employ the historical spatiotemporal data of the user's navigation in the physical space. In [2] and [3] the spatiotemporal navigation log in the physical space is used to predict the user's movements and identify social patterns as well as socially significant places. In [4] space and time data are used to analyze traveler behavior, e.g. to predict the transportation mean. In [5], spatial proximity over time is used to indicate shared interests between people. Other application employing user-based spatiotemporal data include pre-caching of data and services in mobile computing, network infrastructure optimization in mobile communications networks, and spatial reminder applications.

Several proposals in the literature aim to utilize spatial-temporal data to analyze human spatial behavior, e.g. works on Travel Behavior Analysis (TBA).

2. BUILDING THE USER PROFILE

Follow is an overview of the framework components proposed here as shown in figure 1.

1. The systems $f1$ module is responsible for geocoding the raw spatial data.
2. $f2$ then extracts the concepts reflected by

those places and their relative temporal data (representing the user's being in those places) in conjunction with other knowledgebases such as ConceptNet, the Web (where some info about some places may exist), and/or the system's own knowledgebase of places and the concepts they represent.

3. Every place can reflect more than one concept that is then used to build a personalisation profile in ƒ3.
4. ƒ4 represent the techniques that utilize the spatiotemporally enhanced user profile for personalising the Web search results (e.g. by clustering the results based on the concepts extracted from the spatiotemporal log).
5. Notable is the ƒ5 component that is responsible for interpreting the user's web searches. This would affect the future interpretations of places (in ƒ3), and also modify the concepts reflected by the previous places.

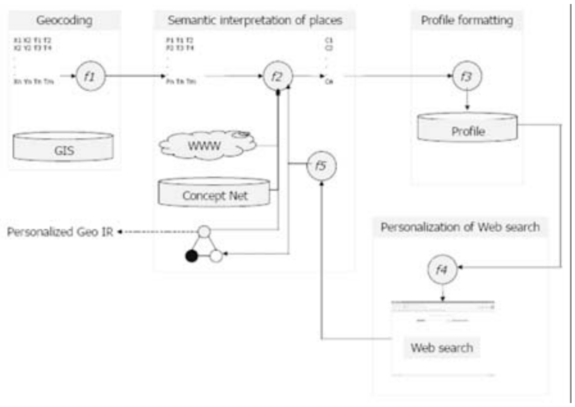

Figure 1. Proposed framework for deriving user personal profile

4. SUMMARY AND WORK PLAN

Building a personalization profile involves two main steps: semantic annotation of space and time data and the development of semantically-rich place data model, and thematic as well as spatio-temporal analysis of the data model to model user activities and behaviour.

A semantically-enriched place model will hold information related to place name, type, relationships between places, as well as other semantics such as the category of services provided by the place. The places identified will be associated with a time stamp to indicate the length of the user’s visit in the place. Places are related to concepts that reflect the user’s interests and goals. Knowledge bases such as ConceptNet can be used for the identification of such concepts. The project will also consider other sources of information for discovering place semantics including the web.

Reasoning techniques will be used to derive the user's personalization profile and to maintain its currency.

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LIDAR for Flood Defence

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BKS Surveys Ltd explain how high-density low-level LiDAR data can be used to abstract flood defence data to provide valuable information that meets environmental policy guidelines whilst also assisting communities protect from the risk of flood.

Introduction

Flood risk management assets protect thousands of homes and businesses from the risk of coastal and fluvial flooding. Accurate survey information of these assets is therefore vital to the EA's approach, both to the day-to-day asset management and to the decision making process for their maintenance, improvement or replacement.

In 1997, to comply with Section 105 of the Water Resources Act of 1991, the UK Environment Agency (EA) began developing programmes to survey floodplains and map flood extents. Since this time, LiDAR from fixed-wing aircraft has been widely used by the EA and their consultants to measure land topography for flood modelling and flood risk mapping purposes. Individual measurements of the terrain are made at a density ranging between a few points per square metre to 2m intervals and provide excellent coverage of the floodplain that allow highly resolved terrain models to be generated.

With conventional, lower density fixed-wing LiDAR data there are difficulties in obtaining an adequate representation of important hydraulic features such as embankment crests, flood defence walls and outfalls. Therefore, it was believed that the utilisation of low-level LiDAR, with a much higher point density, would enable the EA to identify and evaluate these smaller but critical features.

Since 2004, BKS has been acquiring low-level LiDAR data using the FLI-MAP system to assist the EA in the identification of detailed flood defence information. These include; defence type, defence crest, toe levels and cross-sections for large lengths of fluvial and coastal defences. The surveys have demonstrated that remotely sensed LiDAR data taken from a helicopter platform is capable of gathering accurate and detailed information on soft and hard defences, which was not previously possible.

LiDAR Application

In Spring 2005, BKS undertook pilot projects on the Rivers Medway, Swale, Thames and Hamble amounting to approximately 650 linear kms, to demonstrate the capabilities and effectiveness of the low-level LiDAR technique using the Fli-Map II system developed by Fugro *(Netherlands)* in 2000. The system comprised dual class 1 lasers (each emitting 11,000 single return laser pulses a second with a ranging accuracy of 5cm), Inertial Measurement Unit to measure rotational elements of the sensor during acquisition, and GPS for recording of positional information. Additionally, the system has integrated downward and forward facing digital cameras and video cameras. The data was acquired with an operating ceiling of 100m and a swath width of data also measuring approximately 100m.

The main drivers for the pilot studies were to; accurately measure the crest line location and height; identify the defence type; determine crest width; determine defence width and; location and type of structure, all of these were required regardless of the defence type. In addition to these, if possible, the condition of a defence was to be assessed.

It was hoped the technique of extracting defence data from high density helicopter LiDAR would prove to be a quick and accurate method of improving defence asset information and flood modelling, therefore enabling improved flood risk management. Additionally, the simultaneously acquired video and photo images would be an invaluable asset for office based inspections and assessment. The use of low-level LiDAR would offer a major potential to bring asset condition assessment onto a common footing as flood risk mapping and contribute immensely to the Agency's asset management strategy and flood risk mapping policy.

Analysis Considerations

The key elements to the success of the pilot studies were the density of the point cloud and the resolution of the images. The point density was set to at least 12pts per m² to enable measurements on thin wall defences and the digital images were required at a nominal ground sampled distance of 10cm to allow individual flood defence types to be distinguished.

Data acquisition was tied to a series of GPS base-stations within 20kms-25kms of the survey area. In order to quality assure the LiDAR data, small patches of ground survey were established and tied to the local datum at discrete locations throughout the survey area. The LiDAR data was then compared against the ground surveyed data for quality assurance and local bias removed from the final data model.

Data Processing

Collection of the LiDAR data was only part of the project. Once the survey data had been collected, the task of abstracting defence data from the survey could begin. The data was presented in two forms, (1) Point cloud data greater than 12 pts per m² (2) Gridded data provided at 0.25m resolution.

There is a marked difference between the data sets in the amount of processing performed and the detail that can be abstracted. The point cloud data has had minimal processing and as a result still includes some outlier results, from reflections etc. The grid data has had greater processing with outliers and noise between points removed. Although it is much faster to use gridded data in analysis and modelling, it lacks the detail of the raw point cloud data, and for the purpose of this project it was the detailed information which was required. Some flood defences are no greater than two bricks thick and whilst it is possible to pick these features up using the laser point cloud data, they can disappear in the gridded data.

To facilitate viewing, interpretation and post-processing of the point cloud data, BKS supplied the Agency and their consultants with software (FLIP7) specifically developed for rapid display and processing of huge volumes of laser point cloud data that also enables simultaneous inspection of the digital aerial photography and video. The FLIP7 software also enables the end-user to classify the data into terrain and elevation data as well as abstract topographical vector data.

Similarly, an extension to ArcView/ArcGIS, FLI-MAP Analyst, has been developed to assist engineers in the analysis and reporting of the engineering application in a GIS environment, enabling the rapid generation of longitudinal profiles and cross sections at predefined or user selected locations and comparison of the condition of the asset against design profiles or previous survey data. The software also enables the engineer to quickly generate plots and drawings.

The initial analysis of the point cloud data proved promising and comparisons with ground survey data showed minimal differences in height and most significantly provided much higher levels of detail that proved it was capable of identifying the height of earth embankments and vertical walls that was an essential prerequisite of the pilot study.

A helpful by-product caused by the meandering nature of river embankments was a number of areas that necessitated multiple passes to be flown in order to achieve full coverage of ground. This increased the point density in these areas and enabled even greater distinction between features. Within these areas features such as culverts, sluices and even fences showed greater definition.

Further processing involved the identification and measurement of the height and width of the crest of the defence as well as data regarding the total width of the defence. Measurements were taken at 5m intervals and at intermediate points where there was a height change of 0.1m or more. This provided valuable survey data of the assets and enabled information to be derived on the condition of asset at any given location.

FLI-MAP 400 System

Following the successful completion of the pilot project, it was decided to upgrade and develop the current system to improve the service offering for 2006, particularly with respect to river embankment monitoring.

The meandering nature of river embankments requires multiple flight lines and it was therefore considered essential that the new system was capable of producing a much wider swath of data. This would significantly reduce the number of single runs required to cover the survey area, so improving operational efficiencies and minimising project costs.

The original FLI-MAP II system was designed and configured for use within a rigid frame that could be deployed and mounted to a range of types of helicopters without the need to modify the airframe. This rigid frame approach enables the system to be transported throughout Europe and be matched to a suitable helicopter near to the survey area. This approach has proved particularly successful and facilitated operations throughout the world. Therefore, it was decided to redesign the new system around the same rigid frame, which would also simplify and expedite the approval and certification of the new system with the appropriate Aviation Authorities.

Accuracy

Maintaining the 60degree scan angle would result in a similar flying height to data swath ratio. It was decided that an operating altitude of 400m would produce a sufficiently wide swath-width for most applications and also yield considerable benefits to the ease of acquisition, particularly in any urban environments where Civil Aviation Authority regulations restrict low-level flying below 250m. For high detail topographical mapping it was also necessary to increase the point density of the data and improve the accuracy of the data. Previously, the only way of increasing point density where finer details were required was to fly additional cross-passes or reverse direction double passes, proving both time-consuming and costly.

In order to meet these exacting requirements the laser manufacturer designed a completely new LiDAR specifically for use in a low-level operating environment. The new sensor is capable of being operated in the 350m-400m altitude range and so producing a similar 350m-400m swath of data. The dual lasers are replaced with a single rotating mirror laser that generates 150,000 pulses per second. This corresponds to a far greater point density of 25 points per m^2 from 350m altitude and in excess of 100 points per m^2 from the former operating altitude of 100m. An improved ranging accuracy of 1cm and higher IMU and GPS positioning rates combine to produce improved vertical accuracies in the order of +/-3cm RMSE on well defined surfaces.

This greater point density is particularly beneficial where it is important to be able to accurately define the height and location of a flood defence that may be a small brick structure.

It was also considered that enhanced penetration of vegetation would significantly improve the quality and usefulness of the acquired data, particularly for river embankment studies. Therefore, the system was designed to produce a maximum of 4 returns per pulse with a minimum target separation of less than 1m. This would greatly increase the chances of a laser pulse returning a true ground position and also provide a good interpretation of tree structure detail. In conjunction with the redesign of the laser, enhancements were made to the imaging components of the system.

The new Fli-Map 400 system was successfully launched in Spring 2006 and has, to date, acquired data for in excess of 2,000kms of river embankment assets. The new sensor has enabled higher levels of interpretation through increased point density and higher resolution imagery, improved accuracy and penetration of vegetation.

Technology impact

The EA support the Government's drive to make all its services available on-line and have worked with DEFRA and Local Government Authorities (LGAs) to develop a Geographical Information System (GIS) called the National Flood and Coastal Defence Database (NFCDD). The NFCDD currently contains details of flood defence assets that belong to the Environment Agency and LGAs and is being further developed to become the comprehensive source for all flood risk management data.

The Incident & Flood Risk Management reorganisation at the EA in the summer of 2005, has enabled it to target additional resources into providing more accurate data, not only on flood plains but also on flood defences and flood risk management assets. It is anticipated that the EA will increasingly use high-resolution LiDAR techniques to readily and economically capture the required accurate spatial data. With such data in place, management of Flood Risk will become a more scientific activity, with the possibility to consider and assess multiple scenarios whilst more rigorously determining the correct prioritisation of maintenance and asset inspection activities. The increased data quality and accuracy achievable with high resolution LiDAR will, in turn, drive future enhancements to the NFCDD system, to enable these data improvements to be translated into better graphical presentation.

Water Quality Analysis of Aksu-Tarim River Based on Remote Sensing Data

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1.Introduction

Based on remote sensing techniques, various methods have been proposed to detect parameters of water quality, monitor their changes and estimate water pollution(Wang Yun-peng,etl.2001). A well-known conclusion is that, to some extent, water pollution can in fact be detected by remotely sensed image analysis. Combining these images with ground truth observations at the same time, a model can be established to quantitively monitor water pollution.

Wang et al.(2001) employed TM data and limited on-site data to develop a model for predicting 7 kinds of water quality parameters in Tai Hu, namely(SS、SD、COD、BOD_5、TN、TP、DO), This model demonstrates that using single-band and multi-band data factor analysis and PCA can make full use of remotely sensed information and improve the accuracy of prediction(Wang Xue-jun,etl.2000).Yunpen Wang,Hao Xia, et al. used Landsat TM data to analyze the changes of water quality in Shenzhen(Wang Yun-peng,etl.2004). Wang and Ma used remote sensing techniques to monitor and assess the water quality of Tai Hu(X.J.Wang,etl.2001). Yin,Walcott, et al.(2005) analyzed the relationship between water pollution changes and city development in Shanghai. Hellwegeer,Schlosser, et al.(2004) used satellite images to study the water quality of the port in New York.Wan, et al.(2003) employed high spectrum remote sensing to monitor water environment and developed regression models of COD and BOD_5.Wu and Li(1997) used PPR to simulate the water quality of the rivers in the Tarim Basin.Lu(2002) used Landsat TM satellite data to study the water pollution of the Yangtze River around Nanjing.The Remote Sensing Centre of Sichuan Province used TM data to survey the water pollution in the three rivers of Cheng Du, and the classified water pollution into 5 grades, which became the basis to improve the water system around Cheng Du(Diao Shu-juan,etl.2001).

The study area of this paper is the river of the Aksu-Tarim Basin. How to use TM data and routine monitoring data to monitor water quality are discussed. A water quality-monitoring model is proposed.

2. Study Area

As shown in Fig.1,Aksu lies in the middle part of the South Xinjiang Autonomous Region, at the southern foot of Tian Shan Mountains, the northern fringe of Tarim Basin. The range of its geographic coordinates are 78°02′～84°07′E,39°30′～42°40′N. It is respectively adjacent to Bayingguoleng in the east, Kazakhstan in the northwest, Takelamagan in the south and Ili in the north. It is about 510 kilometers from east to west, 350kilometers from north and south. Its area is 132,500km^2,accounting for 1.38% of the area of China.

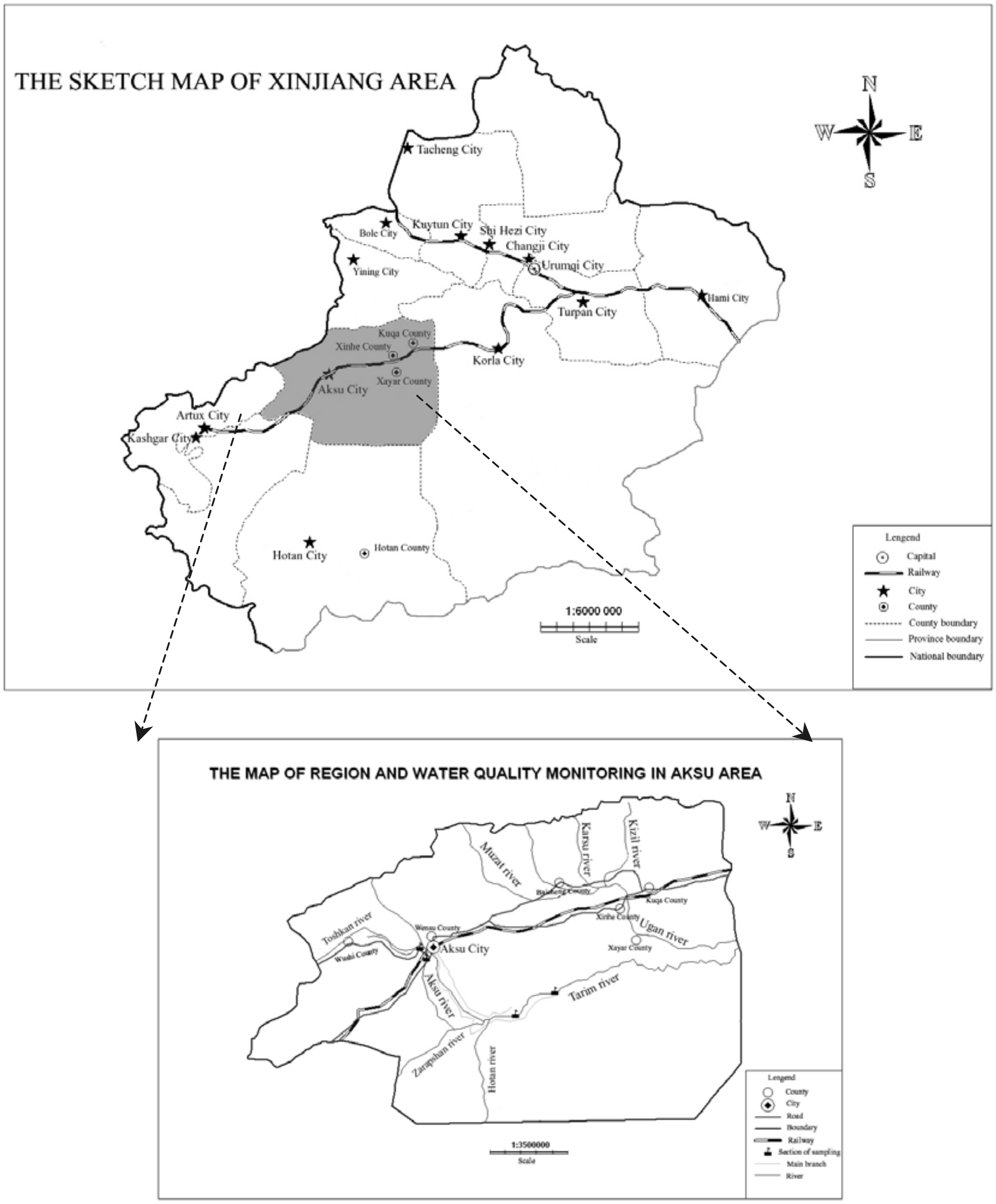

Fig.1 The map of study area

In recent years, along with the economic development of the drainage area,intensive and exploitation of upstream areas has occurred. The amount of incoming water has been gradually reduced in the midstream and downstream segment of the Tarim River(JI Fang, et al.2000).At the same time, the amount of highly-mineralized water directly draining into this river has increased. Water pollution has become seriously(MA Ying-jie, et al. 1999).Especially since the 1970 year, with increased human activities, Water consumption dramatically increased in the middle segment. The volume of salt aggregation is large in the Accra River valley. The improvement of removing salt and meliorating soil further increase the degree of mineralization of this river and blocks the agriculture development along the river of Tarim Basin. The amount is of chlorides, sulphates and mineralization exceed standard levels, which prove that water pollution in the Tarim Basin is mainly due to the salinization of soil.

According to monitoring data from 1985 through 1998, the rates of mineralization in Allard,Xinquman and Kalanian are respectively 1.85g/L,1.37g/L and 1.34g/L.they document that the mineralization rate increases with the increase of the flow, that the mineralization rate is low upstream, and a high in downstream. The reason is that the upstream absorbs a large amount of farmland water. Therefore, in order to improve water quality, drainage from farmland to the river must be restricted.

However, development of the economy must boost the drainage from farmland the Aksu-Tarim valley. In order to fulfill sustainable development in agriculture, it is necessary to the change farmland drainage and their adequate influence on Aksu-Tarim valley. Therefore, remote sensing techniques are employed in this area. Because it is a advanced techniques in nowadays.

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RS & GIS Based Analysis of Snow distribution & Change in Emin River Basin, Xinjiang, China*

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1. Introduction

Detecting of snow coverage change plays an important role in both flood/drought forecast in spring and the research on the relation between snow coverage change and the global climate change. This paper took the Emin River Basin as our typical study area, based on MODIS image, used RS and GIS software, analyzed the change of snow coverage per half-day between March 4th and March 12th in Emin River Basin, with the last method, and then set up the relationship between snow cover and the influent factors, the result is that, the fast rise of temperature was the primary cause of the vast snow melt.

2. Approaches

2.1 The introduction of Research Area

Emin river basin located in the westernmost of Xinjiang, the geography coordinate is E 82° 29' - 84° 45'，N 45° 32'- 47° 14'. The main stream originated from Kmier Mountain, the altitude of mountain is not high, mostly are from 1000 to 2000m mid-lower mountain. The area of Emin river basin is 17137km^2,because of the mountain in the basin is not high; the type of runoff is rain off and snowmelt mixture.

2.2 The pretreatment of MODIS data

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The used data are March 4th to 12th MODIS data, in order to draw snow, we must do the marking computation at first, namely transform the detecting number to physics quantity, we need the reflectance, the correction of the solar altitude angle of the data, and geometry correction, in order to do the analysis integrating the basic geography data. There are two named Latitude and longitude data attribute, which can be used to correct the image.

2.3 Eliminating cloud

In this paper 0.66 μ m (red wave band) reflectance is used, for making a cloud mask, and eliminating cloud. After the examination, taking 0.18 as threshold can get good result, then applying no cloud region snow parameter to snow cover region, using ARCGIS to interpolate information below cloud (Wang Jian,1988).

2.4 The extracting of snow information

2.4.1 unmixed pixel method

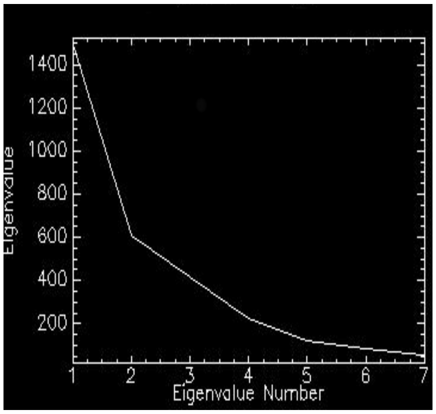
Linear spectrum mixed model is in common use in spectrum mix analysis because MODIS' s lower space resolution, mixed pixel proportion is high, it is defined as: the lightness of pixel is a linear combination, which is composed of the end member spectrum lightness of pixel and it's occupation of area proportion. It is expressed as formula

$$R_{i\lambda} = \sum_{k=1}^{N} f_{ki} C_{k\lambda} + \varepsilon_{i\lambda} \qquad (1)$$

where $R_{i\lambda}$ is the spectrum reflectance of $\bar{I}$ pixel in λ band. $C_{k\lambda}$ is the spectrum reflectance of k end member in λ band. f_{ki} is area proportion of k end member in the pixel. $\varepsilon_{i\lambda}$ is the error of ī pixel in λ band. N is the number of end member. m is the number of band. N<m. Using the least twain multiplication to solve f_{ki} and making $\varepsilon_{i\lambda}$ the least, meanwhile, satisfying the two conditions below: the sum of area proportion f_{ki} up to 1 and every end member area proportion between [0, 1] (Cross M. 1991). The pivotal question of linear mixed model is to determine end member, the most successful method is pixel purity index (PPI).

2.4.2 Extracting of end member spectrum using PPI

Firstly lower data dimension using minimum noise fraction (MNF), MNF is similar to PC analysis, which is used to



separate the noise of the data and determine the dimension, from the band energy change profile (figure1) we can descry: the energy change from band 1 to band 2 is the fastest, Fig1. The rotation of MNF

band 2 to band 3 taking the second place, the energy value of last several band is low and the noise is rather more. Then creating a great deal of stochastic testing vectors crossing through data aggregation inner in succession, then projecting spectrum spot to every testing vector separately, the result of projecting is choosing extreme in this direction by a certain limit, along with constant change of vector direction, recording the number of each pixel of extreme, finally considering the maximal frequency point is the purity point (Keshava N, Mustard J E. 2002). After the PPI operation of the image, analyzing the end member scatter point plot (figure 2), and comparing to ground cover type map, finding there are five end members in the research area. Extracting the spectral eigenvalue of end member (figure 3), the blue curve in figure 3 is the snow spectral eigenvalue.

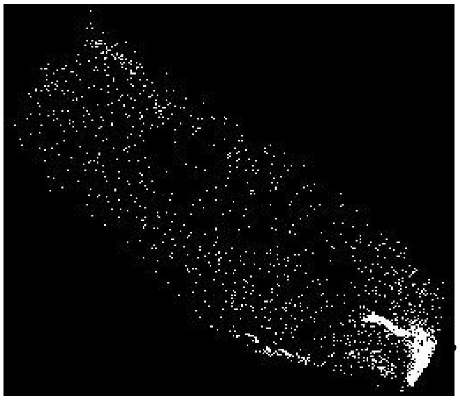


Fig. 2 the end member scatter plots from PPI

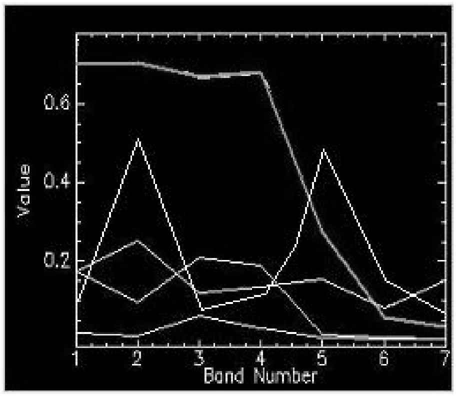


Fig.3 Spectral eigenvalue of land object in study area

2.4.3 Extracting and calculation of snow cover

The results of extracting snow information of MODIS data using linear spectrum mixed model is showed in figure 4, the digital number of each pixel shows the snow area proportion in this pixel. Using statistic function of ENVI can calculate the whole snow cover in research area. Compared the results of snow cover by way of linear spectrum mixed model with NDSI, the two methods demonstrate quite consistent results.

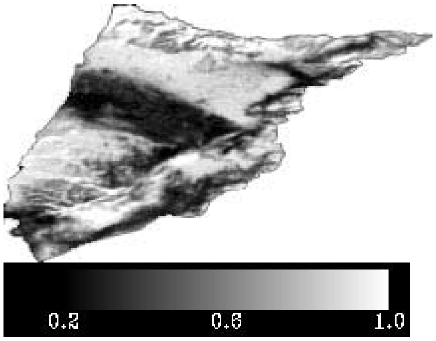


Fig.4 Snow cover of Emin River

2.5 Extracting snow cover according to elevation scope

Because of the difference of terrain and ground condition, the snow distribution in different elevation scope has the great discrepancy (Xu, H, Bailey, J, O, Barrett, E. C. et al, 1993). Extracting snow cover according to elevation scope by DEM of the catchment is the main purpose of snow cover mapping, and it is an important input parameter in simulation of snowmelt flow. In order to get the results, on the basis of remote sensing image analysis, making use of GIS space analysis, the area of snow cover in each elevation scope was extracted.

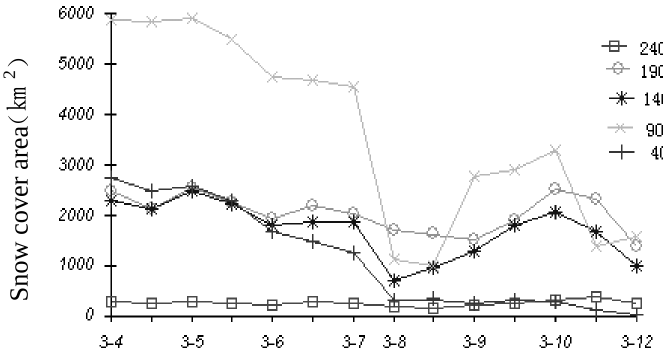


Fig .5 Snow cover depletion curve in Emin river basin

3. The Relation Between Snow cover Change And influcent Factors

In the practical research, many factors have influence on snow cover change as variable Y, and these factors include: average day temperature, precipitation, wind speed, dew point temperature, average sea level pressure and the fastest wind speed. Because of the limit of Emin river basin climate data, we use the stepwise regression method, only build the regression model of daily snow cover change and factors on elevation 400 - 900m. (Formula 2)

$$Y = -5111.93 + 122.47X_1 + 622.2X_2 + 30.29X_3 \qquad (2)$$

Where Y is the quantity of snow area change, X_1 is the day average temperature, X_2 is the gross precipitation quantity and X_3 is the dew point temperature. $R=0.9$, $F=518.7$, pass the test of $p=0.0001$.

From Formula 2, we can see that the quantity of snow area change has the great relativity to the daily average temperature, the gross precipitation quantity and the dew point temperature, and present positive correlativity. This shows that the higher the temperature is, the faster the snow melting, this point cannot be doubly, and the precipitation fall on the snow will accelerate the snow melting.

4. Conclusion

1. This paper makes use of linear mixed spectral model and integrates MODIS data to extract snow information, resolving the problem of mixed pixel, improving the snow monitoring precision.
2. The results of extracting snow cover according to elevation scope show that the snow change in each elevation scope has the great difference, the change of snow cover in elevation scope of 900 - 1400m is the most drastic, this is determined by the character of ground condition, solar radiation, grade and slope.
3. The regression model of snow cover change and factors shows that snowmelt has the most relativity to temperature and precipitation; the hoist of temperature is the main reason of snow melting.

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Updating Road Network Databases: Road Segment Grouping Using Snap-Drift Neural Network

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KEYWORDS: Road Network Update, Local Context Information, Snap-Drift Neural Network, Road Segment Grouping

1. Introduction

At present a number of methods are being used to update road network databases including ground survey, driving along roads with GPS and analysing satellite images to register changes. Previous research has aimed at addressing three update functions: road extraction, change detection and change representation (Zhang, 2004). Different types of image processing algorithms have been developed for each purpose. While image-based road updating approaches have had success, their accuracy is directly tied to the quality of the data (Klang, 1998) and object model used for road extractions (Gerke et al., 2004).

An alternative approach being investigated here is where service users of in-vehicle navigation systems might passively collect characteristics of any “unknown road” (roads not in the database) on behalf of the data provider. These data along with similar track data provided by other service users are transferred back to the provider and inputted into an artificial neural net (ANN) which decides whether to automatically insert the “unknown road” into the road network database on probation. At a later stage when there is enough certainty on road geometry and characteristics (cross-checking where necessary with other data sources such as remote sensing) the probationary flag could be lifted and permanently added to the road network database. The ANN would rely on road and neighbourhood attributes to predict whether any “unknown road” is actually a road that needs to be added to the central database as opposed to long driveways, car parks or off-road tracks which would generally not.

As an initial experiment to inform the choice of ANN and the practical fieldwork, we simulated journey scenarios covering two test sites: East London and near Stansted Airport. We have assumed that the road segments supposedly travelled are not present in a GIS road coverage and we seek to group these road segments into different road types using snap-drift neural network (SDNN) to test the range of attributes that might need to be collected. This will also establish the extent to which the road characteristics naturally fall into road classes (A roads, B roads, minor roads and local streets). We also present some key methodological issues of the investigation, a discussion of the variables and some preliminary results from the SDNN and its prospect for the proposed solution.

2. Snap-Drift Neural Network

Different types of neural networks have been employed in the past for map matching and road extraction purposes. In this study the Snap-Drift neural network (SDNN) developed by Lee and Palmer-Brown, (2004) is deployed. One of the strengths of the SDNN is that in a non-stationary environment where new patterns (e.g. new candidate roads attributes) are introduced over time, the learning process utilises a novel algorithm that performs a combination of fast, convergent, minimalist learning (snap) and more cautious learning (drift) to capture both precise sub-features in the data and more general holistic features. The two learning modes (snap and drift) are combined within a learning system (Figure 1) that can toggle its learning style (Lee et al., 2004).

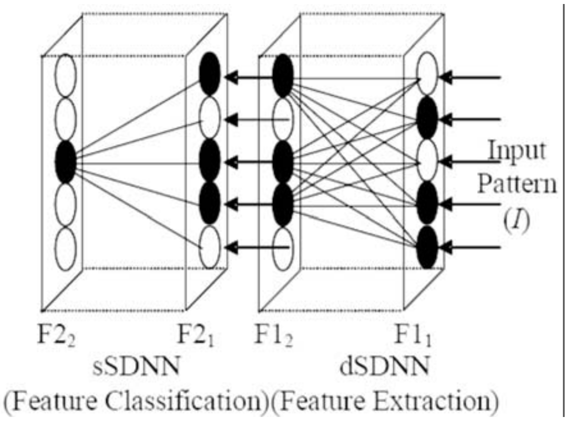

Figure 1: Snap-Drift Neural Network (SDNN) architecture (from Lee & Palmer-Brown, 2005)

On presentation of input data patterns at the input layer F1$_1$, the distributed SDNN (dSDNN) will learn to group them according to their general features using snap-drift (Lee and Palmer-Brown, 2005). The F2$_1$ nodes, whose weight prototypes best match the current input pattern, receive dSDNN outputs as input data to the selection SDNN (sSDNN) module for the purpose of feature grouping. Unlike back propagation which performs optimization for classification (rather than feature discovery), by pushing features in the direction that minimizes error on the output nodes without any requirement for the feature to be statistically significant within the input data, SDNN toggles learning mode to find a rich set of features in the data and uses them to group the data into categories as illustrated below. Thus the SDNN was used to group road segments into the road types based on the road segment information and local context data supplied to it.

3. Data Description

Two simulated journey scenarios, one urban the other rural, were used to generate the study data. Scenario one (Figure 2): 2.3km trip from “Holloway Road” to “Andrewes Gardens” (East London). Scenario two (Figure 3): 18.3km trip from “Manor Road” to “The Grove” (near Stansted Airport). From Ordnance Survey MasterMap data, each road segment terminates and a new segment begins at road intersections. This implies that in both scenarios, the routes were made of sequences of connected road segments between the start and end point. Scenario one consists of 32 road segments while scenario two has 62 road segments. A buffer of 50m for each road segment was created. In total there were 93 road segments made up of 20 A roads segments, 30 B road segments, 13 local streets segments and 30 minor road segments. Table 1 shows summary of all the available road types and the nature of roads within each class. Local context information such as length of road segment, speed limit, number of address points, number of crossings/exits/side roads, and type of road feature was collected for the buffered area of each road segment.

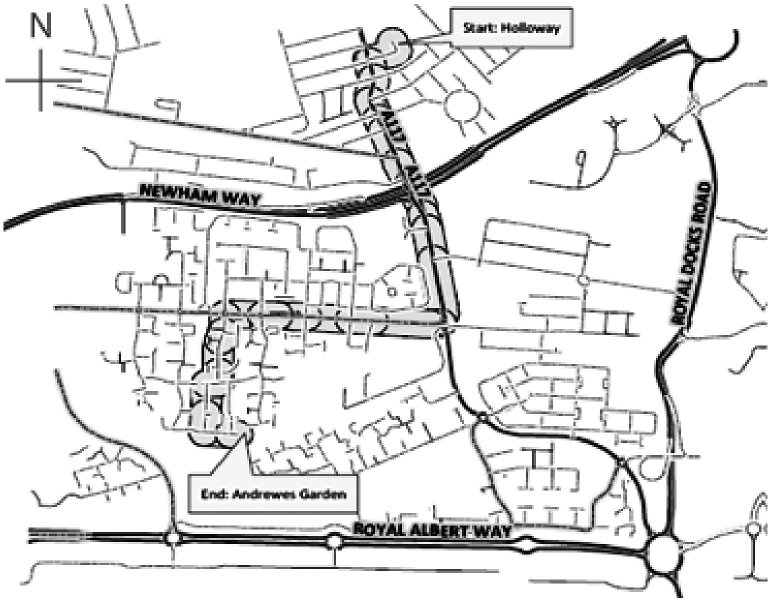

Figure 2: Scenario one in East London (road data Crown Copyright).

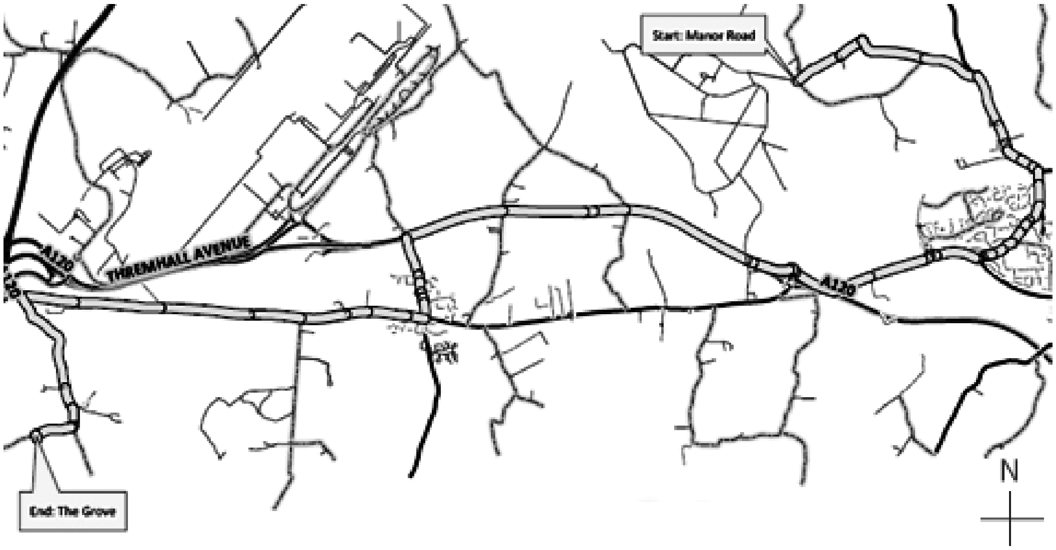

Figure 3: Scenario two near Stansted Airport (road data Crown Copyright).

3.1. Input Representation for SDNN

For the input data set used in the SDNN, there are 9 groups of variables represented by separate fields in the input vector. Length, speed limit, address point counts and number of crossings/exits/side roads variables were real number inputs. 5 bits binary encoding was used to represent the type of road features (Table 1). Out of the 93 road segments, 46 inputs (road segments) were randomly selected half from each road class and used to train the SDNN. The remaining 47 inputs were used for testing.

Type of road feature	A road	B road	Local street	Minor road
Single carriageway	8	20	13	28
Dual Carriageway	10	0	0	0
Roundabout	0	4	0	0
Slip road	1	0	0	0
Traffic Island	1	6	0	2
Total	20	30	13	30

Table 1: Summary of composition of each road class considered.

3.2. Results

Results are presented in Figure 4 and 5 and in Table 2. Figure 4 shows the winning nodes and the road class composition on each node. For instance, winning node 19 is made up of 16 road groupings composed of 75% A roads and 25% B roads (Figure 4). Relying on the concept that the class with highest composition wins, then winning node 19 would be assigned A roads. Using this concept, overall, the SDNN groups about 62% of patterns into their actual classes after 10 epochs and converges after 50 training epochs.

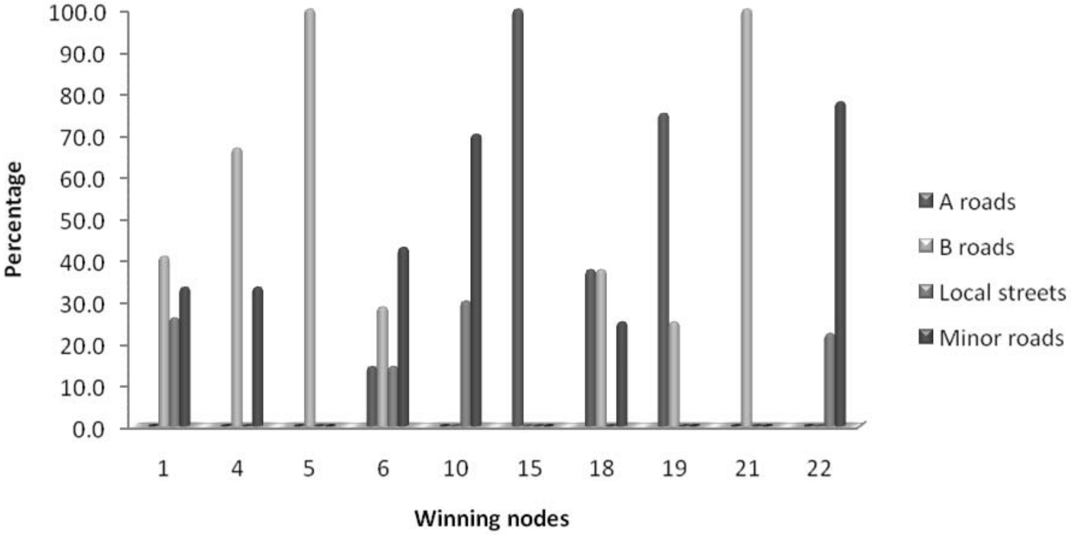

Figure 4: Plot of SDNN output showing the composition of road classes in each winning node

On inspection of the dSDNN (*d-node*) nodes, most of the winning nodes have unique *d*-nodes sequences (dSeq) that in the majority of cases represent unique road classes (Figure 5). In this case winning node 19 is separated, based on its *d-node* sequence, to 19-d_{Seq}A for A roads and 19-d_{Seq}B for B roads. Only the correctly mapped (unique) *d-node* sequences are plotted in Figure 6. Based on the *d-node* output, the SDNN achieved grouping accuracy of over 77% in each class except the Minor roads (Table 2).

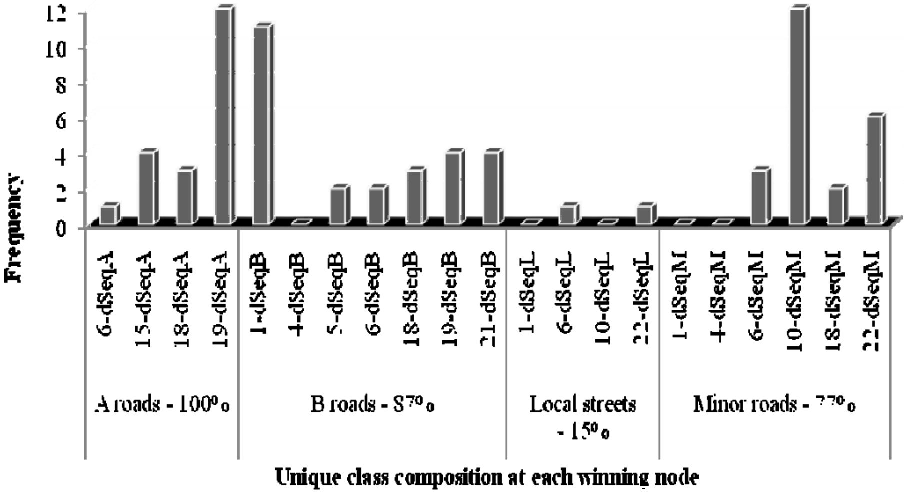

Figure 5: Plot showing distribution of correctly mapped road classes across the winning nodes.

Most of the inaccurate groupings occurred as a confusion between the local streets and minor roads. This is explained by the fact that both road inputs are characterised by few and similar variables as shown in Table 1 and in reality variables like speed limit, address point counts and nature of roads of both local streets and minor roads rarely differ. In addition the small number of inputs available for the training could also affect the local streets class grouping accuracy since only 6 out of 13 available local streets input data were used for training compared to other road classes with between 20 to 30 inputs and half of each class randomly selected for training.

	A roads	B roads	Local streets	Minor roads	Total	Group accuracy
A roads	20	0	0	0	20	100%
B roads	0	26	0	4	30	87%
Local streets	0	0	2	11	13	15%
Minor roads	0	2	5	23	30	77%

Table 2: Grouping accuracy of SDNN results

4. Conclusions and Future Work

The result of the SDNN offers a fast method of learning that preserves feature discovery and is capable of grouping road patterns according to their local context information. However, it is also clear that simply performing unsupervised learning to find the most natural groupings is insufficient to classify all road types accurately. The result represents a positive first step towards updating road network by using a candidate road’s local context information, but later work will involve applying the SDNN for road classification using real user-collected data and much larger road input patterns to see how it performs. The results of this work will be available for presentation at the conference.

Acknowledgements

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Biography

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The generation of river channel skeletons from binary images using raster thinning algorithms.

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1. Introduction

River channel centrelines are important features for the analysis of river channel parameters and dynamics. Networks of channel centrelines allow the computation of stream orders in braided channels (e.g. Gleyzer et al., 2004) and quantification of bifurcation angles (e.g. EGIS, 2002). Analysis of the change in the location of centrelines through time is central to the measurement of channel migration rates (e.g. Mount and Louis, 2005) and the prediction of channel stability (e.g. EGIS, 2002; Burge, 2006).

Commonly, channel centrelines are quantified manually by digitising an operator's perception of the centre of a channel (e.g. EGIS, 2002) or from the coordinates of digitised section lines (e.g. Mount et al., 2003). However, these methods are time consuming and rely on the interpolation of points to form the channel centreline, losing data in the process. A preferred option would be the automatic extraction of channel centrelines from binary imagery, commonly known as skeletisation. Algorithms for such operations are available in many contemporary GIS. However, they commonly have their roots in algorithms developed for drawing automation or character recognition and are, therefore, seldom optimised to handle the topological complexity and boundary noise that one associates with binary images of river channels. The result is highly irregular skeletons that are poor representations on the channel (Figure 1).

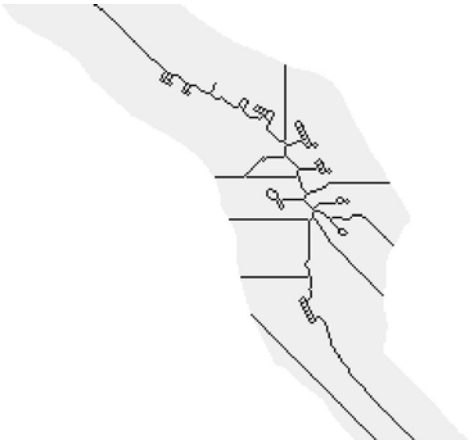


Figure 1. The skeletonisation of a section of the Torrent du Jean Pierre by ArcMap's Thin tool. Spurious limbs and loops are evident.

The skeletisation of binary images is a mature research discipline with several hundred papers published on the subject (c.f. Lam et al., 2002) since the late 1960's. However, virtually no algorithms have been specifically designed and tested on river channels, and those that have (Vincent, 1991) have not been tested in complex multi-channel environments.

This paper outlines a skeletisation algorithm specifically designed for skeletonising complex river channels along with pre and post-processing operations to improve the resulting skeleton. It is based on an amendment to Arcelli et al's (1975) raster thinning algorithm and applied to test data from the Torrent du Jean Pierre in the Ecrins National Park, France. (Figure 2).

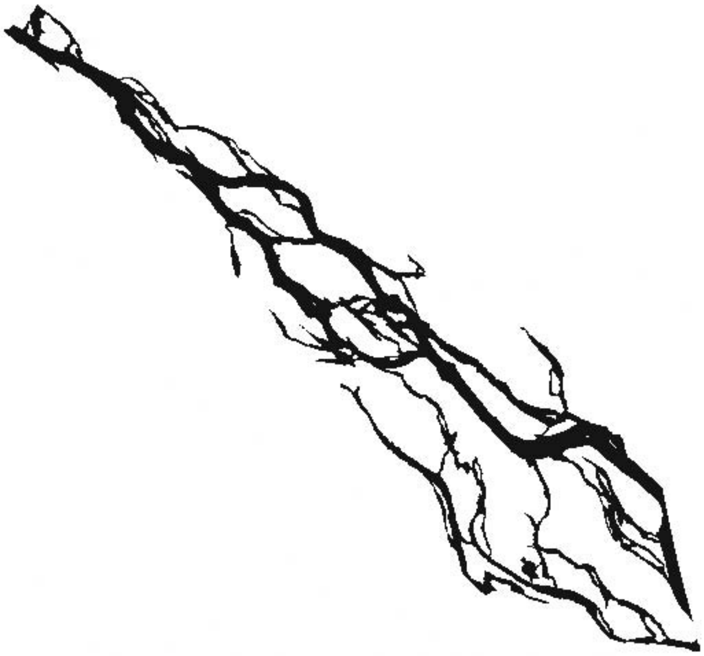


Figure 2: Binary image of the braided Torrent du Jean Pierre, Ecrins National Park, France**.**

2. Using Thinning Algorithms in River Channels

Thinning algorithms reduce binary images to their skeletons via an iterative shrinking process in which each contour pixel is analysed and, if certain removal criteria are satisfied, that pixel is deleted. Many of the published raster thinning algorithms have been designed for applications such as character recognition, in which the data are relatively uniform and possess predictable characteristics. Raster based thinning algorithms for use with river channel data of the complexity of the Torrent du Jean Pierre, must be able to cope with highly irregular, noisy contours, be capable of preserving topology and geometry, and be able to achieve invariance under conditions of rotation.

Non-iterative algorithms, which compute channel centrelines on the basis of the contours of the binary data, are highly susceptible to variations under rotation (Lam et al., 1992) and to noisy contours. Hence, they are inappropriate for use in thinning complex river channels. Different challenges face the use of iterative algorithms. Artefacts such as noise spurs and loops are likely but may be removed by post-processing. More problematic is the occurrence of necking (Figure 3) which is a common error resulting from iterative algorithms and has an impact of topology which is difficult to remove. Accepting these outstanding issues, a parallel iterative approach was chosen (parallel algorithms operating on all or a subset of pixels simultaneously), offering advantages in terms of computational efficiency (important for large rasters) and simplicity of code. The risk of necking was believed to be outweighed by the benefits offered by an iterative algorithm.

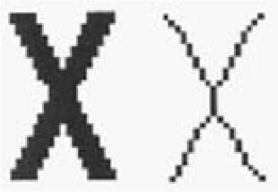


Figure 3. An example of necking, where the topological relationships of the binary data and skeletonised data have been altered.

The noisy contours associated with binary images of river channel data require filtering to prevent the generation of spurious limbs from small convexities in the contour (Dharmaraj, 2005). A simple, median filter, in which a count of the number of 0s and 1s in a 3x3 window is used to determine the value of the central pixel, was applied to decrease contour noise. Small islands, or holes, in the binary channel raster also require removal to ensure spurious channel nodes, and hence bifurcations, were not identified. To this end, an equivalent of ArcMap's Region Group tool, in which unique IDs are assigned to the pixels making up each island, was used, and a deletion threshold area, determined manually, was applied to remove small islands. Following these pre-processing steps, the thinning and bifurcation algorithms can then be applied according to the sequence given in figure 4.

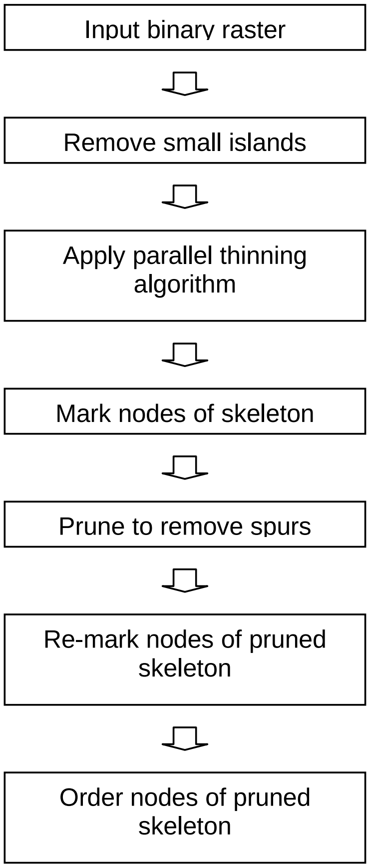


Figure 4. The analytical sequence for generating skeletonised river channels from binary channel images.

3. The application of a thinning algorithm and pruning algorithm to complex river channel data.

Thinning algorithms work via the moving application of a number of masks, of given pixel dimensions (usually a 3 x 3 window), against which the patterns of pixels values in the binary image are assessed. The masks are configured such that, for each iteration, only contour pixels may be deleted based on the presence or absence of given patterns within the contours of the original, binary image. An introduction is given in Ablameyko and Pridmore (2000) with a full review of masks and algorithms in Lam et al., (1992). This study applies a modification of the well-known, parallel thinning algorithm of Arcelli et al (1975), in which additional masks from Hilditch (1983) are applied to address pixel redundancy issues. The algorithm ensures that only a single layer of contour pixels can be removed in each iteration, thereby achieving a more predicitible skeleton with fewer anomalies at the corners.

The modified Arcelli et al., (1975) algorithm results in numerous short, spurious limbs (Figure 5) that require pruning (Dharmaraj, 2005). To achieve this, nodes and end points must be identified so that limbs with short distances between end points and nodes (indicative of a spur) can be identified and deleted. End points may be identified where the number of transitions from 0 to 1 (*T(b)*) that occur when the boundary cells of a 3 x 3 window are traversed cyclically is equal to 1 (Apaphant, 2000). However, in complex river channels, situations in which end points have 2 or 3 neighbouring cells are possible, resulting in up to three transitions. Therefore, the rules for identifying end points can be modified according to figure 6.

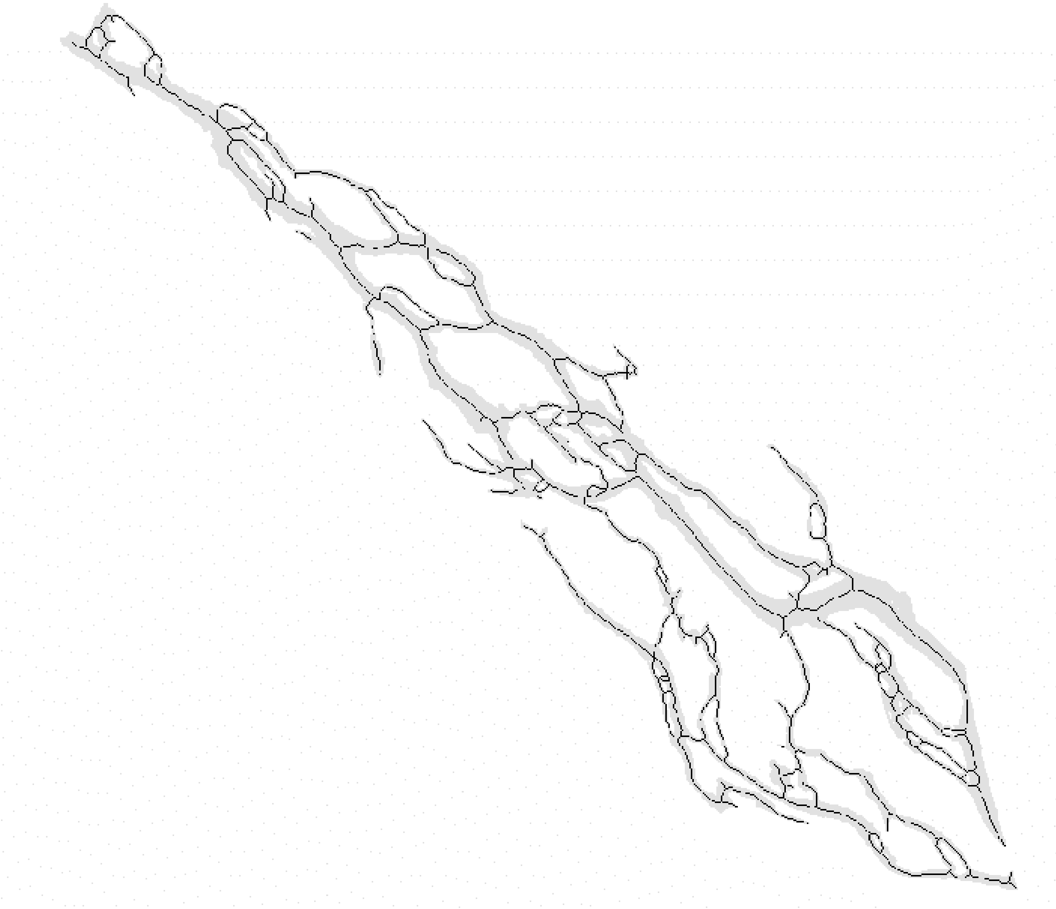
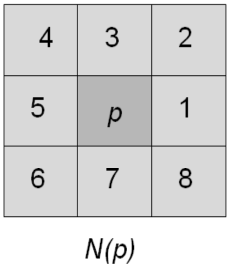


Figure 5: Spurious limbs prior to pruning.

End Point with 2 Neighbours (N)	End Point with 3 Neighbours (N)
_N(b)_ < 3 and N2 = 1 and N3 = 1	**_N(b)_ < 4 and N2 = 1 and N3 = 1 and N4 = 1**
_N(b)_ < 3 and N3 = 1 and N4 = 1	**_N(b)_ < 4 and N4 = 1 and N5 = 1 and N6 = 1**
_N(b)_ < 3 and N4 = 1 and N5 = 1	**_N(b)_ < 4 and N6 = 1 and N7 = 1 and N8 = 1**
_N(b)_ < 3 and N5 = 1 and N6 = 1	**_N(b)_ < 4 and N2 = 1 And N1 = 1 And N8 = 1**
_N(b)_ < 3 and N6 = 1 and N7 = 1	
_N(b)_ < 3 and N7 = 1 and N8 = 1	
_N(b)_ < 3 and N2 = 1 and N1 = 1	
_N(b)_ < 3 and N1 = 1 and N8 = 1	



4	3	2
5	*p*	1
6	7	8

Figure 6. Rules for identifying end points in complex, skeletonised river channels. *N(b)* is the number of black pixels (pixel value = 1) existing in a 3 x 3 window, where N_n is the number of the neighbouring pixel (*N(p)*) according to the numbering scheme shown.

In a similar way to endpoints, nodes can be identified according to the number of black pixels (*N(b)*) and the number of transitions from white pixels (0) to black (1) (*T(b)*) in a cyclical traversal of *Np*. Apaphant (2000) used the rule *N(b)* > 2 AND *T*(*b*) = 2 to identify nodes, but this fails to identify nodes where the configurations shown in Figure 7 occur**.** Therefore, the rule was modified to *N(b)* > 2 AND *T*(*b*) > 2.

From any end point a limb can be tracked via examination of *N(p)* for each cell, finding the next cell in the segment and stepping into it. Where there are two potential cells in *N(p)*, immediate neighbours are tracked preferentially to prevent nodes being missed (Figure 8). By counting the number of cells traversed between an end point and the first-encountered node, the length of a limb can be calculated and, where this length is shorter than a defined threshold, the limb is deleted. By applying these steps to all end points in a skeletonised image, limbs are pruned. A comparison of a pruned and unpruned channel skeleton is given in figure 9.

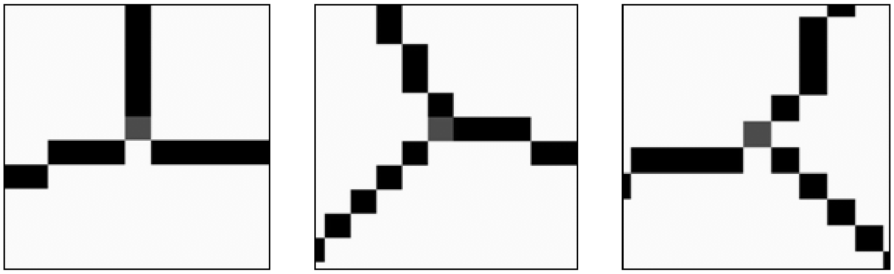


Figure 7. Node configurations in which *N(b)* > 2 AND *T*(*b*) = 2 fails.

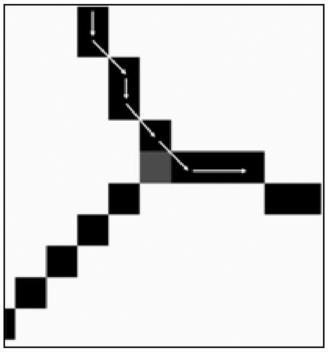
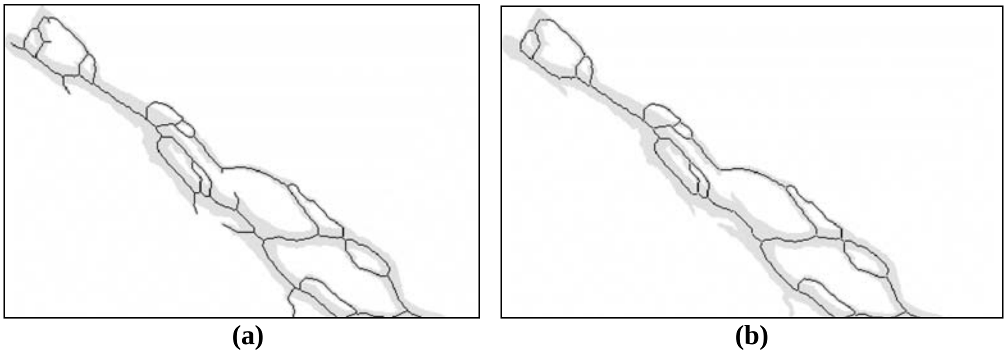


Figure 8. Example node configuration in which a node could be missed without the application of a preference for immediate neighbours.



(a) (b)

Figure 9. (a) Skeletonised channel prior to pruning and, (b) skeletonised channel after pruning.

4. Conclusions

The parallel, iterative algorithm presented here, whilst based upon Arcelli et al's established thinning method, contains a number of specific modifications that ensure it is applicable to the skeletonisation of complex river channels. Initial median filtering, to reduce contour noise reduces the frequency of spurious limbs in the thinned skeleton. Moreover, the application of additional masks from Hilditch (1983) ensure that only a single layer of contour pixels are removed in each iteration, resulting in a skeleton with fewer anomalies. Finally, the modification of the end point and node identification rules of Apaphant (2000) ensure improved pruning of any spurious limbs that exist in the thinned skeleton. The result is a set of tools which enable the successful skeletonisation of complex river channels which can then form inputs for further analyses.

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Biographies

Jonathan Hasthorpe is a 2006 Graduate of the University of Nottingham’s MSc in GIS programme. He developed this work as a part of his MSc dissertation investigating the automation of channel bifurcation angle measurement for complex river channels in Bangladesh. Nick Mount is a lecturer in GIS at the University of Nottingham with a particular interest in the spatio-temporal analysis of dynamic river systems.

Multiscale analysis of hillslope height for geomorphometry

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1. Introduction

Geomorphometry aims to quantitatively characterise the form of surface relief and is an important component of geomorphological research. As the availability of digital data describing topography has increased in terms of both the extent of the Earth's surface characterised by such data and their resolution, so has the use of computational techniques attempting to automatically extract information describing landforms increased.

These computational techniques focus on the use of regular grids of elevation and often use standard techniques to either derive indices with a direct geomorphological meaning (e.g. slope and curvature) or to identify particular features within a landscape (e.g. peaks and passes). Within the GIScience community it is well recognised such analysis is strongly scale dependent, and thus that a particular location may be described differently as measurement scale varies. Thus, for example Fisher et al. (2004) extract features from terrain models at multiple scales and assign locations a fuzzy membership of some feature class. Schmidt and Andrew (2005) argue that despite this broad understanding, "scale issues are poorly recognised and incorporated in current research and applications of terrain analysis".

In general, scale is treated within most applications as a variable dependent on some given sampling window size at a location, where the minimum horizontal length scale at which analysis can be performed is by definition twice the DEM resolution. In practice, sampling windows are generally centred on the cell of interest, thus sampling windows consider $(2^n+1) \times (2^n+1)$ cells where n is an integer. Such approaches clearly show how properties of location can vary with sampling scale, but ignore potential analysis scales inherent in the landscape itself. For example, geomorphologists might be interested in the variation of some parameter across individual hillslopes, drainage divides or mountain belts, where the division between such units is not related to a fixed horizontal length scale.

In this paper we report on the development of a tool for terrain analysis that allows the hierarchical division of 1D profiles according to some terrain-based definition of scale. We apply this method to the extraction of measures of hillslope height, which determines potential energy along valley flanks, thus being a first-order control on most geomorphic processes. Together with local relief, hillslope height is a measure of potential release of topographic stress following processes of crustal unloading, and sets the boundary conditions for numerous surface processes.

The key problem is that measures of both local relief and hillslope height are commonly derived using a fixed horizontal length scale (Ahnhert, 1984; Montgomery and Greenberg, 2000). This does not take into account the variability in topographic wavelength set mainly by geology and drainage density. Thus, such measures implicitly rely on a large enough sampling radius to sufficiently capture the full, or at least characteristic, bandwidth of local relief within a given area. This depends in turn on the scale of the landform to be investigated.

We introduce our method for defining scale within a profile, before applying it to the extraction of hillslope height and compare values derived on the basis of a fixed horizontal length scale. Finally, we briefly discuss the implications of these preliminary results.

2. Methodology

Our aim was to develop a method which could be applied easily to large numbers of 1D profiles of elevation, for example derived across a mountain belt, in order to qualitatively and quantitatively describe such profiles and derive populations on which statistical tests could be performed. The use of such profiles is still commonplace in geomorphology, but analysis techniques remain relatively simple.

Given a profile with values ($z_1, z_2, \ldots z_n$) then this profile can be hierarchically subdivided into a set of sub-profiles based on some given criteria. Any parameter that can be derived for the initial profile can also be calculated for a given sub-profile, as long as the profile length is longer than the horizontal length scale required to calculate the parameter.

We define hillslope height at a given point on a profile as its height above the valley floor, that is

$$hs_i = z_i - \min(z_k,\ k \in \{a,\ldots,b\})$$

where hs_i is the hillslope height of element i
z_i is the elevation of element i
and z_k is height of element k in the profile lying between elements a and b.

The maximum value of hillslope height is therefore the difference between the maximum and minimum elevation in a profile. Thus, the first possible subdivision of a profile is located at the peak within the profile which has the highest value of elevation of any local maximum within the profile. Hillslope height is then calculated with respect to the global minima to the left and right of this local maximum.

Since profiles consist of discrete elevation values, local maxima are defined as points where $z_{i-1} < z_i > z_{i+1}$. If $z_{i-1} = z_i$ or $z_i = z_{i+1}$ then the condition is extended leftwards or rightwards in the profile respectively. Furthermore, profiles are smoothed before searching for local maxima to minimise the number of spurious peaks identified within the profile.

We calculated local relief at different scales as a function of varying window sizes, where the local relief was defined as the difference between the maximum and minimum values of elevation within the sampling window. Slope was defined as the magnitude of the first derivative of elevation, calculated by a centred finite difference scheme.

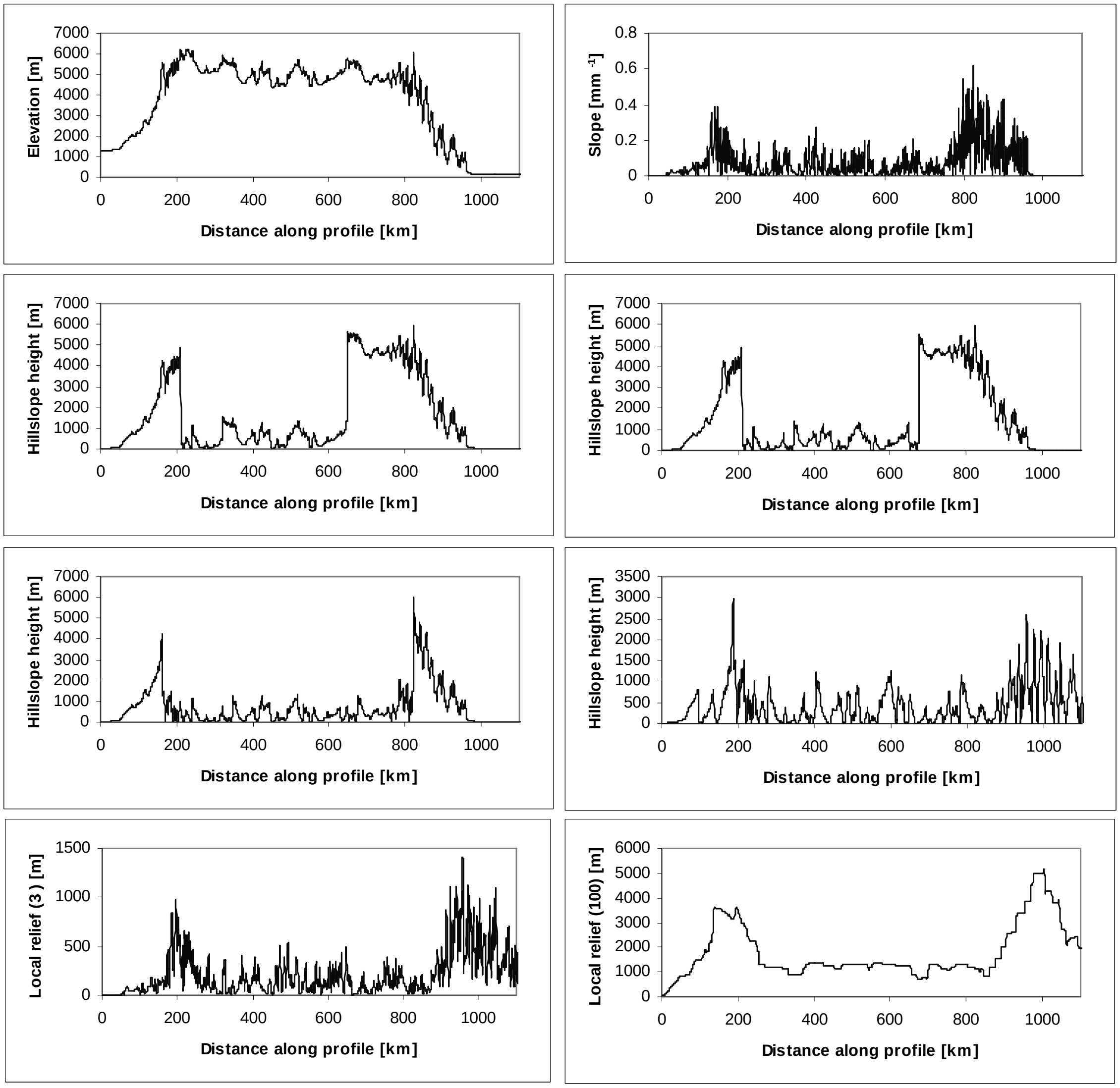

Figure 1: Elevation, slope, hillslope height and local relief profiles. Hillslope heights for profiles defined by the highest 5, 10, 20 and 45 peaks respectively. Local relief for a 3 cell and 101 cell window

3. Results

Results for a range of parameters (elevation, gradient, hillslope height, local relief) are illustrated here for a profile derived in a north-south direction from the Tarim Basin across the Tibetan Plateau and Himalayas to the Bengal foreland (Figure 1), at a resolution of ~860m. The profile was selected to lie perpendicular to the main mountain belt. The variation of hillslope height with the number of peaks used as a reference highlights the hierarchy of the terrain, dominated by two high-relief mountain belts flanking a low-relief high plateau. Despite a similar regional pattern, local hillslope height for 45 peaks does not correlate well with mean local relief derived from a moving window with a fixed sampling radius (Table 1).

	Elevation	**Slope**	**Hillslope height (5)**	**Hillslope height (10)**	**Hillslope height (20)**	**Hillslope height (45)**	**Local relief (3)**	**Local relief (101)**
Elevation	1.00	0.21	0.41	0.34	0.12	0.28	0.23	0.20
Slope		1.00	0.44	0.46	0.55	0.53	0.92	0.64
Hillslope height (5)			1.00	0.90	0.45	0.47	0.48	0.48
Hillslope height (10)				1.00	0.51	0.52	0.51	0.53
Hillslope height (20)					1.00	0.78	0.61	0.81
Hillslope height (45)						1.00	0.58	0.61
Local relief (3)							1.00	0.71
Local relief (101)								1.00

Table 1: Pearson correlations (r) for series shown in Figure 1

4. Discussion

Scale is *the* crucial issue in topographic analysis. We suggest that our method provides a more detailed and hierarchically structured, yet objective, view of topography than is possible from applying commonplace moving-window approaches. This is chiefly because the method quantifies relief as a nested function of local elevation maxima in the terrain. Thus, this method of detection is not susceptible to the averaging effects that are clearly visible in the local relief values calculated for large window sizes as shown in Figure 1.

There are several geomorphologic applications in this regard, as the method conserves information on both the horizontal and vertical pattern of topography. Hence, the length scale of landforms can be delineated and measured. For instance, the width of the Tibetan plateau can be readily extracted as the horizontal distance between the two points with the highest hillslope height along the profile in Figure 1. Using repeat measurements along parallel profile lines could thus aid regional-scale landform delineation.

In the vertical dimension, values of hillslope height derived for low values in the peak ordering provide values of the absolute relief of the Tibetan plateau. Comparable values are not usually given by other methods, as they are limited to (local) variations of a fixed length scale only. Thus, the method allows objective detection of the position and size of the deepest valleys, i.e. where local hillslope height is at a maximum.

However, it is important to note that in order to be geomorphologically meaningful, our method still requires qualitative interpretation based on knowledge of the landscape and, ideally, comparison with additional data on processes that contributed to shape the landscape in question.

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Biography

Ross Purves is a lecturer in GIScience at the University of Zurich.

A Computer-aided Method for Paper Chart Correction

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1. Introduction

For the safety of navigation, the chart must be accurate and new. But this is not the only matter. The published charts have to be updated by small corrections to keep them the newest to the changes in real world. The small corrections are usually implemented manually by the users according to the directions in "Notice to Mariners". A typical way to correct paper charts is like this:
a) The correct or new chart representation(symbols, lines, texts, etc.) is drawn manually onto a medium, usually a piece of transparent paper;
b) Many copies of the medium will be made, still onto pieces of transparent paper;
c) Each of the copies will be attached to a Notice to Mariners and sent by mail to a sales agent or end user of the charts;
d) The correction will be finished manually by the agent or end user according to the new chart presentation on the transparent paper and instructions in Notice to Mariners.

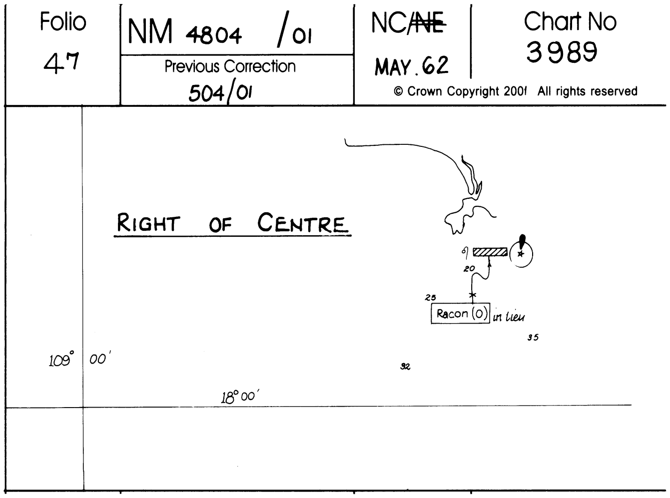


Figure 1. Transparent paper used for small correction

It has been a long dream of the chart publishers and mariners to implement the corrections by the computer automatically. Nevertheless, this problem is so complicated and difficult that no obvious improvement has been reported or seen until our system came into practical use.

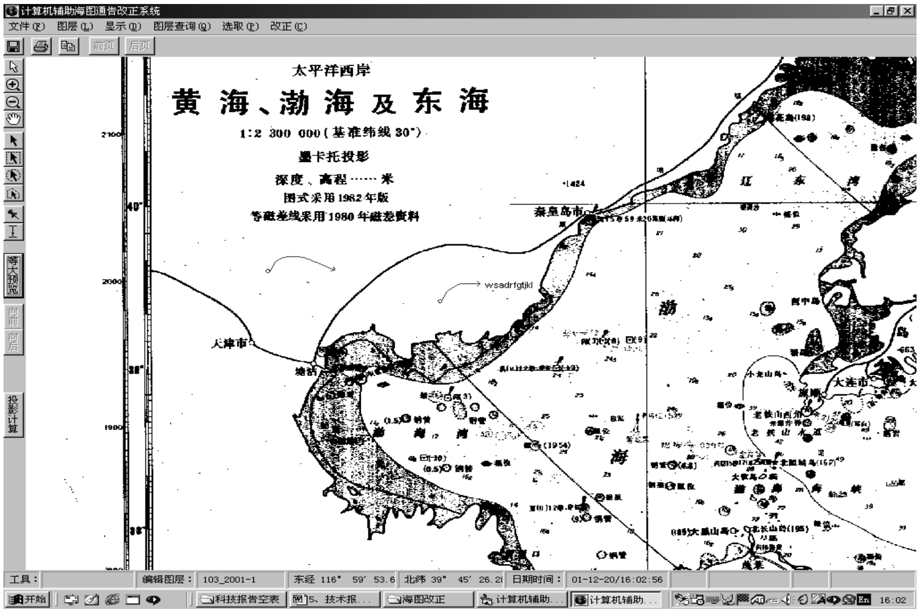
2. System Design

The computer-aided paper chart correction system was developed on the support of MapX controls and VB6.0. It is composed of these modules:

a) Chart mathematical elements processing module;
b) Chart symbol display/drawing module;
c) Related-charts automatic correction module;
d) The printing/output module.

A control file named “index.ok” is used to record the necessary information for each of the correction figures. The contents of the control file include sheet number, sheet name, scale, projection, fundamental latitude, border, etc.

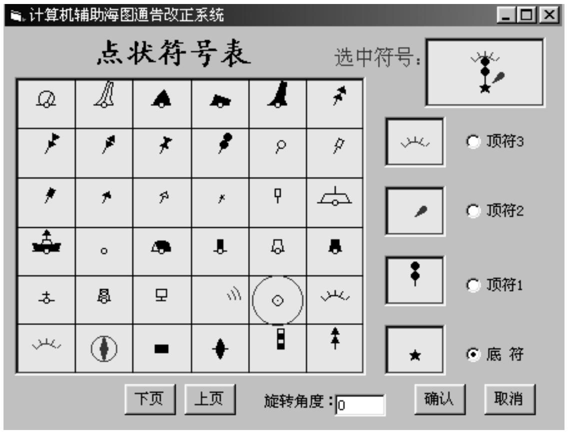
The chart mathematical elements processing module is one of the most important module of the system. It is designed to establish a satisfactory mathematical basis according to chart projection, based on the equi-distant cylindrical projection grid, which the MapX controls provide, so as to achieve the high precision of correction.



工具：
编辑图层：103_2001-1
东经 116° 59′ 53.6
北纬 39° 45′ 26.2
日期时间：01-12-20/16:02:56

Figure 2. The main interface of the system

The chart symbol display/drawing module is designed in a way that symbols can be freely assembled by the user by means of providing tools to generate and parts of the symbols. This module provides a new method to display/drawing the chart symbol, which could improve the efficiency of this intractable work geminately.



○ 顶符3
○ 顶符2
○ 顶符1
● 底 符
旋转角度：0

Figure 3. Interface to select symbol by free assembling

● 限制区界线
○ 锚地边线
○ 海底电缆
○ 海底管道
○ 鱼栅
○ 鱼礁
○ 渔堰
○ 废海底电缆
○ 改正偏移符号

线、面符选择
● 线 ○ 面

线、面符式样
● 折线
○ 曲线
○ 圆

Figure 4. Interface to select line styles

The related-charts auto-correction module finds the charts covering the same sea-area at different scale and corrects them in a run. The final result of calculation and manipulation will be printed/output by the printing/output module through a common stylus printer (or a special printer) onto pieces of stencil paper (transparent paper), which will then be sent to the sales agents and end users. The stencil paper will then be used to print the correction presentation onto the paper chart, successfully avoided the burdensome work of correcting the paper chart manually.

3. Tests and Conclusions

Once the system developed, we have tested it for many charts, both as a single sheet and as one of a chart series. The precision of correction on paper chart was also evaluated. The result shows that the position error is under 0.3mm; the printed figures and texts is clear enough to satisfy the requirements of national specifications and the needs of the user; the time consumed is less than current methods and independent of the chart complexity. Perhaps the only limitation to its spread is the steadiness of the stencil paper.

The main advantages and technical progress of the system includes:
a) The progress of correction method from manual to computer-aided, which makes the work more efficiently;
b) Providing positioning frame which is exactly the same to the corrected chart's geographical grid of latitude and longitude, at the same time when printing the chart presentation to correct;
c) The improved efficiency and ease of paper chart correction in time consumed;
d) The help to the standardization and regulation of chart correction;
e) The help to the personnel training by decreasing the work complicacy;
f) The new correction method by printing the correct or new chart presentation to stencil papers by a common stylus printer;
g) The related charts can be corrected in a bunch.

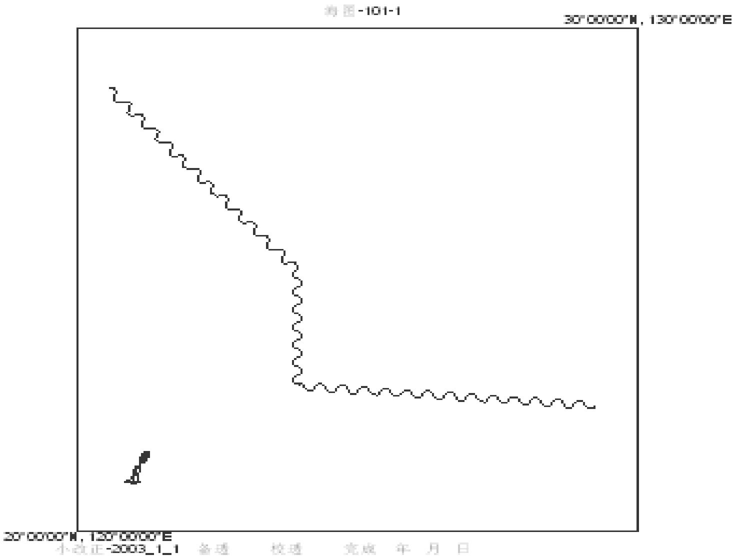


Figure5. The sample of the printed figures

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R. C. PENG, L. X. GUO, Z. P. CHEN, 2005, The Overview of Methods on Digital Chart Updating. Marine Technology, 2, pp. 35-37.

Biography

PENG Rencan, professor, Ph.D, Ph.D supervisor, majors in the theories and methods of charting, the development and application of military oceanic geographical information system, and the high precision models and methods of oceanic delimitation based on the earth ellipsoid.

Royal Geographical Society
with IBG

Quantitative Methods
Research Group

Involved with geographical data analysis?

The Quantitative Methods Research Group (QMRG) is a study group of the Royal Geographical Society with the Institute of British Geographers (RGS-IBG). For over thirty years we have existed to promote the application of quantitative methods in Geography and related sciences.

Our interests are in spatial statistics and spatial modelling as well as research on technological areas such as geocomputation, GIS and remote sensing.

We exist as a not-for-profit organisation, for the benefit of our members. We are committed to supporting students in their research, offering bursaries to conferences such as GISRUK and organising an annual ‘best dissertation’ prize in quantitative geography.

Membership is free for members of the Royal Geographical Society (with IBG). A nominal fee is charged for non-members.

To find out more, please see our website at http://www.casa.ucl.ac.uk/QMRG/, join our mailing list at www.jiscmail.ac.uk/quant-geog or contact orfords@cf.ac.uk.