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Editorial

Whither GIS (as systems and as science)?

After 30 years of technical development we have now reached the not unimpressive situation in which computer hardware and software have made it possible for us to record, display, store, analyse, deconstruct, or simulate very many kinds and enormous amounts of spatial information. We have GIS for making cadastral plans or topographic maps, we have image processors for analysing remotely sensed images, we have statistical packages for setting up and testing hypotheses, we have geostatistical packages for spatial interpolation, and much more. Moreover, we have been able to link models of planning or marketing, of ecology, of hydrological or meteorological or geological processes and the like to our spatial databases in attempts to capture the interactions between pattern and process in geographical space. In addition, GIS has become a multimillion business, an educational challenge and in some areas at least, a simple everyday tool that you might even find on the street as an aid to tourists seeking a hotel or restaurant.

Impressive though these achievements may be, they all rest on a simple set of shared concepts, namely that the essentials of the world can be reduced to a set of simple geographical entities (points, lines, areas, pixels). It is this power of discretization that has made the technology possible.

The links between the complexities of the real world and these simple entities are often seen as parallels with the linking of the simple atomistic or molecular concepts of physics and chemistry with the complexities of the biochemical and geochemical diversity on earth, not to mention the even larger complexities in animal and social behaviour. The basic assumptions are of stable, unchanging fundamental units that can be linked and rearranged in a multitude of ways to produce an immense range of possibilities. Yet the degree to which these assumptions hold determines the validity of the results of GIS analyses, whether we are dealing with a simple SQL retrieval operation or the modelling of groundwater flow through an aquifer. It is crucially important for drawing conclusions either with GIS models or tests of statistical hypotheses that the basic units do not change in unexpected ways that can affect the results. The 'shelf life' of geographic data could be defined as that period for which changes in the fundamental geographical entities have no significant effect on the results of analyses or models.

The problem of 'the shelf life' of geographic data is recognised by many, yet few are in a position to do much about it. Because data collection, input, storage and

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dissemination is such a large and demanding operation, it is only in disciplines with a short prediction horizon that data collection over time occurs rapidly. The prediction horizon for weather is about 3–4 days so regular daily data are necessary, but for other processes we very often just do not know. When we do not know, we have the tendency to assume that no knowledge of change means no change, so therefore we can continue as before.

In standard GIS there are very few examples of developments which provide theory and methods for dealing with the ultimate forms of change, which are that the basic building blocks of our discretisation of the world are themselves changed by the process operating on them, and by so changing may themselves also influence the way the process operates. Yet this occurs frequently. Think of the effect of irrigation on groundwater levels and how these may change the area, shape and salinity of nearby lakes in arid regions. Consider the impact of changing a traffic plan for a town on the optimum location and sales of particular kinds of outlets. These are everyday experiences that we deal with by assuming that form is fixed and process is governed by form, rather than by two-way interactions.

Developments in cellular automata and related areas where dynamic processes in space are modelled in the context of a continuously changing continuum are beginning to shed light on some of these situations in which process and form mutually interact. The methods not only throw light on ecological problems such as ants (Langton's ants cited by Casti, 1997) but also on urban development (Clarke and Gaydos, 1998; Couclelis, 1998) and physical processes in landscapes (Wesseling et al., 1996; Burrough, 1998). Intriguingly, these methods demonstrate how initial, small differences may rapidly lead to major and significant deviations that could not have been foreseen. When seen from a stochastic viewpoint, these findings show how purely random differences in initial conditions may lead to results that have a very different spatial form. On the other hand, it is also becoming clear that it is impossible to model certain complex processes such as the formation of debris fans, deltas or river meanders unless a small degree of randomness in the initial conditions has been built in.

Some scientists believe that with a 'theory of everything' it is possible to write a model that describes completely all the interactions of a stone falling down a hillside. Others (notably Terry Pratchett, Ian Stewart and Jack Cohen in *The Science of Discworld* and other more serious publications — Cohen and Stewart, 1994) explain the differences between *simplicity* — the regime in which simple assumptions of homogeneity hold, *chaos* — the regime in which structure disappears even though the driving process is deterministic, and *emergent order* in which new structures appear at a higher level than the original interactions.

Simplicity-chaos-emergent order: this trio should interest all geographers and earth scientists because it may be the essential link between different scales of behaviour. An essential and centuries-old problem in mapping is 'generalisation' and how to achieve it consistently. In environmental modelling a major problem is how to 'upscale' observations of, for example, soil erosion over an area of 1 m^2 to agricultural fields and subcatchments. This is not just a problem in space, but also in time. Which brings us back to the problem of the event horizon, which is linked to changes in both time and space. Can we (have we?) develop an understanding of the ways in which space–time interactions of key processes move through the phases of simplicity-chaos-emergent order? Clearly, the time horizon of weather is different from the time horizon of seasons, which is different from the time horizon of climate, yet all are interlinked, and the same can be said for many other natural and anthropogenic processes.

One thing is clear, and that is that standard static GIS, or standard static statistics, with their assumptions of fixed, immutable entities and homogeneity assumptions are not going to be of much help, except for providing the initial data and the means for storing and displaying data. New paradigms are needed and some interesting work has already been done. Modern computing environments including the humble PC are providing a laboratory in which these complexity issues can be studied. There are exciting times ahead.

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