Literature revision
Agent-based models

R e p o r t 1 2

Universitat Politècnica de Catalunya

Centre de Política de Sòl i Valoracions

UPC-CSPV

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Eduardo Chica Mejía

Personal de recerca
CPSV

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The ABM originates from the field of artificial intelligence (Matthews *et al*, 2007) in the mid-eighties of the 20^{th} century. However, in the 1950 and 1960 appeared the first theoretical backgrounds about ABM, primarily with the formulation of *general systems theory*, developed by Bertalanffy and *theory of dissipative structures* proposed by Prigogine (Reynoso, 1998); secondly with the emergence of Cellular Automata, proposed by Von Neumann and Stanislaw Ulam in the 1940s. Both researchers were dedicated their studies to self-reproduction and to modeling biological life, trying to devise a mathematical formulation, which could reduce the forces governing reproduction to logical rules (Torrens (2000) cited by Pinto & Antunes, 2007).

The most important development of ABMs occurs in the 1990's, when its use was popular in different branches of knowledge, including social sciences and those related to the study of the territory (Gilbert & Terna, 2000). However, the incorporation of the computer simulation, one of the characteristics of ABMs occurs early, especially as a research methodology adopted in the natural sciences and engineering (Zeigler (1976) cited by Gilbert & Terna, *op cit*).

In parallel with its implementation in the modeling of various natural and social phenomena, the theoretical discussion of the ABM will be extended during the last decade of 20^{th} century until today, especially in the design and study of the intrinsic characteristics to the agent and the modeling agents. The intelligent agent is defined by Wooldridge & Jennings (1995), as a software entity situated in an environment capable of exhibiting flexible autonomous behavior, in order to achieve their own goals, responding to properties of autonomy, social abilities, reactivity and proactivity. Luck *et al.* (2003) difference objects from agents, the second defines as autonomous entities capable of taking decisions, unlike objects, whose decision is taken by the model developer. For Brown & Robinson, one of the important issues related to the agents is the adequate reflection of the heterogeneity of the real world they represent.

The different applications that ABMs have, make the research in this field takes concepts from many domains. The definition proposed by Ferber (1999) (cited by Matthews *et al,* 2007) is quite cross at all. He defines the ABM as a number of agents, which interact among themselves and their environment, are capable of making decisions and therefore change their actions as the results of this interaction Agents may contain their own “model” or their environment built up from its interactions. The behaviour of the whole system depends on the aggregated individual behaviour of each agent.

Axelrod (1997) has termed ABM the “third way” of making science. It is an amalgamation of the two traditional approaches, both inductive and deductive. In the ABM the results emerge from a defined set of rules developed from previous real-world observations.

The fields of application of ABMs are diverse. Bonabeu (2002) defines four distinct application areas: flow simulation, market simulation, diffusion simulation and organizational simulation. The last one is of the most interesting application of ABMs and useful for the analysis and modeling of land use and other territorial processes The earliest published work appears to be the study of Lansing and Kremer (1993), who have modeled irrigation system in Indonesia (Matthews *et al,* 2007).

In this approach ABMs have been especially useful to simulate the behavior of people, primarily in terms of series of territorial issues and secondly, considering their location decisions in the city, as well as configuration of settlement patterns. Matthews *et al,* 2007 highlights different studies such as Berger (2001) in Chile, who studied the dynamic impacts of free trade policies on a large agricultural region in terms of the diffusion of specific innovations and the research of Vanclay *et al* (2003), who built a model, called FLORES, with the aim of providing a tool for policy-makers to anticipate the likely outcome of proposed decisions on communities living at or near forest margins in tropical areas, that was developed in Sumatra, Indonesia. Other researchers, such as Parker & Meretsky (2004) explore the impacts of distance-dependent spatial externalities and transportation cost on patterns or urban development and land-use. Brow *et al* (2004) evaluate the effectiveness of locating greenbelts near developed areas, for delaying the development process. Loibl & Toetzar (2003) used similar approach to understand growth and densification processes in suburban Vienna. In this case, household agents choice of where to live, based on factors such as accessibility, land prices, landscape attractiveness, social and commercial services supply, zoning constraints. Others *et al* (2001) simulate the relative location patterns of households and firms in the city, in order to understand if their patterns are in clusters or sprawl.

Brown & Robinson (2006) developed one interesting methodological exploration about of capacity to ABMs to represent heterogeneity in the characteristics and behaviors of people in order to analyze the residential preferences considering urban sprawl in Michigan, USA. In this case, residential locations are selected by residential agents, who evaluate locations on the basis of preference for nearness to urban services, including jobs, aesthetic quality of landscape and their similarity to their neighbors. Results suggest that adding heterogeneity to agents has a significant effect on model outcomes, measured by aggregate patterns of development of sprawl and clustering.

Other models are being developed that have relevance to it in more detailed urban scale, which analyzed pedestrian and car commuter around the city. Maty (2007) highlights the Helbing & Molnar (1995) and Langton's (1995) research. For Maty, the importance of studying the small scale is that it captures the global properties of urban systems, in a way that local responses are usually consistent with macro properties of the urban system.

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