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Geographic information systems for the public health sector: a proposal for the research agenda

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Summary – Geographic information systems (GIS) are increasingly being used worldwide for the monitoring of important public health issues, proving its potential as a powerful tool in decision making. Studies on GIS in epidemiological studies for large areas is well documented, while other GIS in health applications are restrained due to a current lack of coordination and communication within public health authorities and research networks. To overcome the mentioned constraint, the project described in this paper aims to establish a research agenda for the use of GIS in public health, in the Australian context.

geographic information systems / public health / research agenda / Australia

Introduction

The health sector has been recognized internationally as one area of the potential new applications of geographic technologies [1]. Several groups in Australia and worldwide have been working with the application of geospatial information and geographic information systems (GIS) to aspects of health [2–4].

Since new applications need to address and solve issues that have not necessarily been considered or were not relevant to other applications with a longer tradition in GIS, this research agenda contributes to a more global research agenda on GIS.

Detailed here are the outcomes of the 'Research Agenda for Geographic Information Systems and Health' project carried out at The University of Melbourne, Australia.

A description of the project of a research agenda provides a summary of the major issues in need of discussion and research in the application of GIS to the Australian health sector to date, as perceived by the major stakeholders. The authors consider the issues most able to contribute to strengthening the future use of geospatial information in health service planning and service delivery.

The body of what has been identified as important to a future research agenda has emerged from a consultative process. In particular, this includes the Second Symposium on GIS and Health, 'Developments in the Application of Geographic Information Systems within the Health Sector' [5]; and a workshop on 'GIS in Public Health Research' held in June 1998. Both forums were attended by key public health, research, industry, government and education professionals from interstate and overseas, known to be interested and involved in projects of a GIS and health nature.

Background to the application of GIS

GIS is increasingly being recognized as having the potential to improve population health [6] and contribute to policy development, implementation, and research in public health [7]. Indeed, the World Health Organization has noted that: "geographical information systems are of value in the compilation and presentation of data at national and region-wide levels, particularly environmental data and health outcome data related to the impact and use of health services [8]."

Initially used in sectors such as natural resources, land management, and more recently marketing and others, a GIS is an organized system of hardware, software, geographic data, and people that is designed to efficiently capture, store, update, analyze, and display all forms of geographically referenced information [9]. The two types of information in a GIS are spatial information, which describes the location and size of geographic features (as well as topological relationships), and descriptive information, which characterizes the geographic feature itself [10]. User-friendly Windows-based software and Pentium computer technology have more recently made GIS tools much more accessible than in the past.

The application of GIS in health research is occurring worldwide in many areas: modeling the location of new services, children's health, injury, cancer, environmental health, just to name a few. GIS has begun to be used across the Australian health sector to study equity in the provision of services for the elderly [11], sociodemographic distribution [12], and service characteristics and usage [13, 14]. While able to take advantage to some degree from overseas research, these benefits are unable to be fully realized here due to a number of factors unique to Australia [15] and limited Australian experience, highlighting the need for locally-based research yet simultaneously building and maintaining international links.

Australian governments are increasingly recognizing the need to improve spatial information and the services that relate to this kind of information with the introduction of policies for information technology uptake. In the state of Victoria, for example, an increasing amount of government data is being made available on-line through Land Channel [16], Better Health Channel [17], and Business Channel [18].

The use of geospatial information in the health sector is still evolving, and the mechanisms of delivering information continue to be re-defined [19].

Research agenda objectives

Identification of three basic circumstances gave rise to the development of a research agenda for GIS in the health sector. These are: 1) the recognition of GIS as a valuable tool for policy making, implementation, and research in public health; 2) the emergence of GIS in the health sector in an uncoordinated way, giving rise to the need for greater communication and coordination; 3) unsolved institutional, legal, and technical issues.

The central goal of this research project was to harness international and national expertise in the under-researched fields of geospatial health analysis in order to develop a research strategy for area-based health analysis. Specifically the objectives were: 1) to evaluate and review international research themes and directions, where outcomes and processes have relevance and potential for further development in Australia, appropriate to the health of populations; 2) to bring together the state-of-the-art knowledge and expertise of researchers working with population demographics, GIS, and health data by way of national and international collaboration; 3) to establish

mechanisms for on-going national and international linkages for the enhancement of research into this field.

The potential benefits to be gained from a GIS research agenda for the health sector have been identified throughout this project as: reduction in costly duplication of research issues; greater coordination and improved links between research, education, policy and service delivery; improvement of health sector understanding of the use of geospatial information and of the benefits to public health of its use, where there is currently little or no understanding; and linkage of organisations with complementary strengths to provide more comprehensive interchange and research opportunities and to strengthen the performance of one another's roles.

The agenda

The need for research to be guided by specific issues emerged during this project. Rather than being exhaustive, the issues that follow are illustrative of current deficiencies or unexplored aspects of GIS in health in Australia. The most significant deficits in the current research cover a broad range and emanate from both the health and geospatial sectors. Collectively, they highlight the need for the flow of information between state and commonwealth governments, centers of research, and practice-based participants where relevant.

Confidentiality

Today there is tension between the society's demand for more and more accurate information and the individuals' rights to preserve their privacy. The vast majority of health-related databases has grown from information collected from individuals and groups. The importance of maintaining people's privacy in the use of these data cannot be underestimated and it is generally well accepted that the intention should be to ensure the minimization of any potential harm to people. Traditional techniques of preserving confidentiality, such as aggregation of data, are useful, especially where the data are constituted in discreet, spatial units. Point-based health data are considered superior to area health data, however, for their ability to be geocoded [2]. This raises the question of the use of individual point data in Australia, an issue yet to be resolved. Although more recent techniques of masking individual data, such as random perturbation, have been explored overseas [20], they have not been attempted in Australian conditions. There is scope for the trial of these methods, in consultation with consumer representatives and data custodians.

Data integration

GIS allows data from a range of different sources to be integrated into a unique system. When these data have their origins in diverse environments, several problems are likely to emerge. Differences in data collection routines, data standards, data formats, and spatial scales could make the integration process a difficult task, as many of the 1998 Symposium participants confirmed.

The authors are particularly concerned with the problem of incompatible spatial units. As a consequence, methods are beginning to be investigated that can homogenize the various administrative boundaries to which health data are attached. These boundaries are, in most countries, non-coterminous, which makes the application of cross-analysis techniques difficult.

It is noted that a lack of hierarchically organized boundaries restrains the use of GIS [21]. Recognition of the need to develop and promulgate 'a set of national geographical boundaries, identifiers and aggregations for use in all population-based health data collections and surveys and a mechanism for coding current historical address information to this classification' has been acknowledged in the Australia's National Public Health Information Development Plan (NPHP) [22]. The development of a new model of administrative boundaries based on Spatial Hierarchical Reasoning [23] will contribute to the integration of the data sets to which each agency is custodian.

The concept of a spatial hierarchy was debated during the course of this research. Spatial hierarchy is one of the most common forms of organizing and structuring complex systems. In the past, high priority has been given to research on Spatial Information Theory that investigates the conceptual hierarchy of space and spatial phenomena. It is an issue that has been articulated by all users of GIS, not only in the health sector. The spatial hierarchy issue is being examined by the Geospatial Information Reference Group (GIRG) [24], convened by the Victorian state government, to advise on issues related to the development and use of geospatial information. Research initiatives to address spatial hierarchy include work done by Eagleson et al. [25].

Metadata

The number of databases relevant to the public health of populations and individuals are multitudinous. The Victorian government is attempting to establish common metadata (data about data) for all departments and databases in recognition of the large amounts of good quality data in Victoria. This will permit better access to useful descriptions of what is available. The implementation of engines, standards, and visual display for metadata is currently undertaken by a significant number of research projects worldwide [26].

Access to data

After two decades of use of GIS, there are still many unsolved issues about access to data. The first question is 'Does data exist?' The answer is more often in the affirmative, giving rise to additional questions: 'Who are the custodians?', 'What is the price?', 'It is there any pricing policy?', and 'What are the channels for access to data such as the Internet?' Research is needed to examine how government information policies affect the access to, and use of, data by a broad spectrum of public and private sector stakeholders for a variety of public and private purposes.

Data quality

Quality data is essential in a GIS for a number of reasons. It allows for the interchange of data, it ensures credibility of the data, it maximizes efficiency by permitting faster system development and it improves decision making by the information users. Many data are not routinely collected, or are collected in a random, unsystematic way. This leads to errors including positional errors, attribute errors, logical consistency, and completeness [27]. Extensive differences in data collection techniques, both within the health sector and cross-sectorally, currently create enormous difficulties for the integration of data in a common system for GIS. As an example, one of the biggest gaps in health data is morbidity and treatment data by geographic location, specifically at the individual practice level which, in a GIS environment, could be represented as point data. The application of GIS in the health sector requires a revision in the way that data are collected, used, and displayed. Procedures to collect, deliver, and summarize data are in need of further work.

Ensuring that the data within a GIS are current is an important issue in all GIS-related projects. In order for an implemented GIS to be of value, regular updating is required. Mechanisms to customize the collection and integration of new data into an information system are under investigation [28]. For the health sector, however, where GIS has only recently been introduced, methods of regularly updating health data sets are in need of exploration.

Use of qualitative data

Consideration needs to be given to ways in which qualitative health data, that include lay perceptions of health and illness and the 'lived' or socially experienced dimension of health [29] can begin to be incorporated into a GIS framework. Both the National Center for Geographic Information and Analysis (NCGIA) and the University Consortium for Geographic Information Science (UCGIS) have highlighted the issue of cognitive information and reasoning within GIS. Aspects such as personal preferences, perception of services and cognitive distances have not yet been incorporated successfully in a GIS environment but are important for adequate planning policies.

The UCGIS has been working intensively on the issue of cognition for many years. This organization stated that "it has become clear that an understanding of certain aspects of human cognition is essential if future geographic information technologies are to realise their full potential as tools in the service of human decision making [30]."

Organizational support

One of the components of a GIS is people; however, little work has been carried out on what new users of GIS require in relation to education, training, and on-going support. Organizations and individuals in the health sector for whom GIS is a new tool should be of particular interest. One evaluation research project examining the introduction of a GIS in a primary health setting of general practice has found that the issues of organizational framework and technology transfer require careful consideration [31]. Preparation and on-going support of staff appear to substantially influence the use of the GIS present [32], though follow-up work is needed to investigate more widespread adoption of information technologies such as GIS.

If the health sector is to take up the use of geospatial information on a broader scale, it would be advantageous for planning and budgeting purposes to have a sound knowledge of the support that organisations need to provide as well as what recipient organizations may need in an on-going capacity.

Education in GIS and health

In order to advance GIS in the public health sector, consideration needs to be given to the integration of the instruction of GIS into curricula of public health schools through geography programs, geomatics, and computer science courses. A worthy body of GIS education already exists within Australia and overseas that could be adapted to a new set of demands. A range of initiatives to incorporate GIS in secondary school curricula is underway in the United States. Education could be promoted through formal and informal learning opportunities, part-time options, distance learning and workshops and needs to include basic information technology and health geography [10].

Partnerships

Strategic alliances are necessary when bringing a new technology into a new sector. Although the problem of connectivity related to developing and managing multisectoral research has been identified by Australia's National Public Health Partnership

[22], this has not been the experience of many of those who are working in the health and geospatial sectors.

Real outcomes have emerged from those projects in GIS and health that have used cross-sectoral and intra-sectoral partnerships within Australian and overseas. The concept of partnership also applies to the different agencies that deal with health services and GIS respectively. Links between local, state, and national government jurisdictions have been established, yet this communication needs to be modeled and coordinated in a way that maximizes these associations and harnesses the potential for work to continue between partners.

The importance of a high level of communication and cooperation between the health and non-health sector, has been acknowledged in the National Public Health Information Development Plan [22] and endorsed by the Australian Health Ministers' Advisory Council.

The problem of fragmentation, also identified by the NPHP as a barrier to public health research and development [22] and largely due to geographic and jurisdictional reasons, has emerged during the consultation phase of this project. Valuable and valued links have been developed across the two sectors in question, with geography not necessarily a perceived barrier. However, there was consensus that agencies needed some support to prevent communication from becoming random and to enhance information sharing in an Australian context, given that there is no one body or infrastructure to take a leadership role and represent these issues. This could take place either by way of regular cross-sectoral forums and/or electronic discussion groups for those who work in a common area albeit in different settings.

Time and GIS

Temporal data are crucial to understanding health issues. However, GIS as a tool to manage geospatial information still has problems in analyzing and managing temporal data.

The NCGIA has listed this issue in its Research Initiative 10: Spatio-Temporal. "The objectives of this initiative are to:

- study spatial applications to identify properties of different time concepts such as continuous, discrete, monotonic, and cyclic;
- explore alternative mathematical formalizations to Cartesian coordinates and Euclidean geometry, which represent spatial and temporal reasoning processes better;
- formalize human reasoning processes about geographic space and time;
- build computational frameworks within which geographic phenomena and processes, and their temporal changes can be simulated;
- examine computational reasoning methods with observations from human subject experiments about human spatial and temporal perception and cognition [33]."

In this context, at GEOMED'99, Mark presented a research project that is "developing and testing tools and procedures for spatio-temporal analysis of environmental health data in a GIS framework [34]."

Distributed computing

As the UCGIS states, "digital technology is moving rapidly to distributed computing. It is now possible for parts of a database to be stored and maintained at different locations; for users to take advantage of economical or specialized processing at remote sites; for decision makers in collaborate across computer networks to making decisions; or for large archives to offer access to their data to anyone connected to the Internet [30]."

To be able to integrate datasets from different agencies, custom interfaces are needed to communicate between software across multiple operating systems, networks, and architectures.

These new possibilities and issues are currently under investigation by sectors related to librarians, cadastral information experts, and geographers to name a few, but they have not yet been fully explored in the health sector.

Facilitating research transfer

The practice of disseminating research results is becoming more widely integrated into responsible research practice in the health sector and is frequently now a consideration at the project development stage. Results of research, both successful and unsuccessful, that emanate from health and geospatial research, need to be disseminated to the community which has participated in the researchs and to the community for which the research is intended. Improved cross-sectoral channels of communication would facilitate the transfer of research results by widening the audience beyond individual professional groups and beyond even multidisciplinary groups within each sector. This would permit opportunities for discussion on the action needed on the results and implications of the research, both of which could assist in reducing the gap between research and practice and between different jurisdictions.

Conclusion

GIS has already been shown to be a useful tool for data storage, analysis, and presentation in other sectors. Demands for data and data management are growing rapidly in Australia. More widespread interest in the potential of GIS in the health sector has emerged in recent years, for its ability to meet immediate, operational needs and to assist in decision support.

This report summarizes the gaps in knowledge and skills identified by those interest groups at the intersection of the health and geospatial sectors, currently an area of underdeveloped research. It attempts to identify the action that is needed to improve the application of GIS to the health sector, with the ultimate enhancement of planning, service delivery, and evaluation of programs. The issues most able to contribute to strengthening the future use of geospatial information in health service planning and service delivery have been considered.

A number of the aforementioned mechanisms are required in order for the potential of GIS to be attained in the health sector. These may be overcome, at least in part, by improved coordination, communication and multidisciplinary collaboration. Existing processes can contribute to the realisation of these research issues, however; additional resources will be required to initiate on-going research in a more sustained and widespread capacity.

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References

1 Stakeholder Statement on the NIMA Geospatial Information Infrastructure Plan (GII Master Plan V. 0.21); 14 May 1997; University Consortium for Geographic Information Science; (www.ucgis.org/fNIMA.html).

2 The University of Iowa. Improving public health through geographical information systems: an instructional guide to major concepts and their implementation, CD-ROM version 2.5; 1997.

3 Escobar F, Williamson I, Waters E, Green J. Adding dimensions to information: GIS for the divisions of general practice setting. In: Proceedings of AURISA '98; 23-27 November; Perth, Western Australia. CD-ROM; 1998.

4 Gatrell AG, Loytonen M, eds. GIS and health. London; Philadelphia, PA: Taylor & Francis; 1998.

5 Department of Geomatics, Second Symposium on GIS and Health 'Developments in the Application of Geographic Information Systems within the Health Sector'; 10 June 1998; Melbourne; (www.geom.unimelb.edu.au/HealthGIS98).

6 Bertrand W, Mock N. Spatial information to make a difference: value added decision-making in the health sector with geographical information systems. In: De Lepper M, Scholten H, Stern R, eds., the added value of geographical information systems in public and environmental health, 1995. Dordrecht, The Netherlands: Kluwer Academic Publishers; 1996. p. 265-76.

7 Scholten H. Development of a health and environment Geographical Information System for the European region. GISDATA specialist meeting on GIS and health; Helsinki; 29 May-June 1996.

8 World Health Organization. Consultation on a European environmental health database; 22-25 November 1988; Berlin. Cited by Scholten. Development of a health and environment Geographical Iinformation System for the European region, GISDATA specialist meeting on GIS and health; Helsinki; 29 May-June 1996.

9 Briggs D, Elliott P. The use of geographical information systems in studies on environment and health. World Health Stat Q, 1995 ; 48 : 85-94.

10 Henriques W. 'Introduction to Geographic Information Systems for Public Health Protection', lecture, Agency for Toxic Substance and Disease Registry, Atlanta, Georgia, USA, 1998.

11 Hugo G, Ambagtsheer R. 'GIS, equity and provision of services for a sub group: the example of residential care for the elderly in Adelaide', Second Symposium for GIS in Health, University of Melbourne; http://www.sli.unimelb.edu.au/HealthGIS98/presentations 1998.

12 Glover, J. GIS for health in Australia without the building blocks; are we missing the point?, Second Symposium on GIS in Health, University of Melbourne; http:www.sli.unimelb.edu.au/HealthGIS98/presentations, 1998.

13 Ambagtsheer, R. The social health atlas of young South Australians: monitoring the spatial distribution of health and welfare amongst South Australian children and youth. In: Ninth National Conference of the Australian Population Association; University of Queensland, St. Lucia; 29 September-2 October 1998.

14 Escobar F, Williamson I, Waters E, Green J. The Use of the Internet in the diffusion of GIS for general practices in Victoria, Australia. In: INET'98 Conference; Geneva, July 1998.

15 O'Dwyer L, Burton D.. Potential meets reality: GIS and public health research in Australia. Austr N Z J of Public Health 1998 ; 22 (7) : 819-23.

16 Land Channel, Department of Natural Resources and Environment, Victoria State Government; www.land.vic.gov.au/web/root/domino/cm_da/Lcnlc.nsf/frameset/i_framesetLand Channel.

17 Better Health Channel, Department of Human Services, Victoria State Government; http://www.betterhealth.vic.gov.au/.

18 Business Channel, Victoria State Government; http://www.business.channel.vic.gov.au/.

19 Department of Natural Resources & Environment, Victoria's Geospatial Information Strategic Plan, Land Victoria, 1997.

20 Armstrong, MP, Rushton G, Zimmerman DL. Geographically masking health data to preserve confidentiality. Stat Med 1999 ; 18 (5) : 497-525.
21 Escobar F, Eagleson S, Williamson P. Posibilidades del Razonamiento Espacial Jerárquico en la reorganización de límites administrativos empleando Sistemas de Información Geográfica (SIG), In: Seminario Internacional de Ingeniería "La Ingeniería y la Sociedad del Futuro en el Umbral del Siglo XXI", Bogotá, 18-20 August 1999.
22 Australian Institute of Health and Welfare and National Public Health Partnership, National Public Health Information Development Plan, Australian Institute of Health and Welfare, AIHW Cat. No. HWI 22, 1999.
23 Car A. Hierarchical spatial reasoning: theoretical consideration and its application to modeling wayfinding [PhD thesis]. Vienna: Department of Geoinformation, Technical University; 1999.
24 Geospatial Information Reference Group; http://www.gisconnections.vic.gov.au/content/girg.
25 Eagleson S, Escobar F, Williamson I. Spatial hierarchical reasoning applied to administration boundary design using GIS. In: 6th South East Asian Surveyors Congress; Fremantle; 1-6 November 1999.
26 Polley I, Williamson I, Effenberg W. Suitability of Internet technologies for access, transmission and updating digital cadastral databases on the Web. In: Proceedings of AURISA 97; Christchurch; 17-21 November 1997. 12 pp.
27 Hunter G. Dealing with accuracy and data quality in GIS. In: Proceedings of the 2nd GIS Asia Pacific Conference; Kuala Lumpur, Malaysia; 18-20 September 1996. 7 pp. (published on diskette).
28 Falzon K, Williamson I. Digital lodgement of cadastral survey data in Victoria. In: Proceedings of the 39th Australian Surveyors Congress; Launceston, Tasmania; 8-13 November 1998. p. 339-55.
29 Janes C, Stall R, Gifford S, eds. Anthropology and epidemiology. Dordrecht: Reidel; 1986.
30 University Consortium for Geographic Information Science; www.ncgia.ucsb.edu/other/ucgis/CAGIS.html.
31 Centre for Community Child Health, University of Melbourne, Royal Children's Hospital. Evaluating a Geographic Information System in divisions of general practice. A general practice evaluation program project grant; February-September 1999.
32 Green J, Escobar F, Waters E, Sneddon J. Geospatial information in the general practice sector; development and evaluation of a Geographic Information System. Volume 1. Telehealth International; 2000.
33 NCGIA Research Initiative 10: Spatio-Temporal Reasoning in GIS; http://www.spatial.maine.edu/~maxi/i10.html.
34 Mark D et al. Spatio-temporal GIS analysis for environmental health using geospatial lifelines. In: Geomed'99, Paris, November 1999 [abstracts].