NSF/ESRC Agenda Setting Workshop on Agent-Based Modeling of Complex Spatial Systems: April 14-16, 2007

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Multi-agent systems, mathematical modelling and microsimulation

I consider mathematical modelling and simulation to be both a legitimate intellectual exercise, and a practical aid to policy analysis and decision-making. However to the extent that there is an issue revolving around understanding models versus understanding systems[1], then I am fully committed to the systems camp. I think it is a cop out to produce models which may exhibit all kinds of interesting behaviour under idealised conditions which may bear little or no resemblance to real systems. It concerns me that there is a growing swell within the MAS community which perhaps regards questions like validation and policy application as faintly grubby and beneath the dignity of the simulation modelling community. These days it is easy to generate models which do all sorts of exciting things, and to visualise these models in novel and interesting ways; but it remains as difficult as ever to develop models which give real insights about real systems.

I am excited by the capabilities of e-Research to provide modellers with access to unprecedented riches of both data and simulation power. I think these opportunities are largely being ignored by the academic community, which remains too easily satisfied by proof of concept in relation to problems which are idealised, imaginary or trivial. For example, in relation to complex systems, there is too much rhetoric for my liking on the generation of complex behaviour from simple models as opposed to complex behaviour from complex models. It seems to me that much of the excitement about agents is in the ability to build models with very complex behaviour from agents with very simple behaviour. As geographers, I believe that the agents in our systems of interest actually have quite complex behaviours, whether those agents are consumers, regulators, entrepreneurs or whatever. I think we should be focusing more on realistic social simulations which recognise the existence of complexity throughout the (modelling) process.

One of my main methodological interests is in microsimulation. This technique is used in a number of large, policy-focused applications, many of them economically driven, although 'spatial microsimulation' has been emerging as a distinct research sub-theme. In these models, individuals and households are represented in great detail, in effect as a list of characteristics. These lists are typically generated either by reweighting survey sources, or by synthetic estimation from aggregate data. Behaviours can be added to synthetic microdata, for example by linking to meso-level spatial interaction models[2].

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[1] Sayer R A, 1979, "Understanding urban models versus understanding cities" *Environment and Planning A 11(8),* 853 – 862.

[2] K. Hanaoka & G. Clarke (2007) Spatial microsimulation modelling for retail market analysis at the small area level, *Computers Environment and Urban Systems, xxx* (in press).

Models with this structure can begin to address difficult aggregation problems, but there remains a suspicion that they are overly deterministic. I am intrigued by the possibility that the incorporation of agent driven behaviours within a microsimulation model could somehow dramatically enrich the representation of dynamics at the level of individuals and households. I think the workshop would be a good opportunity to explore whether there are fundamental methodological mis-matches between the microsimulation and agent-based approaches to modelling, or whether these differences are more cultural and terminological.

I guess there is another question here about data, which is whether the two modelling styles – microsimulation and agents – actually require different types of data, with the former focused on 'statistical data' of the type readily available from censuses and major surveys, the latter needing data of a more 'behavioural' orientation, and consequently more difficult to access. This looks to present overlaps into disciplinary and methodological domains like sociology, anthropology and ethnography, although experience indicates that geographers are well-placed to exploit such multi-disciplinary terrain.

These are very real practical concerns, as it is our intention to combine microsimulation with agents in the Moses project. For example, consider the problem of the impact of an ageing population on the provision of social services. From a microsimulation perspective, we can look at this problem in terms of transition probabilities, from young to old, from healthy to sick, from married to single or widowed, and so on. But what effect does something like a social network have on this process, given that the vast majority of social care is provided informally within the context of families and neighbourhoods? Is this something that should be represented with consideration of the interaction between individuals as agents?

Another important concern is with the robustness of forecasts from simulations, whether agent-based or otherwise. Since I have argued that policy-relevant models need to be calibrated to extensive data sets, this presents obvious problems to predictive modelling where 'data' relating to the future is clearly much more difficult to come by. Although there are many potential strategies for the evaluation of forecasting capabilities, such as historical benchmarking (calibration of the model to a historical baseline, so that model 'forecasts' can be evaluated against subsequent events that are known), model training strategies (in which a portion of data is withheld for model evaluation), continuous monitoring, or even running the models in reverse, none of these mechanisms appears to be completely satisfactory.

I have been impressed by a number of high profile simulations of the spread of diseases through spatial networks, notably those emanating from UCL[3] and from Los Alamos,

[3] Neil M. Ferguson, Derek A.T. Cummings, Simon Cauchemez, Christophe Fraser, Steven Riley, Aronrag Meeyai1, Sopon Iamsirithaworn & Donald S. Burke (2005) Strategies for containing an emerging influenza pandemic in Southeast Asia, Nature, 437 (8), 209-214.

now VBI[4][5]. These examples help to establish the credibility of agent models, and the emphasis on real policy applications is particularly welcome. It seems to me that the application of these methods has a much broader relevance to problems of diffusion in space in time [6] – indeed there is direct resonance with our own humble and much less sexy analysis of spatial patterns and retail price dynamics[7]. However the naivete of the spatial networks which underpins these models is alarming. I feel sure there is a whole apparatus of symmetrical nodes, radial accessibilities, well-regulated hierarchies, and all sorts of traditional and unsatisfactory representations beneath these models. It seems to me to be important that as geographers and spatial scientists we can get a message across to a broader MAS community that geography matters, and the workshop would be a useful opportunity to discuss ways to promote this.

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[4] Stephen Eubank[1], Hasan Guclu[2], V. S. Anil Kumar[1], Madhav V. Marathe[1], Aravind Srinivasan[3], Zoltán Toroczkai[4] and Nan Wang[5] (2004), Modelling disease outbreaks in realistic urban social networks, *Nature, 429*, 180-184.

[5] Chris L. Barrett, Stephen G. Eubank and James P. Smith (2005) If Smallpox Strikes Portland ... , *Scientific American, 292 (3),* 54-61.

[6] Bo Lenntorp, Gunnar Törnqvist, Olof Wärneryd, Sture Öberg (2004) Torsten Hägerstrand 1916-2004, *Geografiska Annaler, Series B: Human Geography 86 (4),* 325–326

[7] Heppenstall, A.J., Evans, A.J., and Birkin, M.H. (2006) Application of multi-agent systems to modelling a dynamic, locally interacting retail market, *Journal of Artificial Societies and Social Simulation, 9, 3*.