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Errors and uncertainties in urban cellular automata

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Abstract

Errors and uncertainties are important issues in most geographical analyses and modelling processes. Cellular automata (CA) have been increasingly used for modelling geographical phenomena, such as the evolution of urban systems. Urban simulation frequently involves the inputs of a large set of spatial variables from GIS. The errors of data source in GIS can propagate through CA modelling processes. Moreover, CA models themselves also have modeling uncertainties because they are just an approximation to reality. These uncertainties have impacts on the outcome of urban simulation. Identification and evaluation of these errors and uncertainties are crucial for understanding and implementing the simulation results of urban CA modelling. It is found that some of the characteristics of errors and uncertainties in urban CA are quite unique which are not present in traditional GIS models. The study can help urban modelers and planners to understand more clearly the characteristics and implications of CA modelling.
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Keywords: Uncertainty; Cellular automata; Urban simulation; GIS

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1. Introduction

Errors and uncertainties are important issues in the GIS literature. Compared to traditional methods (e.g. manual overlay), GIS provides more powerful functions and accurate information based on computer technology. However, GIS are not free of errors and uncertainties because of human errors, technical limitations and the complexity of nature. GIS databases are approximations to real geographical variations with very limited exceptions (Goodchild, Sun, & Yang, 1992). Understanding of errors and uncertainties of GIS is important for successful applications of GIS techniques. There are two main types of GIS errors: (a) data source errors that exist in GIS databases; and (b) error propagation through the operation performed on the data by using GIS functions.

There is a growing trend of using cellular automata (CA) to study geographical phenomena. CA were originally developed in digital computing and have been widely used for simulating complex systems in physics, chemistry and biology. Recently, a number of urban CA have been proposed to model complex urban systems with the integration of GIS (Batty & Xie, 1994). Urban CA have much simpler forms, but produce more meaningful and useful results in simulating urban dynamics than mathematical-based models. Temporal and spatial complexities of urban development can be well simulated by appropriately defining transition rules in CA models. The application of CA in urban modeling can give insights into a wide variety of urban phenomena. CA are capable of providing important information for understanding urban theories, such as the emergence and evolution of forms and structures (Webster & Wu, 1999; Wu & Webster, 1998). They are also used as planning models for formulating development scenarios (Li & Yeh, 2000; Yeh & Li, 2001, 2002).

Although there are many studies on urban CA, however, the errors and uncertainties of CA have not attracted much attention. Only a few studies have been carried out by examining the 'sensitivity' issues of CA (Benati, 1997). Huge volume of geographical data is usually used in urban CA simulation, especially in modelling real cities. Spatial variables can be retrieved from GIS and imported to CA modeling processes. Like other GIS models, urban CA also has problems of data errors and model uncertainties. These errors will propagate in CA simulation and affect the simulation outcomes. This requires the evaluation of the influences of source errors and error propagation on simulation results. This paper attempts to examine the influences of errors and uncertainties on urban CA simulation. This can help urban planners to be aware of these issues when CA are used for projecting and modeling future development in urban planning.

2. Uncertainties in urban CA

Urban CA models are subject to errors and uncertainties when they are applied to real cities. It is because urban CA models are quite different from Wolfram's deterministic CA models (Wolfram, 1984). Wolfram's models have strict definitions and

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