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Guest Editorial

A New Age for Geosimulation

In an attempt to learn more about me, an engineering colleague on a Ph.D. committee that we both serve on asked me recently what is currently hot in GIScience (admittedly, he called it GIS rather than GIScience). My response to him forms the basis of this editorial, as I believe that this is the right place to step back from the daily grind and try to look at the bigger picture. GIScience has arguably many branches and niches, and the endeavor to identify the next big thing is an invitation to prove oneself a fool. I see, however, also a confluence of research efforts that moves towards a common understanding at least among the next generation of geography-based GIScientists and I will use these lines to highlight some of their work.

In an attempt for computational geography to finally catch up with the conceptual understanding of the remainder of the discipline, I have long argued for a rediscovery of 'process' as its basic unit. Although not often couched in the same terms, I now see the same perspective being applied in many research laboratories.

Former UCL students Paul Torrens (ASU) and David O'Sullivan (Auckland) coined the term geosimulation and have developed what is probably the most comprehensive body of research on this process foundation, at least from a human geography perspective. Not shy to mix, match and implement geocomputational and visualization tools, they develop a myriad of tools that address many of the shortcomings of today's overgrown GISystems (e.g. Benenson and Torrens 2004). Technical wizardry is balanced with a thorough understanding of contemporary theory in urban planning and geography. The result is a tool chest of relatively simple decentralized, individual-based models that allow one to test theory with traditional GIS data. And as to underline their disciplinary background, they also acknowledge practical limitations imposed by the dearth of individual-level data (O'Sullivan 2004).

May Yuan's work with Oklahoma tornadoes is the mainstream physical geography counterpoint. Her approach is more fundamental in the sense that she tries to capture the essence of geodynamics with new data representations (Yuan 1999, McIntosh and Yuan 2005). Influenced by the vector notation in classical geophysical models, her work bridges the object/process boundary and challenges the traditional cartographic paradigm in GIScience.

Somewhere in between the two approaches outlined above lies the work of two teams, one organized around Dan Brown (Brown et al. 2005) in Michigan and the other organized around Paul Waddell (Waddell et al. 2003) in Seattle. Both groups use GISystems only peripherally and have development teams working with multi-agent based software packages.

These are not the small tools of geosimulation, nor revolutionary new data models; their innovative impetus lies in the interoperability of loosely coupled systems, the size of their projects, and their practical approach to dealing with the complexity of geographic systems.

Using some of the ideas of Bittner and Smith in Buffalo, Edinburgh-based Femke Reitsma establishes the ontological basis for all of the above and has gone a long way towards developing formal executable specifications of a truly process-based computational geography (see Reitsma and Albrecht 2005 for additional details). Reitsma has completely gotten rid of objects; her world consists entirely of processes: a house, for instance, is a small-scale urbanization or a production process, which may transform into a gentrification process. This example is an extreme; Reitsma uses process models in hydrology and climatology, where the claim that everything is process, is easier to stomach. Similar to the limitations of individual-based geosimulations, the lack of empirical process data poses practical constraints on this intriguing approach.

While most of these examples describe the work of researchers in the US, it builds on underreported efforts by colleagues from the European circle of quantitative and theoretical geographers, starting with Wilson (1970), Hägerstrand (1976), and Beguin and Thiesse (1979), and later picked up by Bertuglia (1987), Pumain (1991), and Sanders (1996). Portugali and Benenson (1996) and Sonis (1997) carried the torch until it was finally picked up by the abovementioned new generation.

This is probably the first time that these names have been mentioned on the same page. So what do they have in common? One is that with the exception of Waddell this long list consists entirely of geographers. This is no coincidence; geographers are synthesizers, whose chorological perspective forces them to observe processes across a range of scales (Miller 2005). Second, they have all been looking beyond the end of their disciplinary nose. Not that this is not common practice in GIScience but in the past this has typically been a one-way street towards information science, whereas the new bunch sits comfortably between chairs. Third, there is a distinct departure from low-level basic science approaches towards geographical problem solving.

The question then is, what can we expect to see from this form of geosimulation in the wider sense, say five years from now? I foresee a good number of process models, all well specified albeit in the beginning using different formalizations. The research agenda therefore includes development of a uniform process description language, similar to what the unified modeling language (OMG 2004) does for structures (UML 2 allows for the representation of activities but falls short of the needs of dynamic process modeling). Ideally, such a language would have the expressiveness and ease of use of the web ontology language OWL (McGuinness and van Harmelen 2004), while extending it to include rules and behavior. The Kepler system for scientific workflows is an early and still fairly primitive example for the kind of process libraries that I see many of us designing five years from now with the same fervor that we currently observe with the development of object model libraries. The value of such process libraries has been recognized both in the business world, where process models are a well-established component in operations research, and in the natural sciences (see, for example, the Kepler system (http://kepler-project.org) that is part of the SEEK program which is heavily funded by NSF).

One of the more intriguing aspects of geosimulations is the opportunity they provide for testing geographic theory. Comparisons between simulation outcomes and empirical data help us to falsify theories and may help us to judge the validity of competing new schools of thought for well-defined situations. An example, adopted from the work of Liz Groff at the University of Maryland, may illustrate this claim.

Geographers and criminologists have over the years come up with a variety of ideas about what geographic factors contribute to or prevent crime. It is now relatively easy to reject models of criminal behavior such as biosocial criminology, if no reasonable combination of factors causes a geosimulation to result in empirically observed outcomes. On the other hand, successful theories often bear offspring, for instance when a cause is accepted as in routine activity theory but not the means of combating the effects. Geosimulations go a long way in helping us to answer whether "hot spots policing" or "community policing" is the appropriate approach and under what conditions one should be preferred over the other.

One danger associated with any new approach is that its advocates promise too much. We all remember the excitement with which artificial intelligence was touted as the panacea of everything. It is therefore worthwhile to clarify early on the relationship between geosimulations and reality – or what we take to be reality. Part of the problem is the doubt that the empirical data informing our simulations (by setting initial values) is not truly representative for "the real world". As long as we were forced to represent our world in the form of points, lines, and polygons, the critics certainly had a point here. However, following Luhmann (2002), I argue that geosimulations allow us to re-create what has been lost in the encoding of our knowledge. They enable us to switch from general observations to second-level observations of oneself (both at the individual level for example in the form of risk management as well as at the societal level, for example in the form of education, policing, or the introduction of working-at-home programs). In system theoretic terms, we move to the observation of previous observations by the same system. This in turn requires a specification of research problems that can process both first-order observations as well as reflections on these observations, which unfortunately leads to self-referential systems with undetermined outcomes (Casti 2002). In other words, we now need tools that help us distinguish between the two levels of operating, and their interaction effects.

Anticipatory systems, first described by Rosen (1985) contain at a minimum a model of itself and can hence distinguish between these two levels. Applied to social systems, anticipation can be used for the construction of the simulation's next stage. In the process of doing so, social systems and their agents are learning – in reality as well as in the model, i.e. they reconstruct reality in terms of the meaning that is provided to the system (see Figure 1). This reconstruction, for example in the form of reaction-diffusion systems,

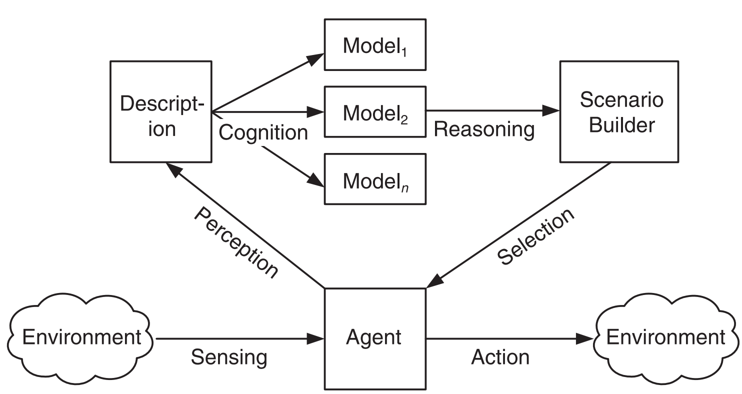

Figure 1 Foundherentic (Haack 1995) setting of geosimulation as an anticipatory system

is the same as the re-creation of knowledge lost in the encoding of the system referred to above and opens the doors for new statistical analyses of model outputs. But that would be reserved for another editorial.

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