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Revealing Hidden Dynamics in Spatial Data

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Over the last 15 years, geography has witnessed an explosion in the provision of both computational power and digital spatial datasets. This has brought a greater awareness to geographers of the nature and significance of small-scale individual-level dynamics and their effect on larger scale complex system dynamics. Geographers are now beginning to use concepts and notions from complexity theory to reappraise geographical systems. This marks a significant departure from the traditional treatment of complexity - aggregation of people to groups, and the accompanying statistical treatment of these groups, by empirical techniques for example, regression based models. Such models are now recognised as lacking the ability to detail the effects of small-scale and individual level histories, interactions, or even, in any realistic sense, behaviour.

Advancement in both computing and understanding has been accompanied by the development of new techniques, such as agent-based models (ABM) and microsimulation, for simulating complex systems. These methods have provided us with the ability to begin modelling and analysing the impact of individuals and their behaviour over both space and time. The current range of ABM applications in the literature demonstrates its vast potential as a tool for dissecting and understanding the inner workings of complex systems. One significant advantage of ABM is its ability to produce good simulations without detailed data; unlike our more fortunate colleagues in the physical sciences, social scientists are not blessed with detailed temporal and spatial data. However, I feel that more work is required on developing techniques for extracting additional information (e.g. system structure and behaviour) from available data to enhance our models.

In most ABM applications, information fed into agents is typically drawn from observational or simple empirical analysis. In some cases this may be sufficient, but it is inadequate if our goal is to understand structure and dynamics, patterns and behaviour, how individuals or behaviour evolves and adapts in our systems. We simply cannot capture the underlying structure and dynamics of the environment that the agents are embodied within. To achieve this we need to be able to unravel system dynamics and behaviour of the components of the system, in both real and model data.

Investigations into the applicability of methodologies from other disciplines such as physics, chemistry or mathematics, for analysing and modelling complexity in geographical systems are largely absent. This appears to be a significant omission if we are to fulfil the potential of ABM for examining the impact of small-scale individual dynamics on the larger system. I feel that we need to be concentrating on (i) developing better techniques for analysing real complex systems (to provide more detailed and realistic inputs into ABM) and (ii) developing sophisticated methodologies to analyse the results from ABM.

I believe that this can be achieved if research is directed towards the development of tools for identifying/visualising structure and underlying dynamics/relationships within spatio-temporal data. This could lead us to characterise the behaviour of both individuals within a system and the entire system. Through this type of work, we can begin to (i) identify the many threads that exist within the systems and how these contribute to the behaviour of our systems and (ii) understand which techniques are the most appropriate for our analysis.

For characterising individuals and systems, there are several methods that we can borrow from mathematics and physics. For example phase diagrams allow us to chart the behaviour of one or many individuals or the whole system. This can give us insight into the whether behaviour is stable, chaotic or entirely random. Experimentation using ABM and the notions of, for example, catastrophe theory and bifurcations may also yield useful information. These types of nonlinear behaviour are not produced by “traditional” models meaning that these issues have not, to date, been widely addressed in geography.

Wavelets allow us to decompose the system into signals – further work in this area may help to identify “noise” or weak signals in data; we have no way of either identifying or knowing whether these weaker noisy signals over a period of time stabilise and control systems. Investigation into other methods such as recurrence plots may help us to visualise hidden structures and dynamics within data. The results of this type of work may help us to characterise our systems and their behaviour.

The areas briefly alluded to above all have great potential for our understanding by providing new information and insights into our systems that we can feed into our models. However, considerable work needs to be done to develop these methods for application to spatio-temporal systems. Many techniques available in other disciplines have been specifically developed for time series or spatial data (for example image processing). In geography, the spatio-temporal nature of the data adds additional problems. Available techniques require modification and development for geographical applications. I would like part of the workshop to concentrate on this area.