Chapter 25
DG-ABC:
An Integrated Multi-Agent and Cellular Automata Urban Growth Model

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ABSTRACT

Urban land change phenomena include spatial and a-spatial dynamics. As Holland (1995) suggests "a city's coherence is somehow imposed on a perpetual flux of people and structure." However, it seems that most of the traditional economic and geographic studies have tried to separate the two entities associated with land use change (human decision-making and its spatial consequences), into two separate models (Sethuram et al., 2008). In order to explore the two fluxes (the spatial and a-spatial dynamics) this chapter presents an integrated model that incorporates ABM (Agent Base Model), CA (Cellular Automaton) and a Genetic Algorithm (GA) to include both spatial and a-spatial dynamics in an urban system in order to supply a new solution for urban studies. In the authors' model (DG-ABC stands for 'Developing Genetic-Agent Based Cells'), the social economic behaviours of heterogeneous agents (resident, property developer and government) will be regulated by GA and the Theory of Planned Behaviour (TpB). With a pilot study conducted in order to test and calibrate the model this chapter analyzes how the macro level of the spatial pattern change (the emergence phenomena) is produced from the interactions of actors at the micro level (by the heterogeneous behaviours and interactions between agents, and the discrete spatial dynamics represented by CA). The simulation demonstrates that the integrated model can provide reasonable representations of the future evolution of cities.

1. INTRODUCTION

Both the spatial dynamics of an urban system predicated upon, for example, biophysical variables (i.e., slope, soil type, and hill-shade) and the a-spatial dynamics based on the social economic variables (i.e., demography, social network and economic utilities) are essential to urban modelling. However, it seems that most traditional economic and geographic studies try to separate the two entities associated with land

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use change, human decision-making and environmental consequences, into two separate models (Soman et al., 2008; Wu & Silva, 2009c; Wu & Silva, 2010). As a result, two research streams can be detected: in one of them cellular automata are decisive to the understanding of complexity across spatial scales, and the other one focuses on behavioural and social systems complexity (Silva, 2004; 2008). This study proposes that the integration of CA and Agent based model might be a better solution for urban dynamics modelling and answer in a better way to the wave of complexity represented by urban phenomena.

In this paper, a genetic agents and cellular automata based model is presented, which incorporates agent based modelling, CA and GA (Genetic Algorithm), with both spatial and a-spatial dynamics included in an urban system in order to supply a new solution for urban growth phenomena studies.

Urban land use dynamics are the direct consequence of the actions of individuals, public and private corporations acting simultaneously in time over the urban space (Barredo et al., 2002; 2003). The urban land change partly emerges from the micro interactions of residents' and developers' location behaviours and discrete choices they make (Batty 2007, Li & Liu, 2007; Waddell, 2002). However, most traditional economic studies model human actors only as utility maximizing functions (Ormerod, 1994). To some extents, this is against the norm of most human psychological studies which argue that most humans make decisions constrained by cognitive limitations and bounded rationality (Simon, 1957). To take into account these different perspectives of land use change in this model, the social economic behaviours of different agents (resident, property developer and government) are regulated by GA and the Theory of Planned Behaviour (TpB) (Ajzen, 1985).

The structure of the chapter is as follows: First, it presents the overview of the integrated model, and describes the most important components of the model. Next, it discusses the modelling environment including spatial and a-spatial environments with which the actors interact. Third, model's multi-actors (the heterogeneous agents and CA) are introduced. Then the dynamic behaviours of agents are described. Following this, the integration and synchronisation processes of agents and CA are introduced. This research then presents a pilot study of the integrated model to analyze the applicable practice of the model. Finally, this chapter concludes with a discussion of a potential path for transferring the model to an empirical context.

2. CONTEXT: THE USE OF CA, GA AND ABM IN URBAN MODELING

Land change is driven by the combination of synergetic spatial and a-spatial factors, which trigger the dynamic process of land change with their interactions. At the same time, urbanization of cities and the changes in physical, social and ecosystem aspects that result from urban growth provide feedback to the drives of land change – and this requires the inclusion of the dynamics of land change.

The pitfalls of traditional analytical methodologies, particularly the static and top-down approaches of traditional modelling such as linear and mathematics modelling, limited the insight into the dynamic complexity and nonlinear properties of land change. Until recently, the great strides of computer techniques, and in particular, with the areas of complex analysis and artificial intelligence coming into the field of spatial analysis during the 1970s (Tobler, 1979; Batty, 2007; Silva & Clarke, 2005; Silva, 2008), fundamentally changed the traditional methodologies are providing deeper theoretical insight into the dynamics of land use change. Artificial intelligence is now explored in many scientific fields as it is more inclusive and allows to include high levels of complexity in the modelling process that previous models couldn't represent.