Web-based geo-visualisation of spatial information to support evidence based health policy

Abstract

Place is of critical importance to health as it can reveal patterns of disease spread and clustering, associations with risk factors, and areas with greatest need for, or least access to health care services and promotion activities. Furthermore, in order to get a good understanding of the health status and needs of a particular area a broad range of data are required which can often be difficult and time consuming to obtain and collate. This process has been expedited by bringing together multiple data sources and making them available in an online geo-visualisation, *HealthTracks,* that consists of a mapping and reporting component. The overall aim of the *HealthTracks* project is to make spatial health information more accessible to policymakers, analysts, planners and program managers to inform decision-making across the Department of Health Western Australia. Preliminary mapping and reporting applications were developed that have been utilised to inform service planning, increased awareness of the utility of spatial information and improved efficiency in data access. The future for *HealthTracks* involves expanding the range of data available and developing new analytical capabilities in order to work towards providing external agencies, researchers and eventually the general public access to rich local area spatial data.

Keywords: public health informatics; evidence-based health care; access to information; geographic mapping

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Introduction

Providing analysts and decision-makers with timely access to reliable epidemiological, social demographic measures and environmental health measures at a high spatial resolution is a key priority to facilitate evidence-based decision-making (Brownson, Fielding & Maylahn 2009; Gudes et al. 2010; Jacobs et al. 2012). Australia is one of the few countries that have comprehensive, high quality, datasets on many aspects of health measures, service utilisation and environmental health that contain spatial information (address or at least postcode) that can be geo-coded such as deaths, hospitalisations, community mental health occasions of service, cancer incidence, communicable disease notifications and air and water quality testing. However, the value of such datasets is only realised when they are used to inform evidence-based decision-making, policy development and research (Brownson, Fielding & Maylahn 2009). Visualisation of spatial health data offers a powerful tool for knowledge translation and decision support within health service agencies (Driedger et al. 2007; Schuurman, Leight & Berube 2008).

Mapping of health data has a long history in the form of static, pre-rendered maps and atlases (Cromley 2003; Evans & Sabel 2012). Traditionally, broad level government reports of individual datasets were routinely produced at specified time intervals (e.g., state level annual reports) and static maps generated by a limited number of analysts trained in the use of Geographical Information Systems (GIS) desktop software, thus wide-spread adoption of spatial information by decision-makers has generally been limited (Joyce 2009). However, with recent advances in web-mapping capabilities and the availability of online data, timely access to customised reports and maps of health information at a detailed spatial resolution can now be easily provided to health professionals and decision-makers (Croner 2003; Evans and Sabel 2012; Friedman et a. 2013; Gao et al. 2008; Studnicki and Fisher 2013). Online mapping and analytical processing can provide a broad range of data and analytical tools for analysis, visualisation, modelling and planning without the need for expensive software and technical expertise (Kamadjeu & Tolentino 2006), and such interactive mapping tools have been demonstrated to be more useful and preferred by public health professionals over statics maps for comparing health outcomes and risk factors (Cinnamon et al. 2009).

Internationally, many online tools have been developed for specific disease outcomes or single health care services (Foley et al. 2010; MacEachren et al. 2008; Rinner et al. 2011; Shuai et al. 2006). However, the issues facing health and health care are complex and there is a growing need for tools that support the construction of knowledge from relevant, comprehensive, high quality and easy to interpret evidence to inform health policy (Bhowmick et al. 2008a; Dummer 2008; Gudes et al. 2010). The primary advantage of geospatial data is the ability to integrate, visualise and interrogate a wide range of data sources such as health outcomes, social demographic measures, risk factor prevalence and health service utilisation. Furthermore, the role of small area, multidisciplinary local community health networks is increasing in Australia, as is the requirement for outcomes-based performance measurement at local public health unit level, thus intensifying the need for access to cross sectoral health, environment and demographic data at the local level (Baum et al. 2010; Gudes et al. 2010; Medicare Locals 2013; National Health Performance Authority 2013; Studnicki et al. 2010).

In order to get a comprehensive understanding of the health status and needs of a particular area, a broad range of health, environmental, demographic and other information is required, that can often be difficult and time consuming to obtain and collate (Nutley & Reynolds 2013). Online geovisualisation tools hold the promise of facilitating investigation of a broad range of large and complex datasets rapidly (Studnicki et al. 2010); for example, an investigation into the varying contribution of community demographic composition within a defined region on multiple outcomes such as hospital separations, deaths, cancer incidence and communicable disease notifications. Other examples of the utility of spatial health data include disease surveillance and cluster detection; health service utilisation, needs, and resource allocation; investigation of health determinates and risk factor associations; and understanding inequalities in health outcomes and access to services (Boulos 2004; Cromley 2003; Gudes et al. 2010).

Insights from published evaluations of online health geospatial tools

More than 35 state health departments in the United States have implemented a web-based data query system containing one or more health datasets (National Association for Public Health Statistics and Information Systems 2012). A review in 2005 showed that all systems allowed users to query data by geographic level (e.g., county) and about half enabled users to produce static maps, but less than 20% included an interactive mapping component (Friedman & Parrish 2006). Unfortunately, a more recent review of developments since then is not available. A number of other interactive geospatial tools have been developed to enable interactive exploration of multivariate health data in map, chart or table format either as a stand-alone downloadable tool or online through a web browser. Examples described in the literature include:

- GeoVISTA Studio;
    - Exploratory Spatio-Temoral Analysis Toolkit (ESTAT) (Robinson et al. 2005)

    - Visual Inquiry Toolkit (VIT) (Chen, Maceachren & Guo 2008)
    - GeoVIZ Toolkit (Hardisty & Robinson 2011)
    - Visualisation System for Space-Time and Multivariate Patters (VIS-STAMP) (Guo et al. 2006)
    - Pennsylvania Cancer Atlas (Bhowmick et al. 2008a; Bhowmick et al. 2008b)
- Spatial Online Analytical Processing Visualization and Analysis Tool (SOVAT) (Scotch & Parmanto 2005, 2006);
- Adaptive Visualization for e-Science (ADVISES) (Sutcliffe et al. 2010); and
- Epidemiologic Visual User Environment (EpiVue) (Yi et al. 2008).

Important insights have been generated from extensive evaluations of these tools. ADVISES was found to increase appreciation of, and facilitate creativity in, spatial data exploration among epidemiologists and health data analysts (Thew et al. 2011). SOVAT was demonstrated to be preferable and more efficient compared to using a combination of traditional GIS and statistical software packages by public health professionals and students as it reduced the number of steps required during analysis and provided a more intuitive user interface (Scotch, Parmanto & Monaco 2008). Evaluation of ESTAT with end users determined that the most useful features were the highly interactive and flexible nature of the tool and the dynamic internal linkage between the interface components (bivariate map, scatterplot, parallel coordinate plot and time series animation slider tool) so that selection of an area on one highlights the corresponding areas on the others (Robinson 2007).

Bhowmick et al. (2008a) conducted in depth interviews with public health professionals working in cancer prevention and control and found large variation between the level of prior experience with spatial data and analysis tools and also the spatial scale and types of data required. Therefore geo-visualisation software must be simple and intuitive enough for novice users, but also have extended functionality available to more advanced users who wish to explore and analyse the data in detail (Bhowmick et al. 2008a). They implemented a user centred design process to develop an interactive online cancer atlas and key design issues for the development of dynamic online health visualisation tools were identified (Bhowmick et al. 2008b). Detailed tutorials demonstrating the application of the tool and context specific help documentation including both information of how to use the tool and definitions of key terms and concepts used were important. Even more important was the need for dynamically generated supplementary information in the form of explanatory text and tables to assist users to interpret the significance and key aspects of the data. Flexibility to query data at multiple geographies, across multiple variables and to export for later use in reports or presentations was also necessary (Bhowmick et al. 2008b).

This paper describes progress in the development of spatial visualisation and reporting tools in Western Australia and future plans to redevelop existing tools, building on current knowledge and best practice identified in the published descriptions and evaluations of previous geo-visualisation tools discussed previously, to produce an integrated mapping and reporting tool that incorporates a broad range of health, environmental measures and demographic information.

Spatial visualisation and analysis tools in Western Australia

Two applications with basic spatial functionality have been developed in collaboration between Curtin University of Technology and the Department of Health Western Australia (DoHWA) through the Cooperative Research Centre for Spatial Information (CRC-SI). *HealthTracks: Reporting* is an epidemiological report generation tool and *HealthTracks: Mapping* is a web based mapping tool. The primary objective of these applications is to provide decision support tools to improve knowledge translation and utilisation for health decision-makers that leverages the power of spatial health information and provides instant access to a simple, yet valuable and innovative display of spatial health information.

HealthTracks: Reporting generates customised reports with informative epidemiological measures such as number of cases, age standardised rates, standardised rate ratios and associated 95% confidence intervals for a selected geographical area. An extensive range of datasets from a range of areas across the Health Department have been collated on a central server and are updated at least annually (See Table 1). The data can be queried by health outcome, age, sex, Aboriginality and area from State to Health District level. All health outcome and population data tables are stored in a Microsoft SQL Server database and processed through an Active Server Page (ASP) web application based on the defined query parameters. This provides users the ability to query the data according to their day-to-day needs and increase the efficiency by avoiding pre-processing pre-defined layers with multiple combinations.

Report output includes figures, charts, notes and importantly, expert knowledge and context specific interpretative text. The text has been written by experienced epidemiologists and incorporated into the reporting tool to facilitate interpretation by end users. The majority of reports result from users interrogating a single dataset in detail. However, a general overview report can also be created which collates data from multiple sources about a specific region in order to cater for a range of user needs (Figure 1).

HealthTracks: Mapping is a client-side GIS based application that allows users to spatially visualize health and demographic information together with data from external agencies or by uploading their own data. Particular attention was given to the thematic display of health, demographic and population datasets. *HealthTracks: Mapping* incorporates web-mapping services (WMS) to access spatial data from external organisations or custodians. The functionality meets the need of 'Where Is?' queries from agency staff with the geographical location of health services, multiple administrative boundaries (e.g. health regions, health districts, local government areas, statistical local areas, suburbs and postcodes) and other contextual information (e.g., fast food outlets, public drinking water resources). To allow users to visualise differences between the various datasets, a tool was included to rapidly transition between two layers of interest. A selection of 16 commonly requested health conditions and diseases were included with consideration given to those that had reliable rates for Statistical Local Areas (SLAs) - the chosen geographic area for display. For example, Figure 2 depicts the display for the number of births in the Perth Metropolitan area in 2008 which is demographic layer list in *HealthTracks: Mapping.*

Development and release

The development of *HealthTracks: Mapping* involved a series of discussions, consultation meetings and testing by three stakeholder groups from the DoHWA. The first stakeholder group included experienced GIS staff, the second was executives from the Public Health Division and the third was end-users with a range of roles and levels of responsibility within the health system. GIS staff were able to examine a database of requests to their branch to inform the choice of datasets to include and executive staff gave insight into their expectations and health measures required. Users were consulted to prioritise the list of required functionalities and inform the interface design. Information collected from these consultation meetings was incorporated into a detailed specifications document to guide development. The process with users was then followed by three qualitative evaluation sessions in which users were observed interacting with early versions of the system and asked to undertake a series of tasks to gauge usability. Users were then asked to provide feedback that was used to improve the final version before release.

Notification of the availability of *HealthTracks: Mapping* was broadcast to DoHWA staff in August 2010. Word of mouth and smaller presentations provided more detailed demonstrations of

HealthTracks: Mapping capabilities to user groups within DoHWA. An average of 2.7 unique users accessed the application per working day, primarily amongst those users who were previously familiar with the existing Geographic Information System services provided by DoHWA.

In contrast, *HealthTracks: Reporting* was designed to provide more efficient access to data that was commonly requested and which previously had to be manually extracted and analysed by Epidemiology Branch staff. It was initially developed by an experienced epidemiologist and was refined over several years based on user feedback and suggestions. However, it was decommissioned in 2005 after the initial developer was not longer able to provide technical support. As part of the current project, the system architecture was updated in 2011 and user awareness and engagement was conducted over a six month period. This involved high-level discussions to obtain support at executive level, followed by presentations at meetings during which development priorities and requirements were gathered.

A passive dissemination process was used to facilitate a staged re-release of *HealthTracks: Reporting* in June 2011. Firstly, managers were informed and asked to disseminate to relevant staff. This was followed by an email to all internal staff that had previously requested data. Finally, a number of groups within DoHWA requested further details, so information sessions were delivered to increase user engagement.

Uptake and impact

Uptake of the reporting tool has been encouraging. From release at the end of June 2011 until the end of March 2013, 309 unique users within the Department registered to access the system and used it at least once. At total of over 18,000 reports were generated during this period (Figure 3).

An adapted version of the *Missouri Information for Community Assessment (Intervention MICA)* participant feedback survey published in Freidman and Parrish (2008) was used to evaluate end users experience with HealthTracks in April 2012. Users who had produced at least 10 reports (n=69) were invited to participate in the online survey, of whom 24 completed it (35% participation rate). Users were asked for feedback regarding a range of aspects including design, navigiation, tehnical elements and content using a five point Likert scale. Feedback was generally positive with 91% of respondents indicating they either agreed or strongly agreed that HealthTracks was straightforward to use. Furthermore, 96% indicated that the data presented was useful and 88% were satisfied with the tool overall. Some areas for improvement were also identified. For example, only 70% of users agreed or strongly agreed that the tool was flexible enough to easily extract the required data and only 64% were able to easily extract data and import into an external spreadsheet, database or report. Qualitative practical examples of the impact the tools have had on accessing data to inform decision making are discussed in the case studies below.

Case Study 1: Primary health care needs analysis

A rural General Practice Network requested a primary health care needs analysis to be compiled within a short timeframe to form part of their tender for Medicare Local funding and identify gaps and key areas of need to better inform and target primary health care services under the new reforms. This needs analysis required a broad range of data including population demographics, hospitalisations, mortality, cancer incidence, immunisation coverage, health service utilisation and health behaviour and risk factor prevalence. Previously, such a request would have taken many weeks to complete due to the complexity and broad range of data required. However, a large majority of the required data was obtained through the *HealthTracks: Reporting* application, and in conjunction with some further manually extracted data, the needs analysis was completed within the required timeframe.

Case Study 2: Regional Aboriginal health profiles to inform the Closing the Gap initiative

A series of regional Aboriginal Health Profiles were produced to inform Aboriginal Regional Health Forums in prioritising and allocating funding under the Closing the Gap initiative. The profiles include population data, morbidity data and mortality data and were initially created before *HealthTracks: Reporting* was available, which was a fairly labour intensive exercise that required a working group of five analysts from who worked solely on the profiles for a number of weeks. The profiles were updated recently and *HealthTracks: Reporting* was used to source the majority of the epidemiological data required, reducing the amount of time required to prepare the profiles by approximately two thirds. Staff within the unit noted the value of having up to date epidemiological data readily available in a user friendly platform, describing *HealthTracks: Reporting* as 'extremely beneficial' and a 'leap forward' in efficient access to data to provide the evidence base for a variety of planning and decision making purposes and meeting tight reporting deadlines.

Case Study 3: Hospital service planning

Providing planners and clinicians in Princess Margaret Hospital for Children, the principal paediatric hospital in Western Australia, with access to spatial information and the ability to map their own data has been valuable in trauma service planning. *HealthTracks: Mapping* was used to upload and display a subset of cases by postcode, which was then used as a decision support document in subsequent face-to-face stakeholder meetings by providing visual insight into where trauma patients were coming to the hospital from. Based on the preliminary investigation using *HealthTracks: Mapping*, further requests for detailed spatial information were requested and used for trauma service planning and identifying areas of research interest that could be pursued further.

Case Study 4: Plan for tackling drug and alcohol problems in the population

The Western Australia Drug and Alcohol Office used *HealthTracks: Mapping* to upload and visualise the geographical locations of drug and alcohol related service-centre calls from residents in the Perth metropolitan area. A series of maps were also created including socioeconomic index for area and projected population as well as rates of drug-related hospitalisations, mortality, ambulance callouts, police reported drug-related offences, treatment episodes recorded by drug and alcohol services. These maps were visually compared and contrasted to identify the at-risk populations and areas where services were most needed, to evaluate the association between socioeconomic status and drug-related health outcomes, and to estimate the future service need for different geographical areas. The service planning would not be achieved with ease without the use of *HealthTracks: Mapping*. The secure single-session data storage was an advantage for those users working with confidential data.

Conclusion

The primary aim of the *HealthTracks* project is to provide a decision support tool to assist health policy-makers and service planners with evidence based planning and policy development. While researchers may also benefit through rapid access to data and analytical tools, it is important that all end users are aware that causal inferences cannot be drawn from ecological associations between spatial health outcome and risk factor data (Robinson 1950). Therefore, such applications can be used as a research tool for hypothesis generation but not hypothesis testing, and studies using individual level data and utilising high resolution analysis are still required to investigate causal links (Subramanian et al. 2009; Wakefield & Shaddick 2006).

Privacy and reliability are the two most important considerations in the provision of spatial health data that can be queried across multiple dimensions arising from the resultant small numbers in each cell or polygon (Boulos 2004; Rudolph, Shah & Love 2006; Scandol & Moore 2012). This is particularly significant in Western Australia where the population distribution is highly uneven with almost 80% of the population living in the greater Perth metropolitan area (0.3% of the land area) with the population density in the rest of the State averaging only 0.2 persons per square kilometre (Australian Bureau of Statistics 2011). Consistent with most current public health reporting standards, counts of less than five in a specific area are not reported due to privacy considerations and rates based on counts of less than 20 are deemed unreliable and suppressed (Rudolph, Shah & Love 2006).

Advances in information technology and software development have made it cost-effective to provide powerful and flexible mapping, reporting and analytic capabilities and the field continues to rapidly evolve (Highfield et al. 2011). Globally, a number of geovisualisation tools have been developed for health data and user testing has revealed important insights in published evaluations (Robinson 2007; Scotch, Parmanto & Monaco 2008; Thew et al. 2011). The release of the online mapping and reporting applications has increased the uptake and use spatial information in the DoHWA. However, they were always intended to be proof of concept applications and there is a large scope to further enhance usability, functionality and the range of data available.

HealthTracks is currently in the process of being rebuilt in order to integrate the mapping and reporting functions into a single analytical tool and make use of the latest software tools. Open-source software will be used given the wider variety of tools available compared with proprietary software, especially in the domain of lightweight client and server-sided solutions (Anderson & Moreno-Sanchez 2003; Moreno-Sanchez et al. 2007). User feedback and lessons learnt from the demonstration applications, along with the recommendations made in the published evaluations of other spatial tools reviewed previously will be incorporated. The challenge of balancing privacy with the demand for more detailed spatial queries, in order to work towards facilitating access by external agencies, researchers and the general public, will be addressed by performing server-side analysis of individual-level data, with only aggregated information deployed to the client, provided the requested combination of dimensional cross-sections meets specified privacy and reliability criteria. Data will be stored in an Online Analytical Processing (OLAP) based data warehouse to minimise processing time and maximise data storage efficiency (Studnicki et al. 2010; Tremblay et al. 2007). Further details and technical specifications are described in Moncrieff et al. (2013). The rebuild will also address the issues identified in the user feedback survey and expand the range of data available to include socioeconomic and remoteness measures, burden of disease and injury, and environmental monitoring in order to assist in identifying and addressing health inequalities and accessibility, emerging health issues and the ever-increasing demand for spatially based information for effective and timely health service planning and policy development (Granell, Fernández & Díaz 2013).

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Table 1: Datasets contained in the current version of *HealthTracks: Reporting.*

Source	Dataset
WA Hospital Morbidity Data System	Hospitalisations by International Classification of Disease (IDC) coding
	Hospitalisations by Major Diagnostic Category (MDC) and Diagnostic Related Group (DRG) coding
	Hospitalisations by external cause coding
	Drug and alcohol related hospitalisations
	Potentially preventable hospitalisations
WA Register of Births, Marriages and Deaths	Deaths by ICD coding
	Drug and alcohol related deaths, avoidable deaths
WA Cancer Registry	Cancer incidence
WA Notifiable Infectious Diseases Database	Communicable disease notifications
WA Mental Health Information System	Mental health occasions of service
WA Health and Wellbeing Surveillance System	Self-reported health service utilisation, risk factor and chronic disease prevalence
WA Emergency Department Data Collection	Emergency Department presentations
Australian Bureau of Statistics	Estimated resident population by age, sex, Aboriginality and area