Chapter 3.7
A Computational Agent Model of Flood Management Strategies

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ABSTRACT

A geographically explicit flood simulation model was designed and implemented as a tool for policy making support, illustrated here with two simple flood management strategies pertaining to the Upper Tisza area in Hungary. The model integrates aspects of the geographical, hydrological, economical, land use, and social context. The perspectives of different stakeholders are represented as agents that make decisions on whether or not to buy flood insurance. The authors demonstrate that agent-based models can be important for policy issues in general, and for sustainable development policy issues in particular, by aiding stakeholder communication and learning, thereby increasing the chances of reaching robust decisions. The agent-based approach enables the highlighting and communication of distributional effects of policy changes at the micro-level, as illustrated by several graphical representations of outputs from the model.

INTRODUCTION

In the period 1988-1997, the cost for major natural disasters was approximately USD 700 billion, according to 1998 figures from Munich Re, with floods causing around 50 per cent of economic losses (Abramovitz, 2001). As a result, policy makers at the national level are facing increasing costs for compensation and mitigation of floods. Most countries have a disaster compensation policy based on solidarity, in which the government compensates for losses that individual property owners suffer. A higher degree of private responsibility is a distinguishing feature for compensation policies in only a few countries, such as the UK and Australia.

Our simulation model estimates the economical consequences of floods, with respect to different flood risk management strategies. Part of the Upper Tisza river in the relatively poor Szabolcs-Szatmár-Bereg region of Hungary was investigated, with a focus on financial mitigation measures and insurance. For such a complex model—solving the kind of problem that Weaver (1948) famously dubbed a *problem of organized complexity*—to be useful, it must integrate data from different systems. In our case, this translates to geographical, hydrological, economical, land use, and social systems.

We seek to provide evidence for the usefulness of spatially explicit agent-based models in the domain of disaster policy management. In our model, the government, insurer, and property owner stakeholders are represented. Property owner agents are spatially explicit agents in the model, in that their properties have specific locations, affecting agent actions. In each simulated year, for example, the agent makes a decision on whether to buy insurance or not, for a particular property. In a simulation, the model is run to cover a long period of time, normally 50 years. Floods of different magnitude occur stochastically and cause damages to properties in the area. A flood causes either a levee failure or seepage. Different flood management strategies are tested and compared, and a strategy can implement a policy, e.g., subsidy insurance premiums for all poor households and set the compensation level from government to 50 per cent of property loss. The financial consequences for all stakeholders are then estimated at the end of each simulation round.

In the following section, we frame our work inside the field of related research. The third section describes our model, the fourth presents two policy scenarios and their analysis, and the final section gives our conclusions.

BACKGROUND

While the agent area started off with artificial intelligence assistants, service robots, and many other forms of one-agent systems (Agre & Rosenschein, 1996), the potential for societal applications naturally reside with multi-agent systems (O'Sullivan & Haklay, 2000; Gimblett, 2002). In geography, physical components of a complex system—vegetation, fauna, soils, and climate/hydrology—are usually separated from socio-economic ones, like demography, culture, economy, and policy (Reenberg, 2001). An agricultural management strategy then advices and implements a policy by carefully considering those two sets of components separately. An agent-based model like our own, by contrast, lets the stakeholders be represented by agents taking actions in various states of information and in various geographical spaces, in situations where agents are informed of all components to very different extents. Heterogeneity in the agent population is thus an important feature (Wooldridge, 2002).

In microsimulation, the population is usually homogeneous. Early models (Orcutt 1957; Orcutt *et al.*, 1961; Hägerstrand 1975) purported to address the shortcomings of the macro models then reigning in economics, demography, and geography (Merz, 1991), a promise delivered on as computing power became available with which to execute models in scenario analysis fashion (Caldwell & Keister, 1996). The development in computer hardware and software has naturally also benefited agent-based simulations, making them a widely used complement to mathematical theorizing (Axtell, 2000). When to go for agent heterogeneity and when the simpler microsimulation models suffice is a question part of a methodological scientific development still in rapid progress (Boman & Holm, 2004), but agent-based social simulations have proved increasingly important to policy making (Polhill, Gotts & Law, 2001).

The computational model reported on here has in part been discussed in academic theses

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