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The Sustainable Space Development Model Based on Smart Urban

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The paper, from four levels--monitoring, collection, interconnection and sharing of city data; grooming and comprehensive analysis of operation problems in city systems; simulation and decision-making evaluation of city space development; planning system of city space development--tries to construct the overall framework for sustainable urban space development model based on smart cities, which is of great significance to enriching theoretical framework of city sustainable development and guiding the spatial planning and construction practice of smart cities.

1. Introduction

Smart city is an advanced form of city development, and its nature is to make full use of new-generation information and communication technologies to solve various problems of cities, thereby enhancing the quality of city development (Wang et al., 2015). The construction of smart city is a comprehensive performance of informationization and urbanization's continuous in-depth development; in essence, the ultimate goal of both smart city construction and new urbanization construction is to achieve the sustainable development of the city. Concerning how to understand the development concept, the author holds four measures are of help: the first is to ensure the interconnection and sharing of data and information in urban areas and facilitate the sustainable co-development of the city by relying on a new-generation information and communication technologies and through the construction of data and information sharing platform in urban areas; the second is to conduct dynamic monitoring, early warning and management of city space by way of city sensors and enhance the efficiency of city space; the third is to solve unexpected city problems in a timely manner through the smart city emergency processing platform and maintain a healthy and efficient operation of city systems; the fourth is to achieve the optimal allocation of urban elements and rational distribution of city space via smart spatial planning, to promote intensive and thrift use of land, improve efficiency of resource use and accomplish the sustainable development of city space. Based on the above thinking, the paper sorts out the existing situation and problems of traditional city model from the perspective of sustainable development, searches for a meeting point of smart city construction and city sustainable development and attempts to sort out a new thought of studies on sustainable development of city space based on smart city, all of which are of great significance to enriching theoretical framework of city sustainable development and guiding the spatial planning and construction practice of smart cities with sustainable development as the ultimate goal.

2. Sustainable development model of city space based on smart cities

Smart city construction, as a strong handle in China's promoting new urbanization and sustainable development, not only provides massive data support for the city space research, but also facilitates the transformation of city space planning methodology (Magsino et al., 2014). The paper starts from three aspects--the objectives, architecture and model in modeling to illustrate the overall framework of city space development model, whose basis is the integration and analysis of city operational data, orientation is the grooming and resolution of city problems, means is the simulation and evaluation of city elements' operation and goal is the city space development planning, all in order to enrich the existing theoretical framework and lay the foundation for future study.

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2.1 Objective of model building

The sustainable development model of city space based on smart city proposed in the paper fully absorbs and integrates the concepts of traditional city sustainable development model, city space development model and city simulation model, centers on the integration and analysis of city operational data and is oriented by solving city problems; on the basis of reflecting city form and the land spatial expansion rules with the nature of structural change, the paper achieves the dynamic simulation and collaboration configuration of various elements and resources' operation - industry, transport, community, culture and ecology through the dynamic monitoring, analysis, integration and use of city elements' operational data (Ferdinand and Danlin, 2011). It has the following three objectives: the first is to monitor and evaluate the operation and development status of the city; the second is to optimize the spatial layout and resource allocation; the third is to provide smarter city space planning methods. The big data (position data, text data, image data, video data, etc.) generated in the process of elements' operation will be focused for mining and analysis to evaluate the quality of city space development and actual land use efficiency and predict the growth trends and size of future space, so to carry out optimal adjustment and scientific layout for the city space structure and infrastructure with an aim to assist the entire process of city space--planning, construction and operation.

2.2 Modeling framework

On the whole, the sustainable development model of city space, shown as Figure 1, based on smart city described in the paper can be divided into four levels specifically:

(1) Monitoring, collection, interconnection and sharing of city data

City data is the basis for the whole modeling, and its completeness and sophistication will directly affect the results of model analysis and simulation. The smart city space development model, centered on data analysis, makes use of sensors, Internet of Things and other means of information technology to collect, filter and integrate the urban residents' behavioral data, traffic data, meteorological data, video surveillance data, energy and facility data, economic statistics, etc. on one hand; on the other hand, the model, through the construction of internet data sharing platform and the way of sharing and exchanging, facilitates the circulation of data in various departments and industries and builds the a database of city thematic elements and historical information database and geographic information database for the classification and effective management of various types of data so to provide data support for analyzing city problems, city development simulation and spatial layout of elements as well as other functions in the model (Romero and Choi, 2011).

(2) Grooming and comprehensive analysis of city operation problems

The paper docks the operational data of various city element systems through constructing the operation model library of city space elements (Figure 1) and builds sub-model from eight aspects--city public security, transportation management, community development, resource bearing control, pollution control, social resource optimization, infrastructure regulation, economic development, so to simplify the stimulation of the operation of various element systems. Meanwhile, the city public service, operational efficiency, social governance and ecological environment are analyzed profoundly and are disassembled into sub-problems in various areas corresponding to element operation model for phenomenon simulation and problem reproduction.

(3) Simulation and decision-making evaluation of city space development

Based on the collection, storage and analysis of city operational data and through various visual means of GIS spatial visualization and virtual reality, a simulation of elements' operation in cit space is carried out; what's more, an evaluation and analysis of city elements' operation is conducted by combining with construction scale and intensity of city development and population density status to offer supplementary decision-making support for the optimal allocation of various factors, including city land, construction, energy, food, technology and social service.

(4) Planning system of sustainable city space development based on smart city

The objective of building smart city space development planning system is to improve city quality of well-being of residents based on the construction and implementation of city economic and social development strategic goals and through appropriate city scale, rational layout of the city and good city environment, so to enhance functions of cities and promote the comprehensive and coordinated development of urban social economy (Yau et al., 2012).

2.3 Creation of model

(1) Model description

The basic assumptions for the BUDEM model building are: 1. The city is a complex adaptive system, which can adopt bottom-up approach for the simulation of city space growth; 2. The driving force of city growth is divided into two categories—growth facilitating factors and growth limiting factors; also, it can be divided into market-driven factors and government-guiding factors, and the effect of these factors decreases with the increases in distance; 3. The historical rules are applicable to predicting the future with same trends; 4. Other

scenarios can be generated based on the benchmark space growth scenario (i.e. the continuation of historical trends) and according to the differences in development modes (Chau and King, 2008).
According to the above logical framework, a BUDEM model is built based on CA, whose conceptual model is shown as in Equation 1. On the whole, the state of cellular is affected by macro socio-economic constraints, space constraints, institutional constraints and neighborhood constraints. In current stage, BUDEM only simulates the transformation from non-urban construction land to urban construction land, and does not simulate the reverse process and consider the urban redevelopment process.

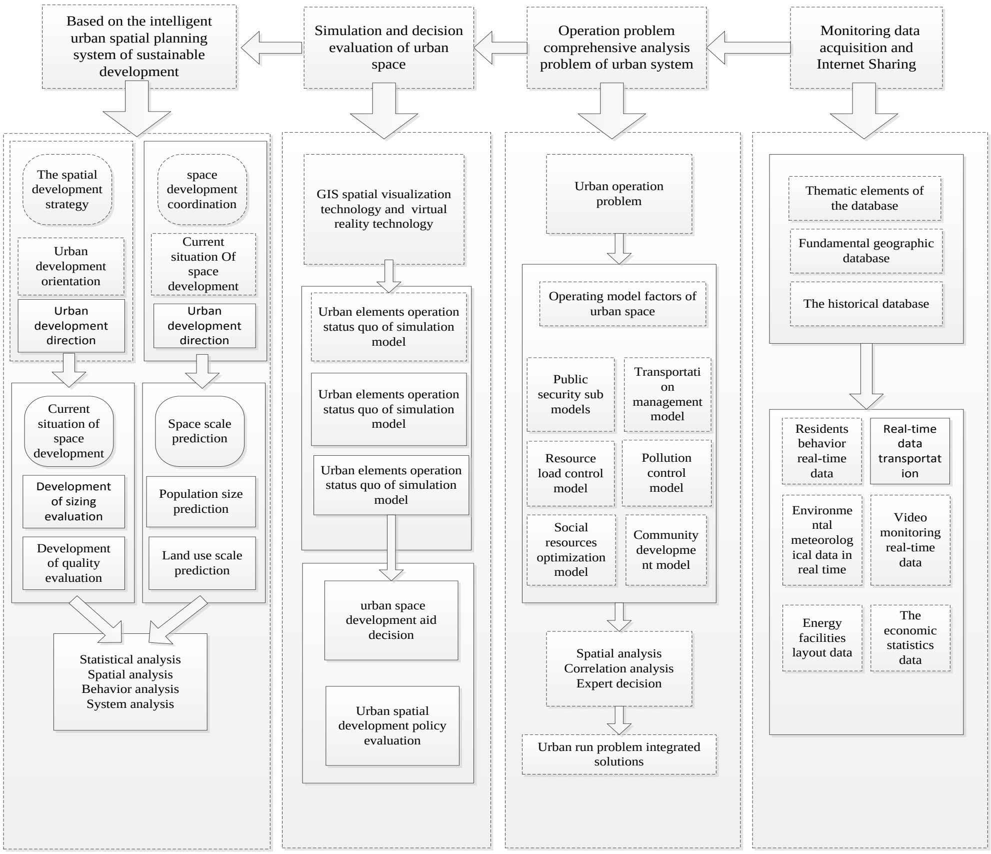

Figure 1: The Sustainable Space Development Model Based on Smart Urban

Table 1: Spatial variable of BUDEM

Type	Name	Value	Description	Data
	d_tam	≥0	Habitants Behavior	LOCATION
	d_vcity	≥0	Traffic Capacity	LOCATION
	d_city	≥0	Environment	LOCATION
LOCATION	d_vtown	≥0	Energy Sources	LOCATION
CONSTRAINT	d_town	≥0	Economic Development	LOCATION
	d_comm	≥0	Community Development	LOCATION
	d_land	≥0	Land Planning	LOCATION
	d_bdtown	≥0	Security of Society	BOUNDARY
	d_space	≥0	Spatial Scale	PLANNING
GOVERNMENT	d_tech	≥0	Modern Technology	BOUNDARY
CONSTRAINT	d_rgn	≥0	Distance with Big City	LANDRESOURCE
	d_road	≥0	Distance Between Roads	LANDRESOURCE
NEIGHBOUR CONSTRAINT	d_planning	≥0	Land Use Types of Urban	PLANNING

$$V_{i,j}^{t+1} = f\{V_{i,j}^{t}, Global, Local\} = \{V_{i,j}^{t}, LOCATION, GOVERNMENT, NEIGHBOR\}$$

$$= f\begin{Bmatrix} V_{I,J}^{t} \\ d\_tam_{i,j}, d\_vcity_{i,j}, d\_city_{i,j}, d\_vtown_{i,j}, d\_town_{i,j} \\ d\_river_{i,j}, r\_road_{i,j}, d\_bdtown_{i,j}, f\_rgn_{i,j} \\ planning_{i,j}, con\_f_{i,j}, landresource_{i,j} \\ neighbor_{i,j}^{t} \end{Bmatrix} \quad (1)$$

Where: lattices is cellular space; V is a state variable, in which V = 1 means the urban construction land, V = 0 means the non-urban construction land; $V_{i,j}^{t}$ is the cellular state at time t in position ij, and f is a switching function of cellular state .

(2) State transition rules

Substitute the remaining 12 spatial variables in addition to the neighborhood action neighbor variable into Logistic regression equation and obtain the dependent variable using historical data, the regression will generate regression coefficient, namely the weighting factor w1~12. Based on this, make use of a single parameter loop mode (MonoLoop) and select the maximum factor in point-to-point matching degree (goodness-of-fit, GOF) as the weight coefficient wN* identifying neighbor. The use of historical data, on the one hand would obtain a truer and more comprehensive rule of city growth; on the other hand, it would greatly reduce the computation time of the model. In addition, the final state transition rule is shown in Equation (2). Firstly, determine the cellular number in transition at different stages according to the macro conditions, the calculate the suitability $S_{i,j}^{t}$ of city growth based on constraints, so to calculate the overall probability $P_{i,j}^{t}$ and the final probability p^t. Eventually, in the process of Allocation, identify the cellular needing transition according to stepNum values.

$$LandAmount = \sum_{t} stepNum^{t}$$

$$\begin{cases} s_{ij}^{t} = w_o + w_1 \times d\_\mathrm{tam}_{ij} + w_2 \times \mathrm{vcity}_{ij} + w_3 \times d\_city_{ij} + w_4 \times d\_vtown_{ij} + w_5 \times town_{ij} \\ + w_6 \times d\_\mathrm{comm}_{ij} + w_7 \times r\_road_{ij} + w_8 \times d\_bdtown_{ij} + w_9 \times f\_rgn_{ij} + w_{10} \times planning_{ij} \\ + w_{11} \times con\_f_{ij} + w_{12} \times d\_tech_{ij} + wN^* \times neighbor_{ij}^{t} \\ p_g^t = \dfrac{1}{1+e^{-s_{ij}^{t}}} \\ p^t = \exp[\alpha(\dfrac{p_g^t}{p_{g\max}^t} - 1)] \\ f \quad or \quad k=1 \quad to \quad stepNum^t \end{cases} \quad (2)$$

$$p_{ij}^{t} = p_{ij}^{t} - p_{\max}^{t}$$

Wherein, LandAmount is the number of the total cellular growth, sijt is the number of cellular growth in each cycle; w is weighting factor of spatial variables; pgmaxt is the overall probability after transition; α is the diffusion coefficient; pt is the final probability; pmaxt is the maximum value of final probability for different sub-cycles within each cycle, and the value constantly update in the sub-cycles (Chau and Yau, 2008).

In equation (2), stepNum represents the cellular numbers with state transited in each iteration (the discrete-time in a CA), and can be determined according to the macro socio-economic development indicators to describe the degree of tightness in government's land supply policy (in particular the part of incremental land) to control the growth rate. Based on statistical yearbooks, the stemNum in each stage of the history can be obtained; when perceived from medium and long term, the annual growth of urban construction land in the study areas will be 30 km^2 (10cells / iteration) in the future.

Based on the established CA state transition rules established, simulation process of BUDEM is shown in Figure 2. First, set the environment variables, spatial variables and corresponding coefficients of the model, and calculate the stepNum parameters in different time periods based on macro-economic conditions and calculate the land use suitability, overall probability and final probability as well as variables in the CA environment; finally adopt cyclic manner for the spatial identification of cellulars in the Allocation process to complete the simulation of a CA discrete time. According to the target time of simulation, determine the number of cycles; with continuous cycles of CA model (multiple-time Allocation process), the entire simulation process finally completes.

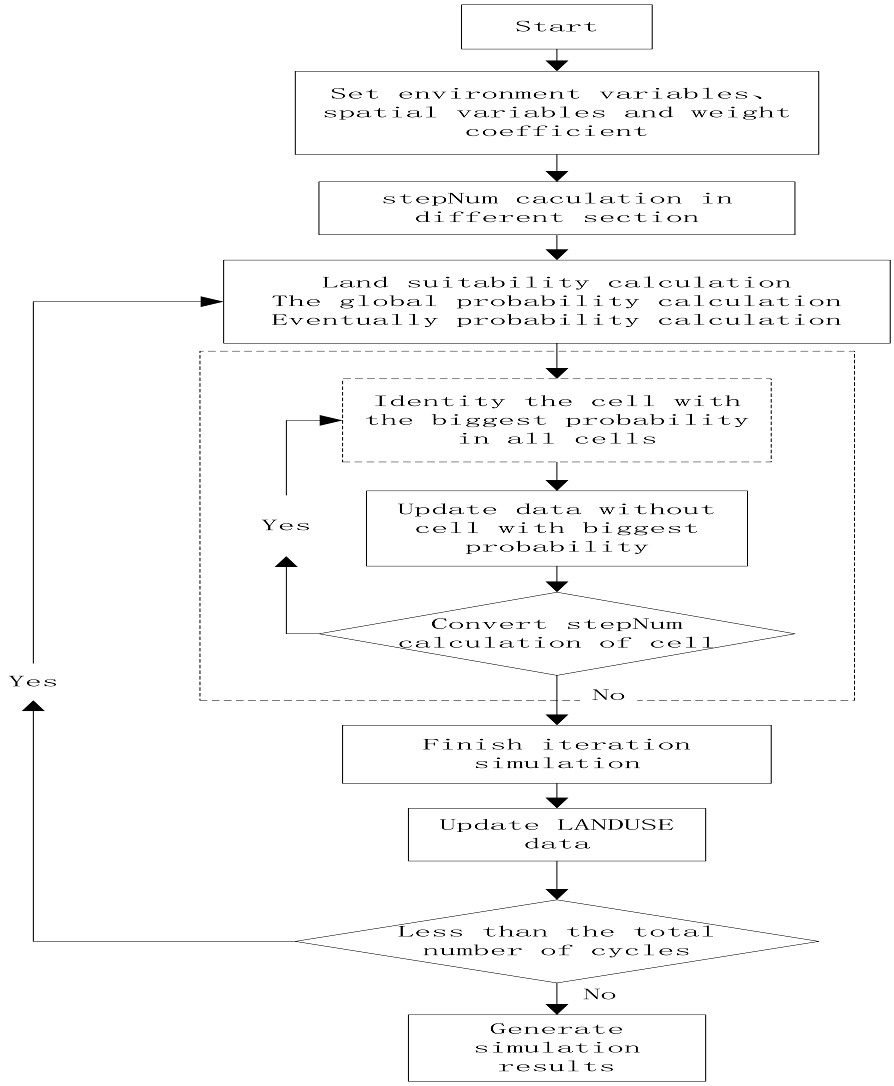

Figure 2: Simulation process of BUDEM

(3) The method of parameter identification

In the state transition rules, the initial probability is the function composed by 13 spatial variables, and the dependent variable is dichotomous constant. The forthcoming land-use is divided into developed (transition from non-urban construction land to urban construction land) and undeveloped (not in the transition from non-urban construction land to urban construction land), which does not satisfy the conditions of a normal distribution. Then adopt Logistic regression analysis method to get the CA state transition rules, whose specific form is shown in Equation 3. Equation 3 is a semi-logarithmic equation; the regression coefficient b reflects the sensitivity of variables, namely, the effect imposed by the change of variables in 1 unit on overall probability, in which the greater the absolute value is, the more sensitive the corresponding variables are.

$$P_{Logistic} = \frac{1}{1+e^{-Z_{ij}}}$$
$$z_{ij} = a + \sum_k b_k x_k \quad (3)$$

3. Conclusion and outlook

Based on the relevant research both at home and abroad, the paper mainly discusses the objectives and principles of building sustainable development model of city space based on smart cities from the theoretical level, and constructs the framework guiding further research. However, sustainable development is a major issue of coordinating all kinds of city elements, so how to delve into the intrinsic link and organizational structure among various element sub-models in the city and quantify evaluation indicators in each sub-model under existing framework will become a direction of further research in the area of smart city space development model in the future. In the meantime, how to tap the multi-dimensional space-time characteristics of urban activities and environment & space under the role of information technology and how to use GIS technology for city space simulation and visualization will be the difficult points in future city model studies. Moreover, an important direction in future studies on and applications of smart city development model is to explore the decision support system of city space planning centered on the simulation of residents' activity space and flowing space to build a city information sharing platform targeting at the government, enterprises and the public.

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