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Choosing agent types for a spatial decision support system for Auckland city

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Spatial models are frequently used as decision support systems, tools to explore possible future developments of a city, region or country. Given that most of those spatial developments are driven by human action and interaction, agent based approaches are a logical choice for simulating these processes, as agents are a natural representation of actors that make decisions. Over the past decade, several prototypes and more advanced simulation models have been reported that claim to include agents, or at least include agent behaviour. When analysing these different models, it quickly becomes clear that the definition of *agent based* in spatial modelling is rather broad and varies in the way decision-making bodies are perceived and represented in the model. Additionally, agent based models are often associated with complex systems and emergence, where the latter refers to global properties that originate from strictly local interactions. However, urban dynamics are typically driven by a combination of top down and bottom up effects. Top down effects include macro-economic drivers and most policy decisions, such as taken by the government. Bottom-up effects at the other hand are those effects that results from many decisions of local actors, such as congestion, or the formation of land prices.
In this presentation we will explore different types of agent-based models that currently are described in literature and evaluate them for inclusion in an Integrated Spatial Decision Support System (ISDSS) that incorporates top-down and bottom-up processes and aims to support planning in an urban environment.

By some, cellular automata (CA) are considered agent-based models (White and Engelen, 2000). They are by now commonly applied to address land-use changes, and urban growth in particular. CA consists of a lattice of cells. Each cell has a state that represents its predominant land-use type. Cell states can change according to a set of transition rules which include the influence of neighbouring land uses. In fact a location, represented by a cell is considered the decision making unit, hence the agent.
Constrained CA models are a special type of CA models in which a cell state is no longer a function of a location and its neighbourhood only. In fact the amount of cells to be allocated for a land use type is now defined externally, while the CA itself determines the exact allocation. Hence the land use is the agent, which searches for the optimal location for its activity. In that process it can face the competition of other agents (land-use types) that are also looking for a suitable location.
However, in this paper we focus on agents that are added to a cellular framework. In such cases, land use establishes itself on a lattice, while dynamics are driven by agents that act on top of this land use layer. For a true agent based approach agents are considered to be actors that act on top of the spatial representation of the landscape, such as population looking for a location to live, or companies looking for a location for their activities. Based on existing literature we defined three distinctive, but somewhat overlapping types.

Recently, cellular automata models have been expanded with more detailed information on the activities that are taking place on a location, such as its number of inhabitants, or the number of jobs. This addition to the CA framework is named Activity-Based modelling (Van Vliet et al., accepted). It bears resemblance to the constrained CA framework as the amount of activity is defined exogenously, while the model allocates this activity on the lattice. This allocation however is purely bottom up as it considers only local and neighbourhood characteristics. Still, in the Activity-Based CA model, the cell is still the unit of computation and not the agent. The advantage of this approach to conventional CA is that it allows for a diversity of densities per cell, and, because activities are not strictly related to land uses, mixed land uses can be included. This approach allows for incorporation of human behaviour, but agents are not yet units that make decisions themselves.

Agents that represent a group of actors can interact on a high level. These agents can for example be used to simulate competition and interaction between environmentalists and locals (Ligtenberg et al., 2005). Their interaction is global, and after that their result is visible local. Interaction between agents in itself does therefore not take place at the local level. Therefore these agents are particularly suitable to simulate top down effects.

Finally, the closest one can come to approach human decision making is to simulate each individual as an agent. This has the obvious benefit that behaviour can be approached closely. Individuals have been represented as agents in small scale models, for example in an economic context, or to evaluate evacuation plans. On a somewhat larger scale, agents have been used to represent units that take their decision locally, such as families, companies or farmers. A well known example is the studies of Anasazi settlements in Longhouse Valley (Dean et al., 2000).

However, processes like land-use change and urban growth are typically not represented at this lowest level, as indicated from the overview presented in Parker et al. (2003). The most obvious drawback for this approach is that a typical urban growth study would comprise a large number of agents which makes such study computationally very demanding. Additionally an urban growth model that uses individuals or families is agents will bee very data demanding. At the same time, one can argue if it is really necessary to simulate behaviour at that level.

This presentation summarizes three types of agents that have been reported in spatial models and reviews some of their pros and cons for incorporation in decision support systems for urban environments. Specifically, the overview examines what type of decision a specific type of agent can make. Related to that is the scale at which this decision takes place, and the amount of information that is required to make this decision. Finally, some practical issues are considered, such as the data required for model application, calibration and validation, and the type of information that can be obtained from it.

The review is made in the context of the Sustainable Pathways project (http://www.sustainablepathways.org.nz/) in which an ISDSS is being developed with applications to Auckland and Wellington City.

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