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Building Temporal Dynamism into Applied GIS Research

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Most human phenomena vary considerably over space and time. Historically, GIS research has focussed on developing approaches that allow spatial phenomena to be recorded, investigated, and displayed. This emphasis on the spatial meant that time was largely relegated to a simple column amongst other attribute data. This uncertainty about how to handle time is evident through the debates[1] and work produced in the early 2000s. Often time was given only cursory treatment – for example by comparing spatial patterns in one year to another – resulting in little impetus to collect more dynamic temporal information at higher resolutions. That is not to say that geographers were not aware of the importance of time in their analysis – Hägerstrand introduced time-geographic concepts in the 1960s after all – but that without the availability of computational tools to manage and analyse the influence of time on a phenomenon, the analysis that GIS professionals could perform was very limited.

In recent years, however, two important changes have brought the capability of analysing temporal phenomena to the fore. Firstly, the tools to manage and analyse time in a GIS have advanced significantly. Time can be represented in common GIS's such as ArcGIS and QGIS, and there are packages to support spatio-temporal analysis for commonly-used statistical software tools such as R – see, for example, the *SpatioTemporal*[2] package. Secondly, the volume and availability of temporal data have blossomed. The 'age of big data' has led to the creation of vast new datasets that capture spatio-temporal information – about people, the environment, animals, goods, etc. – at unprecedented resolutions. As Yuan's (2018) recent review shows, there is a rapidly growing interest in the use of new technology and data to conduct empirical analyses of space-time human dynamics. Whilst there are, of course, legitimate ethical questions about the risks associated with such high-resolution (often personal) data, the opportunities to better understand the temporal dynamics of a range of phenomena are extremely exciting.

[1]For an example of the temporal database debate, see the opposing suggestions for how time should be represented in Date et al. (2003) and Snodgrass et al. (1998).

[2]https://cran.r-project.org/web/packages/SpatioTemporal/

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It was in this rapidly changing environment that the 2015 GIS Research UK conference was organised by the School of Geography, University of Leeds, UK. The use of time in GIS research emerged as an important research theme during the conference, and so this special issue called for *spatial analysis papers that expose the different ways that we can deal with time in GIS research*. This special issue brings together four papers that exemplify the different ways that both traditional and novel forms of data can be explored to uncover spatio-temporal phenomena.

The paper by Rosser and Cheng experiments with a relatively new model, the self-exciting point process (SEPP), to assess the success with which it can make predictions about future crime locations from historical crime data. They use an administrative dataset, that of recorded crime events in Chicago, US, and conduct experiments at a temporal resolution of 1 day (i.e. they try to predict the most likely locations for the following day's crimes). Whilst the use of police recorded crime data is not unusual, similar studies aggregate their data to relatively large temporal windows (e.g. 12-month aggregations are common) whereas with Rosser and Cheng's work a much higher temporal resolution is required. This is particularly important for real policing policy as patrol routes are often determined on a daily basis, hence crime predictions at a temporal resolution more coarse than a 24 h will have limited policy relevance.

For Rosser and Cheng, 'traditional' administrative data describing the phenomena of interest were available. This is often not the case, however, as the remaining three papers demonstrate. The work of Ellison et al. involved an extensive period of data collection over three years. The authors required information about how people navigated the city at a very high spatial and temporal resolution and so developed a bespoke smartphone application to track the movements of the 500 study participants. In total, 96 million observations were recorded at a near-continuous temporal resolution of 5 s; a feat that would have been unimaginable in the early days of GIS. The paper dissected the data to identify places where people stopped for a given time duration. The results are applicable to policy in that they showed that the locations of the participants' activities shifted (on aggregate) towards new cycle paths, providing evidence that they were actually being used as expected.

Although they were not suitable for exploring the daily spatio-temporal behaviour of residents, reliable administrative data did exist in the study area for Ellison et al. (Sydney, Australia) and could have been used were they appropriate. In some cases, however, there are not any appropriate administrative data to begin with. This is the case for the paper by Manley and Dennett. In their study area of Dakar, Senegal, there are few rigorous administrative datasets available which hampers efforts to better understand human activity patterns. To make headway, the authors made use of mobile telephone *call data records*; these are records of the times and (telephone mast) locations at which users of mobile phones undertake some activity with the device. By examining the volumes of activity over time and space, and coupling this with a land-use classification, the authors provide insight into the interactions that occur across different land uses. Importantly, the data have a temporal component so Manley and Dennett were able to show how these patterns of interaction change throughout the day.

The volumes of data that underpin the papers by Ellison et al. and by Manley and Dennett are striking: 96 million observations and more than 3.5 billion observations respectively. In the final paper, by Wilson, Lovelace and Evans, similar volumes might have been expected. The authors used data from Twitter to better understand peoples' perceptions of a particular walking trail in the north of England (the Pennine Way National Trail). Given that there might be as many as 500 million tweets sent globally per day, it was somewhat surprising that only 161 tweets were found to be associated with walks on the Pennine Way (although it is important to note the analysis only included messages with a spatial component). Nonetheless, the authors found that areas of the Trail that were administered under a particular environmental stewardship scheme correlated with higher tweet sentiment, which has potential important policy implications for the implementation of the scheme.

Regardless of the source of their data, all of the papers represent important changes in the way that spatial research deals with time. Whilst the rigour of more 'traditional' administrative data are unmatched, new forms of data from mobile phones, smartphone applications, social media contributions, etc., have the potential to offer new insights into spatio-temporal human activity patterns that would not have been possible only a few years ago.

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