For office use only	Team Control Number	For office use only
T1 ________________	**87007**	F1 ________________
T2 ________________		F2 ________________
T3 ________________	Problem Chosen	F3 ________________
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2018
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Summary Sheet

an Evaluation System for Smart Growth of a City

Summary

With the emerging problems of urbaniation, increasing city planners lay emphasis on the practice of smart growth. This paper proposes an evaluation system for smart growth from four aspects: land use, transportation network, ecological environment and information flow. We also develope the growth plan especially for Jianye and Canberra.

Firstly we use a Cellular Automata Model to analyze the dynamic changes of land use types. Further, based on the Artificial Neural Network, we predict the land use of Jianye and give specific land use planning.

Next we simplify a transportaion network as a graph with nodes and edges. After selecting ten important nodes in a map of Canberra, we generate an optimal network by Ant Colony Algorithm. Comparing the original network and the generated one, we calculate the number of spanning trees and find the generated network has a tighter connectivtity.

Then we give a comprehensive evaluation of urban ecological environment, considering 15 indexes totally. The weights of the indexes are determined by the Analytical Hierarchy Process which show good consistency as well.

Finally, we take the efficiency of information flow as a matric for smart growth. Specifically, we introduce the block chain which has lots of applications in the smart growth of a city.

Above all, using our evaluation system, a reasonable growth plan could be tailered according to the local situations of a city .

Contents

1 Introduction

The accerlaration of urbanization provides us a modern city, but it brings about severe problems at the same time. Air and water pollution, resource consumptions, traffic congestion, employment pressure...They are the concerns of almost every citizen. To deal with the increasing problems in urbanization, smart growth, an original urban planning theory is introduced.

'Smart growth is about helping every town and city become a more economically prosperous, socially equitable, and environmentally sustainable place to live [1].' Concretely, It has ten principles which are proposed by American Farmland Trust (AFT) and other organizations in 1996. Smart growth aims to construct a smart city. In 2010, International Business Machines Corporation (IBM) claimed that the functions of smart cities focus on services and infrastructure [2].

Nowadays, increasing people realize the importance of data science which plays an essential role in planning a smart city. Professor Pan proposed a framework of trace mining for smart cities [3]. The system of smart city contains three layers: trace, knowledge and applications. Similarly, Yu Zheng gave out the framework of urban computing which includes trace, data management, data analysis and servies supply [4]. Above all, smart growth is based on data access and management, then using various analysis techniques to provide convenient services to citizens.

There is no city planning suitable for every city, a growth plan must be tailor based on its reality. However, more studies focus on the theory on a macro level, without concise models and specific city planning. Meanwhile ther are also some city plannings without the strong support of theory.

So our study pays more attention to the combination of theory and reality, we give out the specific city planning based on quantified standards. Our paper is organized as follows.

Section 2 shows the general assumptions of our model. The following four sections analyze the smart growth from four aspects: land use, transportation network, ecological environment and information flow. Especially, we design the growth plan for Jianye and Canberra respectively. Section 5 concludes the aspects above, further proposing some recommendations in detail.

2 General Assumptions

To simplify the problems,our models are based on the following assumptions.

- **We simplify the basic rules of land evolution.**
  There is only one type of land in each unit space at one time, and the evolution of land only depends on its type, surrounding land (adjacent cells) and policy adjustments (state transition functions).
- **We simplify the transportation network as a graph with nodes and edges.**
  It reflects the fundamental features of a transportaion system and simplifies the problems to a large extent.

- **We assume the layout of transportation network meets the transport links among the nodes in the geographical space.**
  The spatial layout of transportation network is a spatial combination of different nodes connected with each other. It has structural forms and hierarchical relationships, which are determined by the relative geographic location and mutual socio-economic status of nodes and potential connection needs.

- **We assume the block-chain is adopted by a large number of users.**
  Block-chain technology is based on the widespread use of people and p2p network operates in a large number of user nodes.

- **We assume multiple factors affect the environment of a city.**
  City's ecological environment is affected by multiple factors such as economic structure, policies, current environmental level, demographic characteristics, infrastructure construction and education level .etc

3 a Plan for the Urban Land Use

3.1 a Cellular Automata Model

Urban land utilization is an important factor to consider in the city planning. It is challenging to arrange different types of land reasonabley and maximize the overall values.

However, different types of land distribute in a mixed way, they effect each other and change dynamically and stochastically under the influence of economy, policy, culture and many other factors. Briefly, the changing process is too complex and it is hard to give a clear boundary of various types of land.

Since a complex system is made up of the interations between different small components. Given a map of types of land use, we rasterize it and each grid represents a type of land. By analyzing how these grids effect each other, we could predict how the land types will change in the future. Our thought can be realized by the method of Cellular Automata Model.

Cellular Automata Model (CA) is a grid dynamics model where time, space, states are discrete. It has a strong ability to simulate the changes of a complex system during a period of time. It has been widely used to simulate the evolution of urban land.

A typical CA system contains five parts: cells, lattice, neighbour, time and rule . We give out their definitions below.

- **cell**
  A cell is the fundamental compomemt of a CA system. In our model, it is a grid of a rasterized map and each one has a state representing a certain type of land. We define six states of cells: farmland, forest, grassland, industrial and mining land, water areas and unused land. We denote these six states as $\{S_1, S_2, S_3, S_4, S_5, S_6\}$.

- **lattice**
  Lattice is a set of cells distributed in space.

- **neighbour**
  The neighbour of a cell is defined as the cells which are within a certain distance from it.

- **time**
  CA is a dynamic system and it is discrete in the axis of time.

- **rule**
  Every time, a cell will remain its current state or transmit to another state of the left five ones. The state of a cell i at the time $t+1$ is denoted as S_i^{t+1}. It is dependent by the its current state S_i^t and its neighbours' current states S_N^t . So we could determine the dynamic function f below.

$$f : S_i^{t+1} = f(S_i^t, S_N^t) \tag{1}$$

Further, since the time is discrete in CA system, in order to simulate the changes of land use better, the number of iterations must be corresponding to the actual time. Li found when the number of iterations equals to the time interval of remote sensing image, the simulation effect could be optimal [5].

Therefore, to introduce the dynamic constraints, we take year as a unit and normalize the number of iterations Δ_r and the interval observation time of history images Δ_T. Δ_r has to be an integral multiple of Δ_T.

$$\Delta_r = n \times \Delta_T, \quad n \in N \tag{2}$$

3.2 Predicting the land use by Artificial Neural Network

The core of the CA system is to determine the transition rules.Since there are too many features to consider, it is hard to define the dynamic function f directly. The common ways are determining the weights of different spatial variables by multi-criteria evaluation (MCE) [6].

Suppose there are n cells totally in a map. Let $a_l(i)$ be the l th variable of the input of the cell i and w_l be the corresponding weight. So $p(i)$, the probability of transitions for the cell i could be calculated below.

$$p(i) = \sum_{k=1}^{n} w_l a_l(i) \tag{3}$$

However, $p(i)$ only reflects the propobility of transition between two types of land. When the land types and the input variables become larger, a matrix is needed and the calculation amount will be extremely large which we cannot afford.

Due to the limitations of MCE, we attempt to make use of the self-learning character of Artificial Neural Network which learns from the past data and make predictions automatically. It investigates the inhernt regulations of land use evolution and determines the transition rules, finally making predictions more concisely and objectively.

Back Propogation (BP) Neural Network contains three layrer: input layer, hidden layer and output layer. The input variable is the related features of the cell k and the output is its transition propability to different types of land.

In the input layer, the number of neurons equals to the number of the input variables n. The number of the neurons in the hidden layer should be set suitable, because a small one cannot learn adequately and a large one requires a long time to learn, sometimes bringing the problem of overfitting. Hence, we choose the number of neurons in the hidden layer as $2n + 1$ according to our experience. Additionally, the number of the neurons in the output layer is the number of types of land use m.

Let $x_i(k, t)$ be the i th varible of the input vector of the cell k at the time t. The input vector of the cell k is

$$X(k, t) = [x_1(k, t), x_2(k, t), x_3(k, t), ..., x_n(k, t)]^T. \tag{4}$$

Then among the $x_i(k, t)$, we use the maximum x_{max} and the minimum x_{min} to normalize the input in order to make it range from 0 to 1.

$$X_i(k, t) = \frac{x_i - x_{min}}{x_{max} - x_{min}} \tag{5}$$

Then the normalized input is transmitted to the hidden layer. Let $w_{i,j}$ be the weights between the input layer and the hidden layer, and $b_j(k, t)$ be the bias of the j th neuron in the hidden layer. The input of the j th neuron in the hidden layer is

$$net_j = \sum_{i=1}^{n} w_{i,j} x_i(k, t) + b_j(k, t). \tag{6}$$

The hidden layer responds to the inputs and transmit them to the next layer. The response function $f(x)$ is defined below.

$$f(x) = tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}} \tag{7}$$

So the input of the output layer is $f(net_j)$. Let $w_{j,m}$ be the weights between the hidden layer and the output layer, and $b_m(k, t)$ be the bias of the m th neuron in the output layer. The input of the m th neuron in the output layer is

$$net_m = \sum_{j=1}^{2n+1} w_{j,m} f(net_j) + b_m(k, t). \tag{8}$$

The final output should range from 0 to 1, therefore we define the response function to output layer $g(x)$ as a sigmoid function.

$$g(x) = sigmoid(x) = \frac{1}{1 + e^{-x}} \tag{9}$$

So the transition propobility of various land types is

$$p(k, t, m) = \frac{1}{1 + e^{-\sum_{j=1}^{2n+1} w_{j,m} f(net_j) + b_m(k,t)}} \tag{10}$$

Since the changes of every cell is small within a short period of time, lots of iterations are required to judge the changes of land types. Here, we set a threshold to prevent the land use changing too fast which is against the reality.

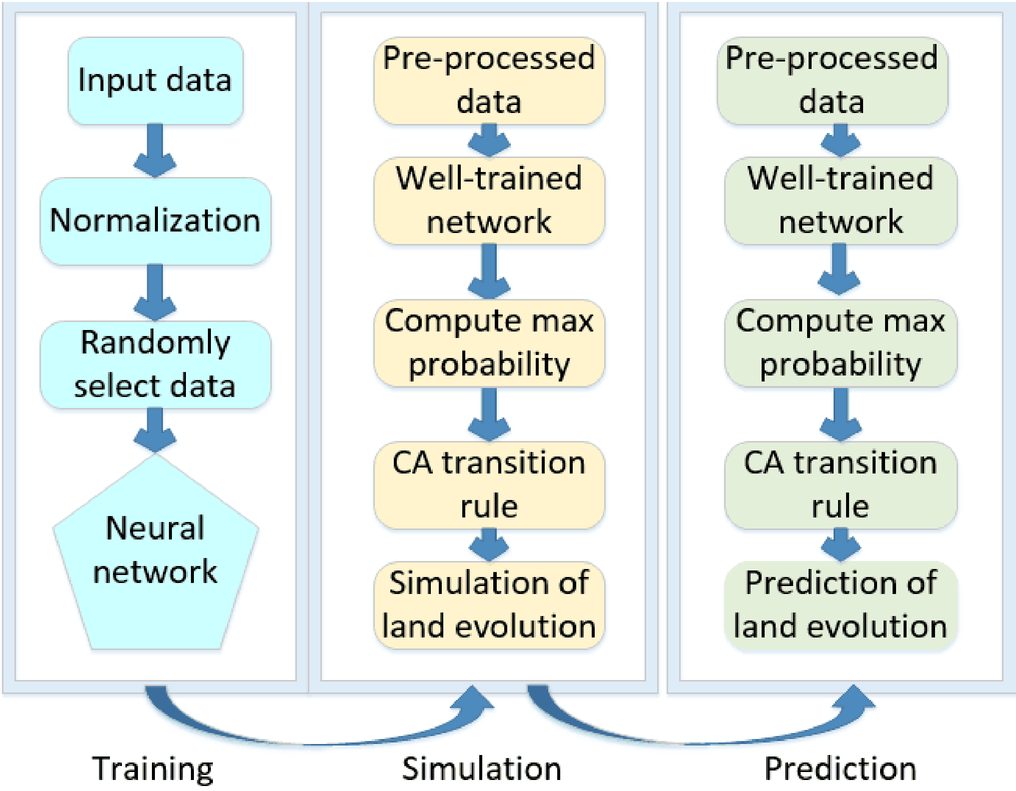


Figure 1: Dynamic model of urban land use

Above all, the framework of a dynamic model of urban land use is shown in Figure 1.The model contains three parts: training, simulation and prediction.

Training a neural network is the first step. After normalizing the input data, the network selects data randomly as its training set, finally transforming to a well-trained network.

Then the pre-processed data are sent to the network and the corresponding transition probabilities of different types of land can be calculated. Through picking out the maximum one and judging whether it overweights the threshold, we can determine the CA transition rule and simulate the current land use by the historical data. Similarly, we can predict the evolution of land use in the future.

To evaluate the accuracy of our model, we introduce the index Lee-Sallee (L-S) which reflects the similarity between the historical land use situations A_0 the predicted ones A_t in the future. Ihe improved L-S index is defined below, ranging from 0 to 1.

$$L = \frac{A_0 \cap A_t}{A_0 \cup A_t} \tag{11}$$

3.3 Growth Plan of the Land Use for Jianye

We select Jianye District as our sample. Jianye is located in Jiangsu, China with a population of 4.5 million in 2015. It has an area of 80.87 square kilometres which is relatively small in China. There are mainly 8 types of land use which is shown in Table 1

Table 1: Types of land use

No.	Types of land use	Examples
1	business	shopping malls, restaurants
2	industrial and mining storage	factories, warehouses
3	housing	flats
4	public management and service	government organizations, public facilities
5	transportation	roads, bus stations, airports
6	water and water conservancy facilities	wetland, forest,canal
7	farmland	irrigated land, dry land
8	others	others

Figure 2 reflects the curve of cost function vs. the number of interactions. From this figure, we can find that cost function decline smoothly as iterating and finally diverge somewhere near 0,which indicates the network are well-trained.Then we use the network to predict the land use in the future 2 years by setting the corresponding time in CA.

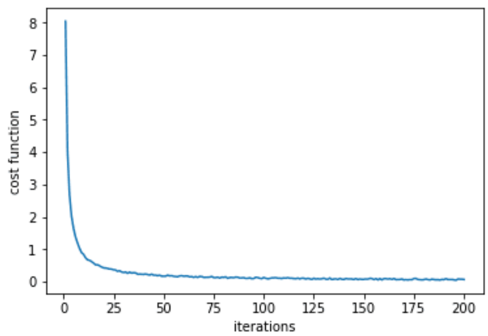


Figure 2: Curve of cost function vs.inerations

Figure 3 shows different types of land in Jianye.

From the map above, we find different types of land distribute closely and it is hard to distinguish them clearly.

Based on our analysis, we recommend taking advantage of compact building design in Jianye. Because Jianye has a relatively small size of area and population in China, a compact building design can maximize the limited resources of land and creating mor business opportunities as well.

It is worthy to mention that Jianye has a long history, it has already been well developed with many local landscape and histotical sites. This is its special strength in fostering distinctive, attractive communities with a strong sense of place. So we suggest the city planner spare no effort to preserve the local landscape and historical sites. It is a wise option to strengthen some existing communities.

Figure 3: Types of land use in Jianye

4 a Plan for the Transportation Network

4.1 Analysis of Transportation Network

Providing a variety of transportation choices is one the principles of smart growth. A reasonable and scientific transport network is crucial to the quality of citizens' lives. How to build and prioritize the transportation projects wisely is a challenge for the urban planner.

In a transportation map, roads and transportation hubs are the fundamental elements, which can be simplified as edges E and nodes V in a topological graph. So the transportation system G can be simplified as a graph $G = (V, E)$. Based on the graph theory, we aim to design the transportation network ,namely, determine how does each node connect to each other.

To analyze the transportation network, our primary task is to determine the nodes. The nodes we select should be typical and distribute reasonably. Meanwhile, the number of nodes should be suitable, because we need to analyze the network comprehensively without great computation cost as well.

Different transportation hubs vary from size, economy, volumn of people, etc. They influence the transportation network in different extent. We denote the importance of a node i as z_i. To quantify its value, we can evaluate several indexes based on the requirement.For the node i , let x_{ij} be the value of the j th index and $\overline{x_j}$ be the average value of the j th index. So the importance of the node i is

$$z_i = \sum_{j=1}^{m} w_j \frac{x_{ij}}{\overline{x_j}}. \tag{12}$$

where w_j is the weight of each index. $0 \leq w_j \leq 1$ and $\sum_{j=1}^{m} w_j = 1$.

Then we could use the entropy-weighing method to determine the weights. Suppose there are n nodes in a transportation network and m indexes to determine its importance. After getting the values of each index for all the nodes, we construct a normalized matrix R_{nm}. Based on the entropy-weighing method, we get the entropy value of the jth index.

$$H_j = -k \sum_{i=1}^{n} f_{ij} ln f_{ij}, \quad j = 1, 2, 3, ..., m \tag{13}$$

The weight of the j th index is

$$w_j = \frac{1 - H_j}{m - \sum_{j=1}^{m} H_j} \quad j = 1, 2, 3, ..., m \tag{14}$$

where $k = \frac{1}{lnn}$, $f_{ij} = \frac{R_{ij}}{\sum_{i=1}^{n} R_{ij}}$.

To further determine the status and function of a node, we use System Clustering Method to classify the nodes based on its importance.

Among all the nodes, we have to decide which of them should be connected. Clearly, we prefer to connect the nodes which are more important. Meanwhile the longer road means the larger investment, so the distance of the road between two nodes L_{ij} is also a factor for us to consider. For the nodes i and j, we use the gravity model to quantify the importance of their connection z_{ij}.

$$z_{ij} = k \frac{z_i z_j}{L_{ij}} \tag{15}$$

where k is the corrected coefficient of the rode's statue.

Besides, the traffic demand between two nodes should also be considered. If we neglect people's demands and only build more roads, sometimes the traffic situation could be worse. We introduce the traffic volumn OD from the origin to the destination. Let the traffic volumn OD from the node i to j as T_{ij} and the average traffic demand of all the nodes as $\overline{T}$. So we improve the importance of a road z_{ij} below.

$$z_{ij} = k \frac{z_i z_j (T_{ij} + T_{ji}) / \overline{T}}{L_{ij}} \tag{16}$$

A bigger z_{ij} means a tighter connection between two nodes and a road is more likely to build between them.

4.2 Generated Traffic Network by Ant Colony Algorithm

Based on the selected nodes, we need to design a growth plan for the transportation network. We determine the layout according to the importance of roads. Given a origin and destination, the problem transfers to seek an optimal road in order to maximize the importance of all the roads. So we use Ant Colony Algorithm to generate a suggested traffic network

The product of the traffic volumn T and the time t_{ij} reflects the effiency of transportation from the node i to j. So the objective function is defined below.

$$min \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{L_{ij}}{L_c} T_{ij} t_{ij} \tag{17}$$

where L_{ij} is the distance between the node i and j and L_c is the total distance of all the nodes.

The steps of the Ant Colony Algorithm are described below.

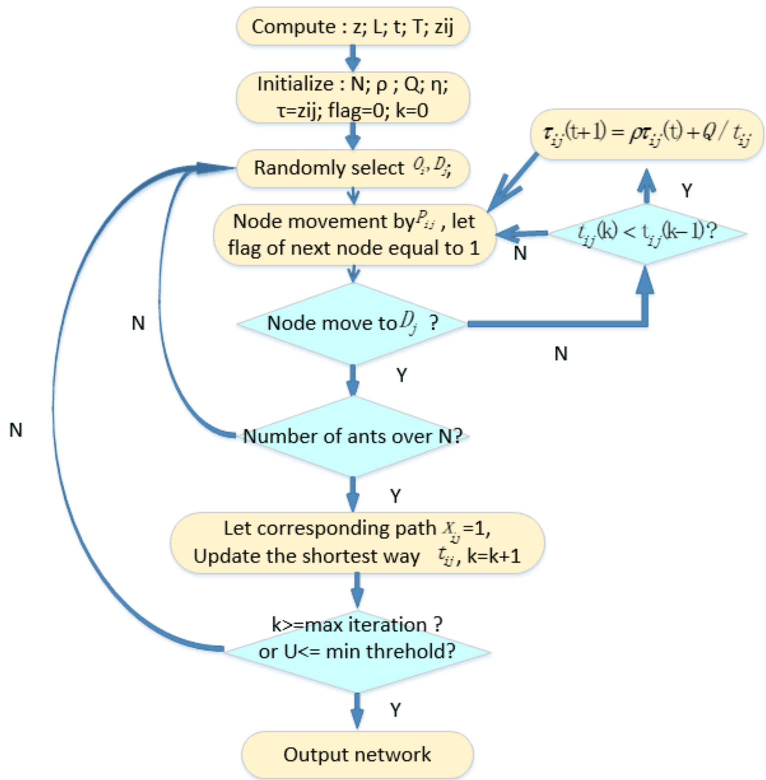


Figure 4: Flowchart of Ant Colony Algorithm

(1) The propability of the i th node being the origin is

$$P(O_i = i) = \sum_j T_{ij} / \sum_{i,j} T_{ij} \tag{18}$$

After the origin is determined, the probability of the j th node being the destination is

$$P(D_j = j \mid O_i = i) = T_{ij} / \sum_j T_{ij} \tag{19}$$

(2) We initialize the parameters. The number of ants is N. The pheromone constant is Q. The persistence coefficient of a path is ρ. The number of pheromones is τ_{ij} and the visibility of a path is η_{ij} where $\eta_{ij} = 1/(t_{ij} + t_{jD_j})$.

If the node is visted, we denote flag=1; otherwise flag=0.

(3) An origin is generated randomly according to the equation (18) while a destination is generated randomly according to the equation (19).

(4) The ant moves to the next node under the maximum probability. The transition probability is

$$P_{ij} = \frac{\tau_{ij}\eta_{ij}}{\sum_{j=1}^{n}\tau_{ij}\eta_{ij}} \tag{20}$$

(5) Continue the step (4) until the ant reaches the destination. Pheromones will be updated if $t_ij(k) < t_ij(k-1)$.

(6)Judge wether the maximum number of ants N is reached. We will jump to step (3) if N is not reached.

(7)Let $x_{ij} = 1$ when the pheromones outweight a given threhold. Then the shorted path is updated.

(8)Let $k = k + 1$, If the maximum number of iterations is reached or the objective function U is not greater than the minimum of threhold, then a network will be generate.

A flowchart of Ant Colony Algorithm is shown in Figure 4.

Above all, we can generate a simplified transportation network. In order to provide multiple transportation choices for citizens, the connectivity of the graph should be satisfying. So we calculate the number of spanning trees in a graph to measure its connectivity.

Given a graph $G(V, E)$, the number of the spanning trees equals to the determinant of a Laplace Matrix (A).

$$L = D - A \tag{21}$$

where D is the degree matrix and A is the adjacency matrix.

Figure 5: Selected nodes in a map of Canbarra

4.3 Growth Plan of Transportation for Canberra

First we select 10 nodes with relatively high traffic densities. The nodes are marked in a map of Canbarra as Figure 5 shows.

To determine the importance of each node, we set four indexes:

index 1 total passenger volumn

index 2 passenger transportation volume

index 3 total freight volume

index 4 freight transportation volume.

From the indexes above, the normalized values r_{ij} can be calculated by

$$r_{ij} = \frac{x_{ij}}{\max_i\{x_{ij}\}} \tag{22}$$

Table 2 shows the normalized values of ten nodes below.

Table 2: Four indexes of nodes

Node	index 1	index 2	index 3	index 4
1	0.078	0.089	0.094	0.073
2	0.061	0.003	0.080	0.006
3	0.020	0.001	0.003	0.002
4	0.003	0.001	0.003	0.000
5	0.001	0.010	0.006	0.002
6	0.003	0.002	0.004	0.001
7	0.007	0.001	0.002	0.000
8	0.007	0.000	0.000	0.000
9	0.018	0.002	0.003	0.002
10	0.001	0.000	0.000	0.000

Using the distance tool in Google Earth, we measure the distance. Then the distance of road between two nodes is shown in Table 3.

Table 3: Road distance between the nodes

Distance \ Node	1	2	3	4	5	6	7	8	9	10
1	0	28.9	41.3	46.2	70.1	59.4	84.2	61.9	38.0	56.1
2	28.9	0	43.7	62.7	99.0	86.6	109	74.3	20.6	28.1
3	41.3	43.7	0	26.4	94.9	90.8	119.6	99.0	61.9	64.4
4	46.2	62.7	26.4	0	78.4	78.4	111.4	94.9	79.2	86.6
5	70.1	99.0	94.9	78.4	0	18.2	31.4	61.9	99.0	123.8
6	59.4	86.6	90.8	78.4	18.2	0	33.0	60.2	86.6	112.2
7	84.2	108.9	119.6	111.4	31.4	33.0	0	63.5	103.1	123.8
8	61.9	74.2	99.0	94.9	61.9	60.2	41.3	0	63.5	90.8
9	38.0	20.6	61.9	79.2	99.0	86.6	103.1	63.5	0	90.7
10	56.1	28.1	64.4	86.6	123.8	112.2	123.8	90.8	28.9	0

The traffic volume OD is shown in Table 4.

Table 4: Traffic volumn OD

OD \ Node	1	2	3	4	5	6	7	8	9	10
1	0	11169	1117	134	1087	159	426	12817	2557	325
2	8706	0	18	124	1084	72	379	923	1680	253
3	620	50	0	0	32	0	0	69	95	0
4	0	34	0	0	0	0	0	205	26	0
5	1010	906	20	0	0	67	0	120	387	0
6	47	114	0	0	114	0	369	22	26	307
7	296	263	0	0	0	416	0	0	180	808
8	11727	641	0	52	161	0	0	0	28	0
9	2397	1542	0	17	452	0	162	86	0	0
10	1790	24	0	0	0	0	0	172	16	0

Using the entropy-weighing method, we successfully determine the weights of the four indexes and the importance of the nodes which is shown in Table 5.

Table 5: Importance of the nodes

Node	1	2	3	4	5	6	7	8	9	10
Importance	0.59	0.23	0.07	0.01	0.35	0.02	0.01	0,01	0.03	0.00

With System Clustering Method, we classify the nodes into three categories as Figure 6 shows.

We use clustering to analyse main nodes in the network layout, analyze the principle of node selection and the calculation of the node importance index. By this way, we classify the different characteristics of nodes,which are the basis of the transportation layout . We add the importance of different cluster nodes to the ant colony algorithm to make the model more realistic.

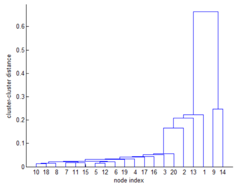


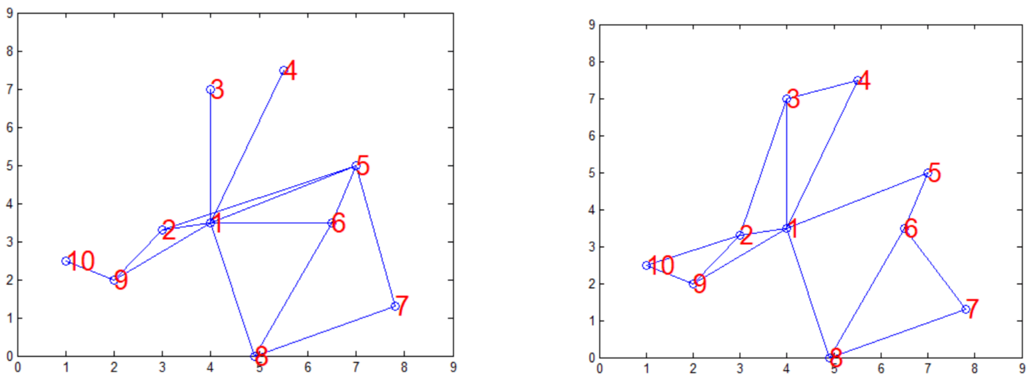
Figure 6: Cluster

Figure 7: Clustering of the nodes

Category	Nodes
1	1
2	2,3,4,6,7,8,10
3	5,9

The clustering results are shown in Table 7.

Based on the Ant Colony Algorithm, we generate a recommendated transportation network, comparing it with the real one in Figure 8.



(a) Current transportation network (b) Recommended transportation network

Figure 8: original transportation network and the recommended one of Canberra

To test our model, we calculate the number of spanning trees in these two graphs respectively. Our results show the original tranportation network has 159 spanning trees and the generated one has 3915 spaning trees. That means the generated graph has a tighter connection among the nodes and it can provide more choices for a trip.

5 Evaluation of Urban Ecological Environment

Environment is a vital factor to evaluate the smart growth of a city. With the accelarating of urbanization, severe environmental problems gradually emerge, such as air and water pollution, gabage pollution, noise pollution,etc. It is necessary to alleviate these problems to ensure a grenn planet for everyone to embrace.

The evaluation should follow three principles.

- Balance the economic growth and eco-protection reasonably.
- The index data should be practical to collect.

- The evaluation should serve as a guide for the development in the future.

Based on the principles above, we propose an evaluation system for the urban ecology. Suppose the number of indexes is n. The score of a city's ecology ϕ can be calculated by the values of corresponding indexes ϕ_i.

$$\phi = \sum_{i=1}^{n} w_i \phi_i \tag{23}$$

weher w_i is the weights of the index i.

Specifically, to assess the urban ecology in a comprehensive way, we select 15 indexes covering lots of fields such as economy, population ,science and so on. Then we determine their corresponding weights by the Analytical Hierarchy Process (AHP). The results are shown in Table 6.

Table 6: APH-derived weights

General index	Specific index	Weight
economic level	GDP per capita	0.0119
	financial income per capita	0.0669
economic structure	proportion of the third industry contributing to GDP	0.1235
urban greening	public green areas per capita	0.0625
environmental quality	number of the days with smog	0.0741
	sound level of the surrounding noise	0.1003
environment management	environmental investment contributing to GDP	0.0027
	rate of the disposed gabage	0.0116
	attainment discharge rate of industrial waste water	0.0243
population	population density	0.0941
quality of life	engel coefficient	0.0376
infrastructure	areas of land per capita	0.0792
	passenger transportation volumn	0.0677
science and eduction	proportion of educational investment contributing to GDP	0.1196
	number of researchers	0.1240

Then we test the consistency of the preferences for this instance of AHP for good consistency. The consistency index (CR) should be less than 0.1 and we get CR=0.027. Hence our evaluation system displays perfectly acceptable consistency and the weights are reasonable.

6 an Information Diffusion Model based on Block Chain

Informaion diffusion plays a crucial role in citizens' daily lives, bringing lots of convenience. In a smart growth city, information flows effectively and more values could be made through the diffusion. To maximize the values of information, sharing information and avoiding information islands is a trend. Our goal to create an open and efficient database can be realized by the block-chain technology.

In essence, block-chain technology is a database of peer-to-peer network. Figure 9 shows the operating principles of block chain which contains four layers: data layer, rule layer, application layer and mobile terminal. We will give a specific description of them below.

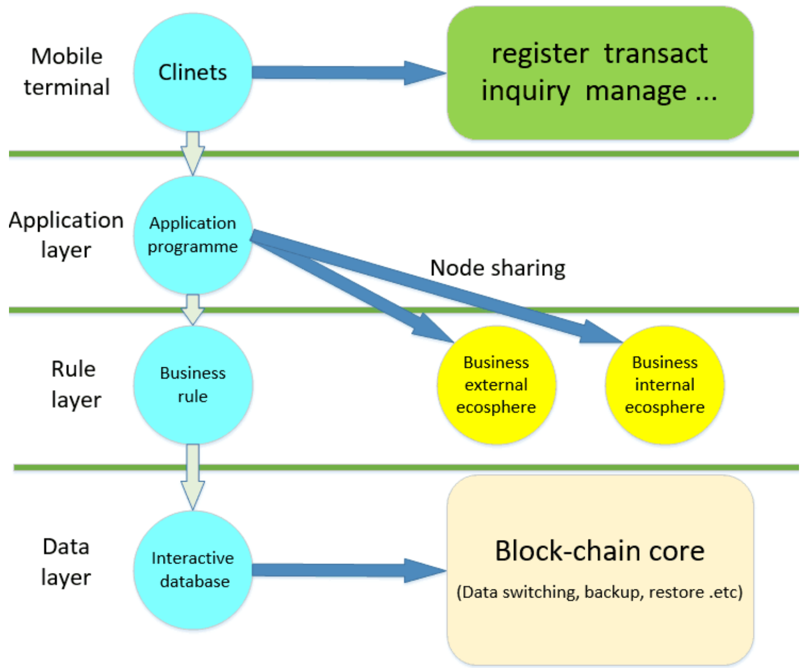


Figure 9: Operating principles of block chain

The foundamental layer is an interactice database which is the core of block-chain. It is used for data switching, backup and restore, etc. The transaction history can only be attached but not tempered. All of the data are stored in a distributed way which is open and transparent. Based on the database, business operate on the rules and many application programmes come up.

Rule layer and application layer are in the middle. Block-chain provides a trust establishment mechanism which is decentralized with no need for trust accumulation. For the network users who are strangers, they can still reach a consensus through contract, point-to-point book accounting, digital encryption and other ways without central trust institutions. So in those application programmes, information can flow quickly and safely among the nodes in the network, thus composing an internal and external business ecosphere.

The top layer of block-chain is the mobile terminal which is tailered for the clinets. It deals with the daily affairs, such as register, transaction, inquiry and management. Based on the advantages of block-chain above, these processes can be fast and safe than the traditional operating model. .

One of the most propserous application fields of block-chain is the evolution of Internet of Things. Block chain technology shall be introduced as a new partner of the traditional Internet of Things to make it intelligent. Due to the distributed network structure, block-chain keeps the consensus between equipments without a central database. Since there is no central data service provider, we don't have to worry about the leak of user information in batch. In addition, if one or a few nodes are attacked, the system of the entire network remains stable.

Block-chain technology is new concept which hasn't been widely used. We come up with several ideas about its applications in the smart growth of a city.

- **Citizen participation**
  To improve the vitality of the city, urban residents need to fully participate in public affairs. Their opinions should be integrated to make a fair decision. Block chain technology can serve as an effective platform to let citizens express their views freely on public affairs and reward the citizens who make contribution to city planning. Meanwhile block-chain is a good option for local elections and legislative issues, ensuring the anonymous voting safe and effective.

- **Convenient registeration**
  For example, to apply a social security card, citizens need to offer a series of documents such as the copies of identification card, household register, etc. When they rent a house next time, they have to prepare these documents again and submit them to different departments.

  Fortunatly, block-chain avoids these complex procedures. It simplifys formalities and enhances work efficiency. Once a citizen submits the materials, all the departments can get it simultaneously, which avoids repeated submissions and single-point failure. The risk of information missing or tempered could be neglected.

- **Economy and employment**
  Smart growth struggles for a resilient economic system with increasing employment opportunities for most citizens. Block chain technology can be used in finicial registering of local business, trade financing, managing operating modes of enterprise. Hence, sustainable value chains can be made by reducing costs and improving transparency. In this way, citizen of different incomes all have more freedom to run their business.

7 Discussion

This paper proposes a system to evaluate the smart growth of a city. Since a city is a complex system, it could not be simplily accessed. So we mainly focus on four typical aspects which can make a brief evaluation in a relatively comprehensive way.

- **Land use**
  'Mix land uses' is an ideal layout of land use. Based on a map of Jianye, we find different types of land distribute closely and it is hard to distinguish. Besides, land uses change dynamically, a growth plan for land use cannot truely reflect the real situations. So we combine the technology of CA and Artificial Neural Network to simulate the land use.

  'Mix land uses' is the first principle of smart growth. It means various types of land should be close to each other in a reasonable way. For instance, if we build houses, parks, shopping malls and offices within a close distance, citizens can enjoy more convenience, meanwhile creating more business opportunities.

- **Transportation network**

  We research the transportation network of Canberra and simplify it as a graph with nodes and edges. Then we design a growth plan for it, using the Ant Colony Algorithm to generate an optimal network. By comparing the original one and the generated one, the generated network has a tighter connectivity.

  According to the principle 'provide a variety of transportation choices', we define the number of spanning trees as a metric to access the smart growth. When a simplified transportation network has more spanning trees, it has a tighter connectivity, thus providing more choices for people to plan their trips.

  Meanwhile, to create walkable neighborhoods, the number of walkable roads is another metric to measure the smart growth. More attention should be paid to the construct of public transportation. Because it alleviates the problems of traffic congestion and provides more healthy ways for citizens to move around. Additionally, a reasonable and effective transportaion system can make the trip more safe and enjoyable.

  We recommend the city planners make reasonable adjustments based on the generated network. A wise transportation plan must consider many realistic situations, which is dependent on the experience of city planner as well.

- **Ecological environment**

  In our evaluation system, we take 15 indexes to make a comprehensive evaluation of the urban ecological environment. To measure more consisely, we calculate the weights of different indexes by AHP. Therefore, we can quantify the success of smart growth in the aspect of environment.

  'Preserve open space, farmland, natural beauty, and critical environmental areas' is one of the principle for smart growth. Our evaluation system can analyze the weakness of a city's ecological development and serve as a guide to the future planning. City planner can design a more tailored project according to the specific situations of the city's environment. Embracing a green community is the dream of everyone.

- **Information diffusion**

  In this era, information flows rapidly and it increasingly plays an important role in every aspect of people's live. Recently more city planner begin to consider how to make the information flow efficiently, conveying messages and creating more values at the same time.

  So we take the efficiency of information flow to measure the smart growth. We introduce block-chain as a new model to exchange information, ensuring the transaction safe and open.

  Block-chain plays an innovative role in making development decisions predictable, fair, and cost effective. We come up with lots of practical ways for citizens to participate in community affirs conveniently based on the block-chain. It can also be used to encourage community and stakeholder collaborate in development decisions.

To sum up, even though we only measure the smart growth from four aspects, we have already fully considered the ten prnciples of smart growth from the analyses above. So we firmly believe our model is a reasonable evaluation system and it is able to provide specific growth plans for cities as well.

8 Strengths and Weaknesses

8.1 Strengths

- Using the characteristics of self-learning of neural network algorithm, we skillfully solve the problem of state transition function in cellular automata that is difficult to be artificially determined. We accurately simulate the process of urban land evolution, thus providing the urban land planning ideas of future development.
- Nodes are the supporting points that form the network structure, which are the control conditions of the network layout. By traffic route analysis and simulation of ant colony algorithm., in case of the existing road in the city, we can achieve efficient use of transport network with few road reconstruction.
- When it comes to information security, third-party features are vulnerable and require extensive mechanisms and cryptographic protocols to protect the entire authentication and authorization process. Blockchain is a mechanism that does not require third parties and it does not require additional security mechanisms. By combining blockchain with smart city, we always can safely manage a complex system of intertwining across sectors such as transportation, energy, water, education, healthcare and more.
- The grading index systematically reflects the elements to be considered in building an eco-smart city. Through AHP, we can determine the weights of the elements accurately and compare them with the actual data so as to formulate a reasonable development policy.

8.2 Weaknesses

- The cellular automata space-time is discrete and the land change is continuous, which will affect the accuracy of the land planning model.
- The city's traffic network is complex and volatile, small roads not being considered in traffic modeling. In fact, the relevant data of the small roads are harder to collect and thereby adversely affect the modeling.
- The technology of building a information system with block chain needs strong computation ability and enough financial support, which are hard to obtain in developing cities.
- Analytic Hierarchy Process has subjectivity. When there are more indicators, the establishment of comparison matrix will be more subjective, which requires us to compare the calculated weight and reality, and adjust the parameters of the comparison matrix timely.

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