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Research Article

Ancient Jing De Zhen Dong He River Basin Kiln and Farmland Land-use Change Based on Cellular Automata and Cultural Algorithm Model

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Abstract: The aim of this study is to understand how farmland has transformed kiln in ancient Jing De Zhen Dong He River Basin; we created ancient virtual maps of study area and conducted a series of spatial analyses of the land-use pattern from the Yuan Dynasty to the Ming Dynasty. The results of the spatial analysis show that kiln can evolve from farmland, shrub, idle land etc. To simulate land-use change we developed a novel cellular automata model. Model parameters and neighborhood rules were obtained with the cellular automata model melt modified cultural algorithm. Virtual land-use maps from the Yuan Dynasty to the Ming Dynasty were used to implement the model with a time step of one year. Model performance was evaluated using Moran's I index estimation for selected landscape pattern indices. The optimized parameter set using Particle Swarm Optimization poorly simulated land-use change as compared to the optimized parameter set using Cultural Algorithm. In summary, our results proved that the model is also effective and feasible in simulating farmland and kiln land-use evolution in ancient times when Geographic Information and System information were lacking.

Keywords: Cellular automata, cultural algorithm, evolution, farmland, kiln, particle swarm optimization

INTRODUCTION

Much of jingdezhen's ancient kiln site research has taken place in Nan He river basin (Lin *et al*., 2008). However, less is studied of the ancient kiln site development in Dong He river basin. Due to the less accessibility to the data, relatively little literature has been found on how the ancient kiln site evolves in this region. For revealing how ancient kiln has transformed Dong He River Basin landscape in Jing De Zhen-Jiang Xi Province of China, we analyze the pattern of land-use change in this region (Jenerette and Wu, 2001). Thus, a spatially explicit model for simulating land-use change was developed. Our modeling objective was to simulate how geographical environment has affected the kiln landscape of Jing De Zhen Dong He river basin.

To accomplish this we created a novel Cellular Automata (CA) model. CA was the typical simulate tool of geographical landscape evolution and suitable for modeling processes where neighborhood influences. Traditional CA model in landscape simulation almost do not use detailed spatial data, cannot consider complex spatial decision behavior (Li and Yeh, 2000), to simulate the actual landscape evolution obviously insufficient. To simulate the actual landscape evolution process, it is necessary to expand the traditional CA model, therefore, while solving spatial decision and optimization problem, the spatial information processing and search ability is the key, in a large number of spatial data quickly to search the optimal solution, artificial intelligence algorithm or evolutionary algorithm is introduced in CA model, is used to solve the Non-Deterministic Polynomial problem (NP) of enormous search space (Li and Yeh, 2005; Openshaw and Openshaw, 1997; Wie and Chai, 2004). Because of this study studies the evolution of kiln site problem lack the information of GIS in the ancient times, this should adopt traditional CA model method for research, but through the computer technology structure of ancient virtual map contains a lot of grid data, so the CA model combined with evolutionary algorithm method to carry on research. In this model spatially transition probabilities of land-use changes were dependent upon these candidate locations using cultural algorithm to calculate and the suitable conditions of these candidate locations and neighborhood influences. Similar frameworks have become popular for describing land-use change in a spatially explicit context (Li and Yeh, 2005; Wu and Webster, 1998).

To solve the complex spatial optimization problems, traditional evolutionary algorithm become effective methods because of their characteristics, such as implicit parallelism and random search (Guo *et al*., 2011). In order to effectively utilize implicit evolution information, Reynolds proposed cultural algorithms which are derived from human culture evolution

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process (Reynolds, 1994). Cultural algorithm is a class of evolutionary social system which was inspired by the evolution taking place in the society and which is used in solving optimization problems in various domains (Srinivasan and Ramakrishnan, 2012). Cultural algorithm is adopted a double evolution mechanism consisting of population space and belief space (Jin and Reynolds, 1999), the population space is a set of possible solutions to the problem are realized, in belief space, implicit knowledge is extracted from better individuals in population and stored in a different way. In human societies, culture can be viewed as a vehicle for the storage of information that is potentially accessible to all members of the society and that can be useful in guiding their problem solving directions (Xue and Guo, 2007), therefore, the whole process has purpose and direction evolution, beyond biological evolution that relying solely on biological genetic. Because of the interdependence of time and space, we examined the effects of spatial on model performance by iterating the model at both Cultural Algorithm and Particle Swarm Optimization. Thus, one of the aims of this study was to evaluate model performance at different algorithms.

The objective of this study is to create the cellular automata and cultural algorithm Model and using the model to examine the abilities of optimization to achieve this dynamic spatial transformation about land-use change in Jing De Zhen Dong He river basin. Our optimization is a comparison of result of using Cultural Algorithm and Particle Swarm Optimization modeling approach to estimate model. With the same model parameters, the simulated Moran's I index is closer to the actual Moran's I index under CA-CA model, proving that the model is more effective and feasible in simulating kiln landscape evolution in ancient times when Geographic Information System (GIS) information are lack and showing that selection the location of kiln can be assessed and trajectories projected both through a statistical extrapolation of the historical trend and through simulation modeling.

VIRTUAL MAP OF STUDY AREA

The study area selection: Jingdezhen City (east longitude 116°57′--117°42′, north latitude 28°44′--29°56′) is located in Northeast Jiang Xi Province. From current archaeological excavations, Jing De Zhen kiln landscape of the Chang Jiang waters mainly focuses on the Nan He and Dong He river basin with the right amount of water (Jia, 2012). This study has the representative kiln landscape evolvement of Jing De Zhen Dong He river basin as the research object. The indicative region is shown in Fig. 1.

Map building: Because Jingdezhen GIS information has not been established at present, it may not have similar satellite maps of it in the Yuan era historical period, which results in the detailed terrain of the study area at that time having no direct access. But by

Fig. 1: Experiment area schematic diagram

Fig. 2: Study area grid map

consulting relevant literature, we know Jingdezhen hasn't made Dong He diversion or moved the surrounding mountain over the years, which provides a basis for Dong He and the surrounding mountain plot position in the study area. In the actual drawing process, by comparison with the screenshot of the study area via Google Maps, located Dong He and the surrounding mountain plot can be first identified and then the plot information except mountain and river is randomly generated. Using this method, we can effectively explore the effect of the evolution of different geographical environment. This study only shows one of them.

In Flash CS 3.0 software environment, the indicated study area in Fig. 1 can be divided into 60 rows and 78 columns grid data by use of Action Script 3.0 language, each grid plot area is 20*20pixels, Using the above method to get the two spatial dimensions grid map. The map is shown in Fig. 2, in this map, indicates the idle land, the farmland, the clay mine, shrub, forest, the river and kiln.

MODELING METHOD OF CA-CA

Improved cultural algorithm: In order to use the cultural algorithm to searching for the optimal target grid in the two-dimensional space, we improved the original cultural algorithm as the following.

- **Integer-coded of population space and individual Position:** For randomly generated Population space in the initial state, that consists of the two-dimensional grid space, we expressed it by $P_n = [x_n, y_n]$. Here, n is population size and then P is uniformly divided into each individual with same size, denoted by p_i, i = 1, 2, 3, …n x denotes the coordinate of rows, Lower limit and upper limit of x is 1 and 60.y denot es the coordinate of columns, Lower limit and upper limit of y is 1 and 78. Namely, the values of the individual position are in the integer space. Thus, $x_i \ni \{1, 2, 3, \ldots 60\}$, $y_i \ni \{1, 2, 3, \ldots 78\}$
- **Definition of fitness function:** In ancient times, Jingdezhen Ceramic production used clay as raw material and wood as fuel and finished products were transported through rivers, so the development of a plot into a kiln to a large extent was affected by the distance from the river, the distance from the mountain and the distance from the clay mine. According to this characteristic, the fitness function of particle swarm optimization algorithm is defined as Eq. (1):

$$f(x,y) = \frac{1}{N}\sum_{i=1}^{3}\left((x-x_i)^2 + (y-y_i)^2\right) \tag{1}$$

where,

(x_1, y_1) = The nearest river coordinates away from the current grid
(x_2, y_2) = Nearest mountain coordinates away from the current grid
(x_3, y_3) = The nearest clay mine coordinates from the current grid
(x, y) = Current grid coordinates

Value of N is 2 or 3, when none of the river distance, mountain distance and clay mine distance is zero, N is 3; when one of them is zero, N is 2.

Cultural algorithm and cellular automata model: Cellular Automata general includes four elements of the unit, state, close range and conversion rules (Liu *et al*., 2008). The four-tuple equation is $A = (L_d, S, N, F)$, among, L represents the grid space divided by a rule, namely a cellular; d is the dimension of L, usually equal to 1 or 2; S means the state of each cell and is a discrete finite set; N is neighbors cellular; F is the conversion rules and is the corepart of CA. The state transition of each cell from the time T to T+1 is determined by the conversion rules.

To facilitate research, this study looks on the study area as an island, the division of the CA of the square grid space as an experimental basis, using the Moore neighborhood, fixed value boundary. Suppose map _maps is a 60×78 grid map, each grid cell is 20*20 pixels, cellular space $L = \{\_maps_{i,j} | 1 \le i \le 60, 1 \le j \le 78\}$, dimension d = 2 ,and state sets s = {0, 1, 2, 3, 4, 5, 6}, number 0-6 respectively stands for idle land, river, mountain, shrub, farmland, porcelain corresponding productive land(kiln), clay mine. Center Cellular _maps[i][j] has eight neighbors cell. The conversion rules f use the improved particle swarm algorithm, described as follows:

- Through improved cultural algorithm to determine the location of candidate target grids from 60×78 grid space, making the average distance from candidate target distance grid to the clay mine, Dong He and the surrounding mountain is the minimum. These regions will be developed into candidate land of the kiln
- To analyze the suitable conditions of the candidate land, if the suitable conditions are satisfactory, it can evolve into the kiln, or it can not. The adaptation function Eq. (2) will return [0,1], such as if the plot itself is river, the return value is 0; if it's mountain, the return value is 0.7; if it's shrub, the return value is 0.8; if it's farmland, the return valueis0.3; and if it's idle land, the return value is 0.5:

$$Con(S_{ij}^{t} = suitable) \tag{2}$$

Among them, S_{ij}^t represents the state of (i, j) block at t moment.

- Whether a block can be developed into a kiln is affected by its own conditions as well as by the surrounding neighbors cell, represented by the neighborhood function Eq. (3). Because the ancient ceramic production needed a large number of kiln men and the traffic was not convenient at that time, kiln men could only perch on the local village. If village is in the neighbourhood, the function value is 1; if mountain and river is in the neighbourhood, the function value is 1; if mountain is in the neighbourhood but river is not in, the function value is 0.6; if river is in the neighbourhood but mountain is not in, the function value is 0.8; if mountain and river is not in the neighbourhood, the function value is 0:

$$\Omega_{ij}^{t} = \frac{\sum_{3\times3} Con(S_{ij} = suitable)}{3 \times 3 - 1} \quad (3)$$

- Whether a region can be developed into a kiln can be obtained by the Eq. (4) and then set the probability threshold, if the result is greater than the probability threshold, it can evolve into the kiln; otherwise, it can't:

$$P_{ij}^{t} = Con(S_{ij}^{t} = suitable) \times \Omega_{ij}^{t} \quad (4)$$

EXPERIMENT SIMULATION AND ANALYSIS

Improved cultural algorithm in Matlab7.0 software programming can quickly search the candidate target block, then put the location of the candidate block into Flash CS 3.0 software and use Action Script 3.0 language programming to realize cellular automata model. After experimental simulation model is built, the evolution of the jingdezhen Dong He River kiln landscape from the Yuan Dynasty to the Ming Dynasty is simulated experimentally.

Simulation of the existing objective facts is the basic condition of judging a model is reasonable or not, however, the more important purpose of the model lies in predicting or deducing unknown facts. In this study, we simulated land-use change, respectively using Particle Swarm Optimization and using Cultural Algorithm, select two periods of simulation results in the Yuan dynasty and the Ming dynasty for comparison when the other related factor is same, Table 1 shows the contrast results.

At present, the model test methods are generally the point-by-point comparison and the overall comparison (Hashemi and Meybodi, 2009). Point-by-point comparison is to congruent the simulation results and the actual situation, then compare and calculate its accuracy point by point; the overall comparison is concerned with the similarity between the simulated spatial pattern and the actual spatial pattern, often using Moran's I index contrast. Moran's I index is calculated based on the covariance relation of statistical correlation coefficient. Moran's I index is commonly used to describe the spatial autocorrelation and its equation is:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ji}} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(x_i - \bar{x}\right)\left(x_j - \bar{x}\right)}{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \quad (5)$$

where, n is the number of spatial units involved in the analysis, x_i and x_j respectively stands for observations of an attribute feature in the spatial units i and spatial unit j, W_{ij} is the neighboring weight matrix of spatial

Table 1: The simulation results of different value

Optimized method	Simulation time and results			
PSO	Yuan dynasty	Fig. 3	Ming dynasty	Fig. 4
CA	Yuan dynasty	Fig. 5	Ming dynasty	Fig. 6

Table 2: Moran's I index contrast

	Time	
Moran's I index	Yuan dynasty	Ming dynasty
Actual value	0.1386	0.1401
Simulate value	0.1386 (Fig. 3)	0.1381 (Fig. 4)
	0.1386 (Fig. 5)	0.1399 (Fig. 6)

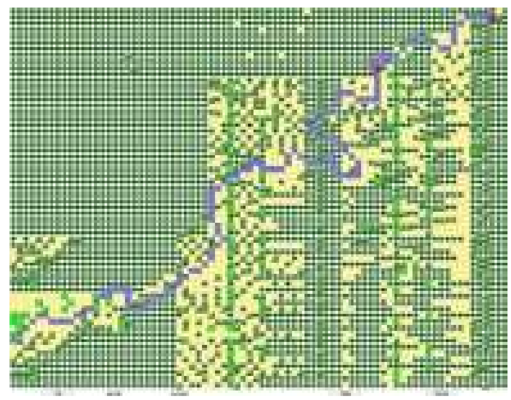

Fig. 3: Simulation result of yuan dynasty using PSO

Fig. 4: Simulation result of ming dynasty using PSO

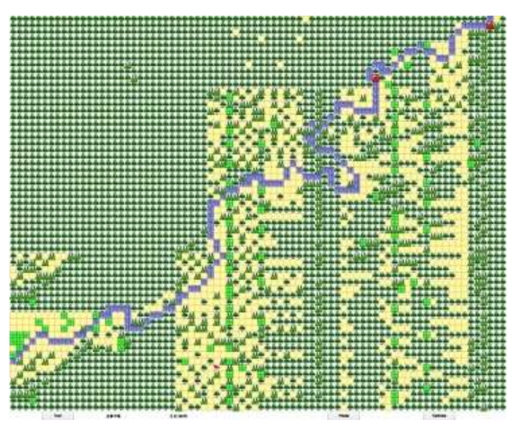

Fig. 5: Simulation result of Yuan dynasty using CA

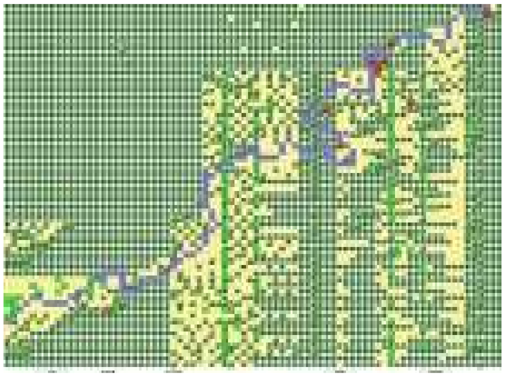

Fig. 6: Simulation result of ming dynasty using CA

units i and j. If adjacent, W_{ij} is 1, if not adjacent W_{ij} is 0. In this study, Moran's I index is used for model checking and the compared results of the Table 1 are programmed in Matlab7.0, as shown in Table 2.
From Table 2, we can find:

- Figure 3 and 5 show the location of kiln in Yuan Dynasty in the right top of the map, until Ming Dynasty the location slowly spread to below, as shown in Fig. 4 and 6. According to these, we guess Yaoli glaze fruit was mined in the Yuan Dynasty, hence, those locations of kiln was relatively near from Yaoli. But along with kaolin was found in the Ming dynasty, those locations of kiln spread gradually to Kaolin
- Figure 3 and 5 show the numbers of kiln in Yuan Dynasty was obviously less than Fig. 4 and 6 show the numbers of kiln in Ming Dynasty in Jing De Zhen Dong He river basin region. It hinted Jing De Zhen Dong He river basin region was prosperous and important place that produced ceramic raw materials in Ming Dynasty
- Evolution process is continuous, so the two dynasties' simulation results should be linked and analyzed. It's found that the optimized parameter set using Cultural Algorithm fine simulated land-use change as compared to the optimized parameter set using Particle Swarm Optimization in the same of population size, because their Moran's I index is closer to actual value and the simulation result is closest to the actual circumstances, realizing many kilns' evolution, such as Raonan, Neiyao, Yaoli and Nanbo, etc.

CONCLUSION

In this study, we simulate the evolution of Jing De Zhen Dong He river basin kiln landscape from the Yuan Dynasty to the Ming Dynasty with two ways and find the optimized parameter set using Particle Swarm Optimization poorly simulated land-use change as compared to the optimized parameter set using Cultural Algorithm in the same model parameters. With the same model parameters, the simulated Moran's I index is closer to the actual Moran's I index under CA-CA model, proving that the simulated spatial pattern is closer to actual circumstances and that the model can solve the problem of landscape evolution caused by GIS spatial data deletion.

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