A Theoretical Learning Model Combining Stochastic Cellular Automata and Economic Indicators to Simulate Land Use Change

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ABSTRACT

The study of change in land use has been included in territorial planning to inform spatial planners and policy makers of the possible developments they face in order to optimize future management decisions. In this paper the authors present the core of an original learning model coupling stochastic Cellular Automata and economic indicators to simulate the land use change. This model is an important step in building an “environmental virtual laboratory” to explore, explain and forecast land use change.

Keywords: Cellular Automata, Land use Change, Reinforcement Learning, Stochastic Model

1. INTRODUCTION

The study of change in land use has been included in territorial planning to inform planners and policy makers of the possible developments they face in order to optimize future management decisions (Francesco Riccioli et al., 2013). Land use change is characterized by complex interactions among socio-economic activities (urbanization, agriculture, economic development...), cultural transitions and biophysical environment factors (land degradation, climate change...) occurring at multiple temporal and spatial scales (Hao Wu et al., 2012). The main driving forces for land use change are usually based on economic reasons, an increasing need
to conserve environmental and population growth (Meertens et al., 1996; Lambin et al., 2003; Alfred E et al., 2008).

Jonas van Schrojenstein Lantman et al. (2011) in an exhaustive analysis of the literature of (i) theoretical concepts and (ii) core principles of land-use change have concluded for the former (i) that the most used theoretical concepts of land-use change in modeling are Cellular Automata, Statistical analysis, Markov chains, Artificial neural networks, Economics-based models and Agent-based systems, and for the latter (ii), they have found that all simulation models of land use are based on at least one of the following four principals:

1. Continuation of historical development;
2. Suitability of land (in monetary or other units);
3. Result of neighborhood interaction; or

Cellular Automata are largely used to simulate land use change for urban environments (White, R. and G. Engelen, 1993, 1997, 2000; Benenson, I. and P. M. Torrens, 2004). In last few years, it was proved that Cellular Automata model can simulate and predict the spatio-temporal dynamic of land use change more easily and accurately compared with traditional model.

In this paper the authors present the core of a generic model coupling stochastic Cellular Automata and Economic indicators to simulate land use change. This model can be adapted to support other factors as socio-economic, population growth, cultural and environmental.

2. THE MODEL

A basic Cellular Automata model consists of four elements: cells, states, neighborhoods and transition rules. Cells are the units, which manifest adjacency or proximity. The state of a cell can change according to transition rules, which are defined in terms of neighborhood functions and other suitability criteria (Novaline Jacob et al., 2008). This model has the following characteristics:

2.1. The Cell Space

The cell space consists of a two-dimensional rectangular grid of macroscopic square cells. In this model it is possible to find many land uses (or related activity types: urban use, agriculture use...) at time $t$ in a cell $i$. So, the study area will be divided in $N$ subareas/cells, indexed by $i=1, 2, ..., N$. The defined system has $M$ different land uses, each of them represented by a value $k$, $k \epsilon \{1, ..., M\}$.

The surface $S_i$ of the cell $i$ is defined as

$$S_i = \sum_{k=1}^{M} S_i^k$$

where $S_i^k$ is the surface of the land use $k$ in cell $i$.

2.2. The Cell States

The authors have already assumed that a cell $i$ can have many land uses at time $t$ (see Figure 1). The probability of a land use $k$ in cell $i$ at time $t$ is given by
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