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The complexity of agent-based spatial models

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In the manuscript for a text that I have just sent to the publishers (Gilbert, 2008), I distinguish between abstract, middle-range and facsimile models (Boero & Squazzoni, 2005) and propose that the requirements for validation differ between these types:

> **Abstract models** aim to demonstrate some basic social process that may lie behind many areas of social life. A good example is Epstein and Axtell's pioneering book on *Growing Artificial Societies* (Epstein *et al.*, 1996), which presents a series of successively more complex models of the economics of an artificial society. … With these models, there is no intention to model any particular empirical case and for some models it may be difficult to find any close connection with observable data at all. … How then might such models be validated? The answer is to see such models as part of the process of development of theory, and to apply to them the criteria normally applied to evaluating theory. That is, abstract models need to yield patterns at the macro level that are expected and interpretable, to be based on plausible micro-level agent behavioral rules, and, most importantly, to be capable of generating further, more specific or 'middle-range' theories (Merton, 1968).
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> **Middle-range models** aim to describe the characteristics of a particular social phenomenon, but in a sufficiently general way that their conclusions can be applied widely to, for example, most industrial districts rather than to just one. The generic nature of such models means that it is not usually possible to compare their behavior exactly with any particular observable instance. Instead, one expects to be satisfied with qualitative resemblances. This means that the dynamics of the model should be similar to the observed dynamics and that the results of the simulation should reveal the same or similar 'statistical signatures' as observed in the real world, that is, the distributions of outcomes should be similar in shape (Moss, 2002).
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> **Facsimile models** are intended to provide a reproduction of some specific target phenomenon as exactly as possible, often with the intention of using it to make a prediction of the target's future state, or to predict what will happen if some policy or regulation is changed. For example, a business may be interested in finding the consequences for their inventory level of reducing the interval between sending out restocking orders. It is likely to require a model that precisely represents all their suppliers, the goods each supplies, and the unit quantities of those goods in order to be able to make reasonable predictions.

Another, very different example, is the work by Dean *et al.* (1999) on the Anasazi Indians in South West United States. These people began maize cultivation in the Long House Valley in about 1800 BC, but abandoned the area 3000 years later. Dean *et al*.'s model aimed to *retrodict* the patterns of settlement in the Valley and match this against the archaeological record, household by household.

If such exact matches can be obtained they would be very useful, not only as a powerful confirmation of the theory on which the model is based, but also for making plausible predictions. However, … Most social simulations contain some element of randomness. For example, the agents may have initial characteristics that are assigned from a random distribution. If the agents interact, their interaction partners may be selected randomly, and so on. The same is presumably true of the social world: there is a degree of random chance in what happens. The effect of this is that running the model a number of times will yield different results each time. Even if the results are only slightly different, the best one can hope for is that the most frequent outcome – the mode of the *distribution* of outputs from the model – corresponds to what is actually observed (Axelrod, 1997; Moss, 2002). If it does not, one might wonder whether this is because the particular combination of random events that occurred in the real world is an outlier, and that if it were possible to 'rerun' the real world several times, the most common outcome would more closely resemble the outcome seen in the model!

I think it is true to say that the majority of agent-based models of complex spatial systems fall into the second and third of these categories, that is, they aim to be either middle-range or facsimile models. In the workshop, I want to explore the relevance of the first category and consider what it might mean to have abstract spatially explicit models. Among the implications are:

a. More effort might be put into developing ABMs representing the classic theories of geography. Issues for discussion include:
    1. Which theories?
    2. Is it possible and useful to cast them as ABM?
    3. What progress has already been made?
    4. What benefits might there be in doing this?
b. The abstract models approach implies a certain kind of epistemology: a realist perspective that assumes that there are 'real', generative social processes (Epstein, 2007) that yield the observable features, and that these social processes are recurrent in different social phenomena (thus, what I have called 'abstract social processes'). Examples are:
    1. Markets. While the observable characteristics of markets vary widely, there is some basic, recurrent and abstract underlying social processes from which market institutions emerge;
    2. Cooperation in the face of social dilemmas. There are many situations in which the long-term socially optimum behaviour is not the individually optimum one, but where cooperative behaviour has 'evolved'. There is now a rather large literature on how this works.

Is this epistemology defensible, and how can it be made more precise?

c. What methodological advice can be offered about how one should develop abstract models? How does one validate an abstract model?

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