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Using geographical information systems and cartograms as a health service quality improvement tool

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ABSTRACT

Introduction: Disease prevalence can be spatially analysed to provide support for service implementation and health care planning, these analyses often display geographic variation. A key challenge is to communicate these results to decision makers, with variable levels of Geographic Information Systems (GIS) knowledge, in a way that represents the data and allows for comprehension. The present research describes the combination of established GIS methods and software tools to produce a novel technique of visualising disease admissions and to help prevent misinterpretation of data and less optimal decision making. The aim of this paper is to provide a tool that supports the ability of decision makers and service teams within health care settings to develop services more efficiently and better cater to the population; this tool has the advantage of information on the position of populations, the size of populations and the severity of disease.
Methods: A standard choropleth of the study region, London, is used to visualise total emergency admission values for Chronic Obstructive Pulmonary Disease and bronchiectasis using ESRI's ArcGIS software. Population estimates of the Lower Super Output Areas (LSOAs) are then used with the ScapeToad cartogram software tool, with the aim of visualising geography at uniform population density. An interpolation surface, in this case ArcGIS' spline tool, allows the creation of a smooth surface over the LSOA centroids for admission values on both standard and cartogram geographies. The final product of this research is the novel Cartogram Interpolation Surface (CartIS).
Results: The method provides a series of outputs culminating in the CartIS, applying an interpolation surface to a uniform population density. The cartogram effectively equalises the population density to remove visual bias from areas with a smaller population, while maintaining contiguous borders. CartIS decreases the number of extreme positive values not present in the underlying data as can be found in interpolation surfaces.
Discussion: This methodology provides a technique for combining simple GIS tools to create a novel output, CartIS, in a health service context with the key aim of improving visualisation communication techniques which highlight variation in small scale geographies across large regions. CartIS more faithfully represents the data than interpolation, and visually highlights areas of extreme value more than cartograms, when either is used in isolation.

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1. Introduction

Geographical Information Systems (GIS) have a long history of use within health care, particularly public health (Wennberg and Gittelsohn, 1973; Twigg, 1990; Bullen et al., 1996; Higgs and Gould, 2001; Nacul et al., 2011), to visualise the epidemiology of disease, delivery of health services and allocation of resources. The use of small-area data to describe variations in healthcare was developed in the 1970s by Wennberg and Gittelsohn (1973); over recent years the increased use and capabilities of technology, combined with improved access to data, has allowed the development of atlases that visualise geocoded health data. The production of atlases in the United Kingdom (UK) (NHS Right Care, 2010), building on similar American atlases produced by the Dartmouth Institute (Dartmouth Medical School, 1998), have raised questions about why there are variations in clinical outcomes at regional and local levels. Subsequently significant strides have been made to reduce unwarranted variation in clinical outcomes through improving the quality and consistency of care processes e.g. a Chronic Obstructive Pulmonary Disease (COPD) Care Bundle (Hopkinson et al., 2012). Whilst atlases have been instrumental in highlighting the disparities in health outcomes nationally there still remains some concern about how these data are translated into strategies to improve outcomes (Joyce, 2009). With the potential for more and more data to be available for such analysis, including patient reported outcome measures (PROMs) and patient reported experience measures (PREMs), the question arises at how technologies can be used to "intelligently" interpret the data to improve the quality of services that will translate into improved outcomes and patient experience.

GIS can often be perceived as simple visualisation of data through mapping, this belies the complexity of data and the interaction with the geographical or spatial plane used for display. Communicating this complexity effectively and accurately provides opportunities for the "viewer" to interpret the data and identify patterns. When visualising datasets, the resolution of display is critical to the information portrayed, with larger geographic aggregations masking heterogeneity at finer scales, and potentially causing incorrect interpretation of the data. However, operating at finer resolutions can result in a loss of data in areas of relatively small geographies and, when using choropleths, importance can mistakenly be assigned to areas of larger extent, rather than areas of higher value (Pickle and Carr, 2010). Different methodologies demonstrate varying strengths and weaknesses for data visualisation; decision makers must utilise the most appropriate method for their purpose.

A key challenge is how to present service activity data in such a way as to be helpful to commissioners, clinicians, healthcare managers and policy makers to support initiatives to improve the quality of services (e.g. Future Hospital Commission, 2013; Green et al., 2012; Noble et al., 2012; Welch and Allen, 2006). In this paper, we explore the use of a combination of methods as a possible solution to this visualisation problem, using health service utilisation data derived from Hospital Episode Statistics (HES) (www.hscic.gov.uk/hes) data as an example.

2. Geographic visualisation-problems and solutions

There are two common problems in geographic visualisations that are often overcome using methods that are simple to apply and interpret; cartograms and interpolation surfaces, which are discussed in the following sections.

2.1. Problem 1

When working with real data pertaining to differences in the geographic sizes of the units in question can prevent ones interpretation of underlying patterns within the data values of interest as larger areas have bigger visual impact. A solution to this is the use of cartograms.

2.2. Cartograms

Modern cartograms stem from Émile Levasseur's work in value-by-area maps (Tobler, 2004) with the aim of creating variable sized rectangles to show a value such as population, and grouping them to correspond to their geographical position. Dorling Maps (Dorling, 1995) produce a visual output without retaining topography, which is the reason it was not chosen for this study, by converting each region into a circle whose size represents the chosen variable. The first computer generated cartogram was created by Waldo Tobler, named pseudo cartograms, where areas are expanded or compressed along the latitude/longitude grid to achieve equal value density. Gastner & Newman's method (2004), a variation of Tobler's termed density-equalising maps, is based on a diffusion process where geographies are said to "flow" until uniform density of the chosen variable is achieved resulting in a lack of real geography. This method provides the functionality to modify the parameters to adjust the amount of geographical preservation and the achievement of uniform density. The development of the density-equalising visualisation technique was to solve problems associated with good spatial resolution, small sample sizes and variable population density. The Gastner & Newman algorithm was developed with the aim of simplifying the complexity of cartogram creation and their outputs by improving their usability, which has been incorporated into a number of pieces of software including ESRI's ArcGIS software (ESRI, 2014) and the open source product ScapeToad (Chôros Laboratory, 2014). However when using a large area high resolution choropleth with high data heterogeneity a cartogram can become visually problematic (Kaspar et al., 2011).

2.3. Problem 2

When data have been attributed to specific points across a study region as discretisation of values can occur with no knowledge about the values in between the points. Spatial point analysis has a history in disease and epidemiology research, dating back to John Snow's seminal cholera mapping to a local water pump in Victorian London. The pattern analysis of such point geographies has been in