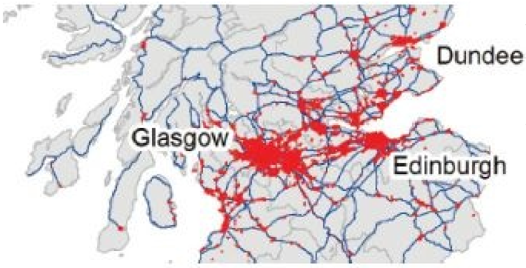
Spatio-temporal Geography and Medical Data



Authors David R. Green and Jan O. Jansen demonstrate through examples how GIS can add explanatory value to the analysis of medical data.

The analysis of spatial data often relies on the use of Geographical Information Systems, with maps being the usual output. However, increasingly, GIS functionality provides more than just a digital mapping toolbox: it can include spatial and network analysis, 3D visualisation, and modelling. GIS can also handle data from many disparate sources, including remote sensing and GPS or GNSS. The latter provides for the accurate capture of spatial locations and an array of attributes including ground-based photographic records, text descriptions, and environmental sensor data. Recent developments in this technology have also led to decision support systems (DSS), online Internet mapping capability, mashups, and real-time environmental monitoring, providing powerful and flexible ways to manage resources, access information, and to engage with the public.

Many GISbased medical and health applications have been reported including mapping applications, for exploratory data analysis; studies analysing the distribution and spread of disease; studies of exposure to pollution sources, such as factories, roads and airports; cluster analysis and to identify the significance and sources of disease outbreaks, and the links between health and pollution; and the use of spatial techniques such as Kriging to generate surfaces.

Remotely sensed data has also been used as a source of environmental information to correlate with health data. Terrain data provides the means to consider the influence of both natural and man-made surface topography on local climate such as temperature, wind direction and speed, and on observed air and noise pollution patterns. Spatial data can also be used in GISbased pollution models. Personal and environmental data can now also be gathered using small GPS based sensors to track an individual and their health condition over both space and time. Witness also the rapid growth in wearable technologies such as monitoring devices in the form of smartwatches, GPS trackers, and Fitbit devices. Subsequently, this information can all be integrated into a GIS with other spatial datasets that may help in an explanatory capacity. Spatiotemporal relationships can also be studied using visualisation tools for data exploration and the generation of map animations that visually alert the viewer to any hotspots of change over time.

Whilst the mapping and visualisation of datasets remains the most common and obvious visual (both hard and soft copy) output from a GIS and the related geospatial technologies, the real power of GIS lies with the potential to generate new datasets, explore spatiotemporal data, utilise techniques and tools for spatial analysis, and to interface with modelling and simulation tools. This is already being significantly enhanced by the addition of further utilities, specialised functionality, spatial statistics, and modelling tools.

In the first of a two-part series of case studies, the following two examples outline, with illustrations, just how spatiotemporal data can be analysed and modelled to provide decision makers and budget holders with the key information they need.

In the next issue, we will look at examples in Geographical Mapping of Hepatitis C infection in North East Scotland using GIS; Proximity of high-density truck traffic near schools but not homes is associated with childhood wheezing; and, An exploratory analysis of the geospatial distribution of the incidence of injury requiring ambulance service attendance in Scotland.

Feasibility and Utility of Population Level Geospatial Injury Profiling

Geospatial analysis is increasingly being used to evaluate the design and effectiveness of trauma systems, but there are no metrics to describe the geographic distribution of incidents. The aim of this study, therefore, was to evaluate the feasibility and utility of using spatial analysis to characterize, at scale, the geospatial profile of an injured population.

This was a prospective national cohort study of all trauma patients attended to by the Scottish Ambulance Service in a complete year (between 1 July 2013 and 30 June 2014). Incident location and severity were collected at source. Incident distribution was evaluated using geostatistical techniques.

There were 80,391 recorded incidents involving traumatic injury. Incident density was highest in the central Southern part of the country and along the East coast, broadly following the population distribution and road network. The overall distribution was highly clustered, and centred on the central Southern and Eastern parts of the country. When analyzed by triage category, the distribution of incidents triaged to major trauma centre care was slightly less clustered than that of incidents triaged to trauma unit or local emergency hospital care, but the spread was similar. When analyzed by type of injury, assaults and falls were more clustered than incidents relating to traffic and transportation.

This study demonstrates the feasibility and power of describing the geographic distribution of a group of injured patients. The methodology described has potential application for injury surveillance and trauma system design and evaluation, as shown by two subsequent analyses of the dataset.

Optimising the Geographical Configuration of Trauma Systems

A trauma system is a network of specialist hospitals, supported by emergency medical services (utilising both ambulances and helicopters). The geographic configuration of emergency care systems is key to maximising accessibility, while also promoting the efficient use of resources.

This study, drawing on the data collected as part of the GEOS study, reports the use of a novel approach to inform the optimal configuration of a national trauma system. The project used a novel combination of network analysis and multiobjective optimisation, trading off characteristics such as travel time, undertriage, helicopter use, and hospital case volume.

The analysis demonstrated that Scotland's trauma network could be optimised with one or two major trauma centres, while requiring an enhancement of aeromedical retrieval capacity.

Analysis of the Geospatial Distribution of Injury Requiring an Ambulance

Geographical variation in the risk of suffering injury is recognised anecdotally, but poorly characterised. The aim of this study was to explore the feasibility of using prehospital data and small area geography to conduct a population-based analysis of geographical variation in the risk of injury in Scotland.

This was a secondary geospatial analysis of data from the GEOS study, described above. Data regarding incident location and injury severity were linked to small area ("datazone") administrative data, and analysed using geostatistical techniques. "Hotspots" and "coldspots" of risk were determined using the GetisOrd* statistic. 80,394 incidents requiring Scottish Ambulance Service attendance were documented, as previously reported. Overall, the risk of injury, of any severity, was low, in most of the data zones, but there were identifiable "hotspots" in the Scottish Highlands and some innercity areas. "Coldspots" were situated within the central belt, the east coast of Scotland, and the islands of Orkney and Shetland. The results and statistical techniques were found to be susceptible to "zero inflation".

This study confirms the feasibility of combining prehospital data, collected by the ambulance service, with small geography administrative data to conduct population-based spatial analyses of incidence rates. Risk appears to be concentrated in identifiable locations. Risk differs from volume – trauma system configuration is determined by the latter, whereas identification of high-risk areas (which may not always be the same as high volume areas) may help to address the causes of excess incidents.

Conclusion

These examples demonstrate that there are many different ways in which spatial data can be used to develop an understanding of the geographical dimensions of medical datasets. Although nearly all output from a GIS or GIS-based analysis results in a map, GIS also provides many geospatial tools and techniques to help spatially analyse medical datasets, e.g. to produce a surface using Kriging, or the use of cluster analysis to produce a map of hotspots. Furthermore, spatial data can be analysed using techniques from other disciplines. Network analysis often requires conflicting objectives to be considered, but conventional techniques frequently do not address this problem well. Multiobjective optimisation, pioneered in engineering and financial risk analysis, permits new insights.

As desktop GIS, WebGIS, and mobile GIS technology continue to evolve there will be many new opportunities for individuals to capture environmental data using wearable technologies including miniaturised sensors, smart technologies and even phone apps, as well as being able to share information and to access publicly available information through the Internet.

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