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# Simulation Study on CA Model Based on Parameter Optimization of Genetic Algorithm and Urban Development

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## Abstract

This paper presents a new method to calibrate urban cellular automata (CA) using genetic algorithms (GA). The GA is used to find the optimal parameter values so that CA models can simulate urban expansion in a more realistic way. Traditional multi-criterion evaluation (MCE) and logistic methods have limitations for deriving the transition rules of CA models. The variables should be independent so that the parameter values (coefficients) can be properly estimated by regression analysis. This assumption is not true in most situations the limitations can be overcome by using GA to estimate these parameter values for these correlated variables. This method is applied to the simulation of urban expansion in Dongguan, a fast developing city in the Pearl River Delta in South China. The model is able to simulate urban Development in 2004-2010 by using the training data from remote sensing data. The analysis indicates that the proposed model can produce better simulation results than MCE based CA models and logistic calibrated CA models.

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*Keywords:* cellular automata; genetic algorithms; urban expansion .

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## 1. Introduction

Cellular Automata (CA) is a cell space consisted of discrete cells with finite state, at the same time, is also a dynamics system evolved in discrete time dimension according to certain local rules [1]. In recent years, CA has already increasingly been applied in geosciences simulation and many significant study results have been acquired [2, 3]. For example, White along with the team workers have simulated the changes of the land utilization in Cincinnati by applying the restricted cellular automata[4]; Wu has simulated the urban sprawl of Guangzhou[5]; Li Xia and Ye Jia have simulated the expansion situation of the land utilization and urban sprawl of Dongguan[6]. All these researches indicate that CA can simulate

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the characteristics very close to the actual urban and the simulated results are in accordance with the reality.

This paper applies the genetic algorithm to optimize the parameters of CA model and has acquired the optimized parameters of CA model with the self-adapting method after the evolution strategies of encoding the chromosome, establishing fitness function, selecting genetic operator and ensuring genetic algorithm. The optimized CA model applied the genetic algorithm simulates the urban sprawl of Dongguan in 2004-2010.

## 2. Research approach

### 2.1. Genetic algorithm (GA)

Genetic algorithm is the global probability search algorithm based on the biological evolution like natural selection and hereditary variation. Genetic algorithm is an iterative method in form, the same as the analytic method based on derivative and other heuristic search method. Start from the selected initial solution, gradually improve current solution via constant iteration until finally find the optimal solution or satisfied solution. In the genetic algorithm, the iterative computational process adopts the evolution mechanism simulated the organism, start from a group of solution(groups), adopt the way similar to the natural selection and sexual propagation on the basis of inheriting the original excellent genes to form the next solution group with better performance index[6].there into, coding of the parameter, setting of the initial group, design of the fitness function, design of the genetic operation and setting of the controls parameter are the five elements of the genetic algorithm. Steps to apply the genetic algorithm to optimize the problem solving are as follows:

(1)Chose the coding strategy to transform the parameter gathering X and domains into string structure space S;

(2)Define fitness function  $f(x)$ ;

(3)Confirm the genetic strategy including chose the population size n, selection, crossover and variation methods and confirm the crossover probability  $p_c$  and variation probability  $P_m$ ;

(4)Randomly initialize the formation group P;

(5)Calculate the adaptive value  $f(x)$  behind the individual string decode in the group;

(6)Act the selection, crossover and variation operator on the group to form the next group according to the genetic strategy;

(7)Judge whether the performance of the group is satisfied with an index or has finished the scheduled iterations, if not, return to step 6 or return to step 6 after revised the genetic strategy.

### 2.2. CA model based on the genetic algorithm

The research shows that the urban development probability of the cellular is mainly related with the variables such as the situation of the cellular in the closed range, the shortest distance from the commercial center, the shortest distance from the residence center and the shortest distance from the streets when CA model simulates the urban development [1]. When simulating the development of the actual urban, all these parameters of the variables need to be revised by the historical data and the logical regression model is usually used to revise the parameters of CA model. On the basis of the logical regression model, the time of a certain cellular  $t+1$  develops into the probability of the urban land utilization Eq. 1:

$$P_{d,ij}^{t+1} = RA \times \frac{1}{1 + \exp(-z_{ij})} \times \Omega_{ij}^t \times \text{con}(s_{ij}^t) \quad (1)$$

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