

Integration of genetic agents and cellular automata for dynamic urban growth modelling

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1. Introduction

The complexity and dynamics of urban systems make the applicable practice of urban modelling very difficult. This is one of the reasons why Lee (1973) made an attempt to bury urban modelling by enumerating the “Seven sins” of large scale models in planning. But Lee’s “Requiem” also evoked our critical thinking on where the future of urban modelling lies and how to enrich model-building in order to make them more applicable.

Several decades of changes in society, science and technology, especially in computer science and information technology are going to forgive (or have already forgiven) Lee's sins (Rabino 2007). The third phase of urban modelling and fifth-generation modelling systems are acknowledged to have the features of integrating artificial intelligence (AI) technology and computational hybrid-dynamics into a single system to furnish assistance for non-experienced users. Cellular automata (CA) based models and agent based models (ABM) are flourishing in this generation. The increasing use of AI approaches has led to a new generation of urban growth models, in which dynamic models based on fine-scale cells and individual behaviours involving agents has begun to find favor to enhance the existing interaction and synchronization between different scales over the model and capture the emergent phenomena resulting from the interactions of individual entities.

In this paper, we present an integrated model that incorporates ABM, CA and genetic algorithm (GA) to include both spatial and aspatial dynamics in an urban system in order to supply a new solution for urban studies. In our model, the social economic behaviours of heterogeneous agents (resident, property developer and government) will be regulated by GA and Theory of Planning Behaviour (TpB). The macro level of emergence (e.g., land pattern change) which is produced by the interactions at the micro level (the heterogeneous behaviours and interactions between agents, and the discrete spatial dynamics represented by CA) will also be analyzed.

2. Theoretical basis

2.1 inclusion of both spatial and aspatial dynamics in urban modelling

Urban land change phenomena include spatial and aspatial dynamics. However, it seems most of the traditional economic and geographic studies tried to separate the two entities associated with land use change, human decision-making and environmental consequences, into two separate models (Sethuram et al., 2008).

So we defend that the inclusion of CA for spatial dynamics and ABMs for aspatial dynamics is a better solution for urban modelling. CA has evolved greatly from its initial concepts, many functions have been improved (e.g., action at a distance, calibration and definition of transition rules) to make CA more flexible and efficient approach for urban studies. However, poor aspatial representation in a CA still limits its ability to reflect the feedback of system and social economic influence on decision making. This can be

improved by incorporating agent based models for their ability to represent the impacts of autonomous, heterogeneous, and decentralized human decision making on the landscape. Thus, it seems, the hybrid model, which is composed of CA and ABM, is a more appropriate method for urban modelling since it possesses the advantages of both CA and ABM (Nara and Torrens, 2005).

2.2 Theory of planned behaviour and decision making mechanism of location choice

Most of the traditional economic studies model human actors only as utility maximizing functions (Ormerod 1994). This is against the norm of most human psychological studies that argue most humans make decisions based on cognitive limitations and bounded rationality (Simon 1957). Individual user decisions on choosing an innovative product is not only a function of the benefit and cost of the product, as described in economic theories, but also, and in some cases perhaps more so, a function of the factors from the user's psychology and the social networks in which the users participate (Zhang and Nuttall 2008). The theory of planned behaviour (TpB) (Ajzen 1985) is a theory about the link between attitudes and behaviour. So, the social network influence on residents' decision and the multiple social behaviours of resident agents can be modelled by TpB. As bounded rational agents, rather than trying to find an optimal solution that fully anticipate the future states of the system of which they are part, they make inductive, discrete, and evolving choices that move them towards achieving goals or levels of aspiration (Simon 1957, Rabin 1998).

2.3 The behaviour regulation of agents with genetic algorithm

GA models can represent decision-making processes that lead to specific spatial actions, so it is important that their behavioural roles are very apt to model individual agents and their behaviour (Silva 2008). It works as a high level pattern of 'human behaviour', which produces solutions for the behaviour choices of 'human' agents in a social-economic environment. With GA, the agents' complex decision-making processes are modelled as adaptive agents which include agents that represent entities and the behaviour regulations that GA exerts on them. So the incorporation of GA into agents as genetic agents might provide a better solution for regulating the behaviour of agents.

3. Concept framework of model

The framework of the model mainly includes three components: three heterogeneous agents (Resident agent-R, Developer agent-D and Government agent-G), cellular automata model (based on SLEUTH), and a GA (Roulette wheel selection). The spatial environment in the model includes land use attributes (slope, land use, excluded, urban, transportation, hillshade), land price distribution, surrounding environment. Aspatial environment includes a virtual real estate market, social network, government policies and casualty problems.

The basic logic in the model is that the three heterogeneous agents interact with each other and the socio-economic environment imposed to them, as well as the spatial environment which is provided by cellular automata model (SLEUTH). The behaviours of actors in the model are governed by Genetic algorithm (GA) and Theory of Planned Theory (TpB). In the virtual market, developers make development plans based on residents' preferences of location choice, and the submitted development plans will be

evaluated by government. At the same time, the interaction between agents and SLEUTH will also be considered in the model.

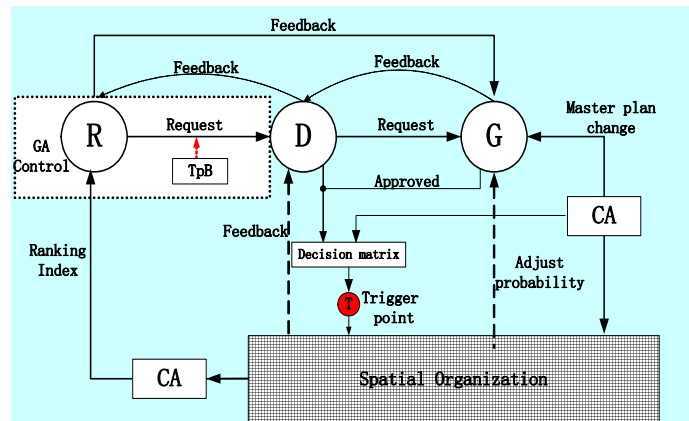


Figure 1 Concept framework of model

The decision processes mainly based on the interactions of different actors as well as the interactions between actors and the environment. There are mainly four decision tables which reflect the four important processes in the system and trigger different behaviours: (1) Resident agents' utility table, which is controlled by TpB model and represents the requests of residents to developers about their demands on locations. (2) The developer agents' development decision table, which represents the responses of developers to residents' requests, and their development applications which will be submitted to government after evaluation. (3) The government's approving table, which reflect the government agents' responses to developer agents' development applications, all the approved applications will be read by developer agents in order to execute developments. (4) Synchronized decision table, which represents the synchronized decision matrix between the agent based model and SLEUTH model on land use change.

3. References

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