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Research on Spatial Differences and Evolution of Agricultural Parks Based on Topological Segmentation and Cluster Analysis

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Abstract:

When analyzing the evolution of spatial differences in agricultural parks, the boundaries of spatial data of common evolution models are not obvious, which leads to the lack of generalization ability of the models. Faced with this problem, this paper puts forward a modeling analysis of spatial differences and evolution of agricultural parks based on topological segmentation and cluster analysis. Cluster analysis technology is used to process the spatial data of agricultural parks. To facilitate the subsequent segmentation, the cluster data is converted into graph data, and then the low-dimensional data space is constructed by mapping. Topological segmentation technology is used to divide the data space into multiple unit spaces according to the spatial differences and cluster analysis results. The efficiency value of each unit space is calculated, and the cross-efficiency evaluation model is established. Combined with the comprehensive relative efficiency of unit spaces, the evolution model is constructed. The test results show that: the spatial data clustering boundary of the designed evolutionary model based on topological segmentation and clustering analysis is obvious. The model has good synergy with internal factors and short evolutionary running time. Its overall generalization ability is enhanced. The study provides certain reference for studying the spatial characteristics of agricultural parks under the influence of different regional environments.

Keywords: *Topological segmentation, Cluster analysis, Agricultural park, Spatial difference, Evolution model, Synergy.*

I. INTRODUCTION

The construction and development of agricultural parks is the key to strengthen the integration of urban and rural areas. The development level of agricultural parks is concerned by many aspects of the society, and the spatial changes of agricultural parks can reflect numerous problems in local social development. Although the construction of agricultural parks has been highly mature after decades of development, there are still big differences among different regions [1-3].

For the research on the development level of agricultural parks, the selected evaluation indicators are often the planning objectives of local governments. Thus, it is difficult to fully reflect the development

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level of a regional agricultural park from only one aspect [4]. Therefore, with the agricultural park as the research unit, the development level of the agricultural park is analyzed from multiple angles [5-7]. For example, the evolution model based on land use data and night light data mentioned in Literature [8] fits the industrial GDP of each region spatially. Different models are established for different industries, and the spatial difference results are displayed in three dimensions. The transparency of data has been realized. But in actual use, the generalization ability of this model is poor, which is manifested in the synergy between the model and indicators, and the clustering effect of data, mainly in the poor spatial data clustering and collaboration. The evolution model mentioned in Literature [9] combines the static spatial measurement model with the dynamic spatial panel model by using the exploratory spatial data analysis method to realize the evolution analysis of the spatial differences of agricultural parks. But this model has not solved the problem of poor generalization ability.

Therefore, a modeling analysis of spatial differences and evolution of agricultural parks based on topological segmentation and cluster analysis is proposed to solve the problems existing in the previous research models.

II. DESIGN OF SPATIAL DIFFERENCE AND EVOLUTION MODEL OF AGRICULTURAL PARKS BASED ON TOPOLOGICAL SEGMENTATION AND CLUSTER ANALYSIS

2.1 Cluster Processing of Spatial Data of Agricultural Parks

To collect the spatial data of agricultural parks, the set consisting of n spatial data is set as Q, $\vec{q}_i \in Q$, where $i = 1, 2, \dots, n$. It represents a data element in the set. Clustering is to divide the set Q into multiple subsets $\{Q_1, Q_2, \dots, Q_k\}$ while meeting the conditions of $Q_u \cap Q_v = \varnothing$, $1 \le u$, $v \le k$ and $u \ne v$ [10]. The clustering result is represented by the matrix H of $n \times k$, and the elements of the matrix H can only take $\{0,1\}$. When $H(i, j) = 1$, it indicates that the i-th sample $\vec{q}_i$ is classified into the j-th category Q_j. Clustering of agricultural parks is to ensure the minimum loss function [11]. The loss function is as follows:

$$\cos t_k = \sum_{j=1}^{k} \sum_{i=Q_j} \left\| \vec{q}_i - \vec{\alpha}_i \right\| \tag{1}$$

In the formula, $\vec{\alpha}_i$ represents the center of the j-th cluster Q_j, and the calculation formula is:

$$\vec{\alpha}_i = \sum_{i \in Q_j} \frac{\vec{q}_i}{\left| Q_j \right|} \tag{2}$$

In the formula, $\left| Q_j \right|$ represents the number of elements in the j-th cluster. k cluster centers are randomly selected, and the distance between the remaining spatial data in the set and each cluster center is analyzed. Under the condition that the nearest distance between the spatial data and the cluster center is given, the spatial data is saved in the cluster corresponding to the cluster center. The above process is

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repeated for each spatial data in the set.

To further analyze the spatial differences of agricultural parks, it is necessary to divide the data according to the clustering results in the follow-up operation. Considering the complexity of the segmentation processing, the clustering problem is converted into the graph segmentation problem [12-13]. Each cluster spatial data point corresponds to a node of the graph, and different nodes are connected by edges. The values of the edges represent the similarity between the nodes, thus constructing a similarity matrix W. The similarity of q_i and q_j is represented as $W(i,j)$. The vertex degree of the graph is calculated by the formula as follows:

$$x_i = \sum_{i,j=1}^{n} W_{i,j} \tag{3}$$

The degree matrix of vertices is defined as $X = diag(x_i)$ to calculate laplacian matrix. The calculation formula is:

$$A = X - W \tag{4}$$

According to the normative equation, the eigenvalues and eigenvectors corresponding to the spatial data and graphs are calculated. The calculation formula is:

$$A_z = \beta X z \tag{5}$$

In the formula, z represents the eigenvector and β represents the eigenvalue. After the calculation of all spatial data, one or more feature vectors is selected to form a feature space, and the spatial data is mapped to the low-dimensional space through data mapping. Similarly, under the condition of ensuring the minimum loss function, all the data in the low-dimensional space will minimize the similarity between classes and maximize the similarity within classes, so as to ensure a more balanced subsequent segmentation as much as possible [14].

2.2 Segmentation of Data Space in Agricultural Parks

In the low-dimensional space, the spatial data exists in the form of classes. According to the spatial differences of agricultural parks, the data is divided into unit spaces. The topological segmentation technology is adopted to segment the low-dimensional spatial data of agricultural parks. The three-dimensional spatial map obtained by clustering operation is assumed to be F, so that $F' \subset F$ forms a subset which contains all data of F. A segmentation set $\{F_0, F_1, \ldots, F_{k-1}\}$ of F divides the three-dimensional space into $\sum = \{R_0, R_1, \ldots, R_{k-1}\}$ partitions, which are denoted as $F = \{1, 2, \ldots, N\}$. The index set of spatial data is denoted as $\eta = \{1, 2, \ldots, k\}$. m is the dimension, and the corresponding label set is $\eta = \{1, 2, \ldots, k\}$, so that each data in the F set is given a unique label:

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$$[\eta, e(i)] = e_i \tag{6}$$

In the formula, e represents the mapping in the low-dimensional space. Under the condition that the label set is given, the state space under the label is $\chi = \eta \times \eta \times \ldots \times \eta = \eta^N$, and a segmentation of the target can be generated by e in the state space [15]. In the state space, an optimal state is searched, and the search condition is that the mapping cost is the minimum or maximum. The segmentation result generated by the optimal state is the optimal segmentation result. After segmenting the low-dimensional data space of the agricultural park, multiple unit spaces are obtained, and these unit spaces are different. These units are used to construct the spatial difference evolution model of the agricultural park.

2.3 Evolution Model Building

After the spatial segmentation is completed, the spatial difference evolution model of agricultural parks is constructed according to the obtained unit spaces. Each unit space contains a large amount of spatial data, including input indicators and output indicators, which are respectively expressed as $x_a = (x_{1j}, x_{2j}, \ldots, x_{ij})$ and $y_a = (y_{1a}, y_{2a}, \ldots, y_{ij})$. The efficiency value δ_{c0} of each unit space is calculated by the following formula:

$$\max T_0 = \sum_{c=1}^{l} \delta_{c0} y_{c0} \tag{7}$$

$$\sum_{i=1}^{m} \varepsilon_{i0} x_{ij} - \sum_{c=1}^{l} \delta_{c0} y_{c0} \geq 0 \tag{8}$$

$$\sum_{i=1}^{m} \varepsilon_{i0} x_{ij} = \delta \tag{9}$$

In the formula, the differentiation values $\varepsilon_{i0} > 1$ and $\delta_{c0} > 1$. Wherein, δ represents the smallest and best weight combination of unit c. According to the above formula, the cross efficiency of sustainable development of unit c and unit j is calculated, and the calculation formula is:

$$\omega = \frac{\sum_{c=1}^{l} \delta_{c0} y_{j0}}{\sum_{i=1}^{m} \varepsilon_{ic} x_{ij}} \tag{10}$$

The evaluation value of sustainable development of the j-th unit space is obtained by the above formula. On this basis, the average value of cross efficiency of other regions is calculated, with the following formula:

$$\bar{\omega}_j = \frac{1}{N} \sum \omega \tag{11}$$

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Formula 11 is further optimized to obtain an aggressive cross-efficiency evaluation model of unit space:

$$min\sum_{c=1}^{l}\delta_{c0}\left(\sum_{j=1,i=1}^{N}y_{c0}\right)=0 \tag{12}$$

$$\sum_{i=1}^{m}\varepsilon_{i0}\left(\sum_{j=1,i=1}^{N}x_{ij}\right)=1 \tag{13}$$

$$\sum_{c=1}^{l}\delta_{c0}y_{c0}-T_0\sum_{i=1}^{m}\varepsilon_{i0}x_{ij}=0 \tag{14}$$

Based on the spatial differences of agricultural parks and the above formula, the calculation formula of comprehensive relative efficiency of all unit spaces in low-dimensional space is calculated:

$$\omega^{(c)}=\frac{\sum_{j=1}^{N}\lambda_j\sum_{c}^{l}\delta_{c0}y_{j0}}{\sum_{j=1}^{N}\lambda_j\sum_{i=1}^{m}\varepsilon_{i0}x_{ij}} \tag{15}$$

In the formula, λ_j represents the coordination variable. After solving the formula 15, the optimal coordination weight of the evolution model is obtained, and the optimal solution is substituted into the formula to get the optimal evolution model.

So far, the design of the spatial difference and evolution model of agricultural parks based on topological segmentation and cluster analysis has been completed, and the spatial changes of agricultural parks can be known through the calculated efficiency values.

III. AN EXAMPLE TEST OF SPATIAL DIFFERENCE AND EVOLUTION MODEL OF AGRICULTURAL PARKS BASED ON TOPOLOGICAL SEGMENTATION AND CLUSTER ANALYSIS

3.1 Example Test Environment

Taking an agricultural park in the middle of a county in a province as an example, a comparative experiment is designed to study the practical application effect of different spatial difference evolution models. The regional bitmap of the experimental case is shown in Fig 1.

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Fig 1: Experimental case agricultural park

In Fig 1, seen from the location, the agricultural park is adjacent to the urban area, with a good location advantage for the integrated development of cities.

Taking the agricultural park shown in Fig 1 as an example, two groups of comparative experiments are designed. One is spatial data clustering effect experiment, and the other is model collaboration experiment. Taking the method in Literature [8] and the method in Literature [9] as the contrast objects, the generalization ability of each spatial differential evolution model is compared and analyzed through two groups of experimental results.

3.2 Experimental Results and Analysis of Spatial Data Clustering Effect

The spatial data comes from actual cases, and the attributes of spatial data are used as variables. Using column function and transpose function of Excel tool, spatial data is organized into three columns; the internal tool is used to delete duplicate values of data and write the serial number of attributes, and the data is stored in the same experimental database used by each model; spatial data is input into different evolution models, and the attributes of spatial data are used as experimental variables. The data clustering results are output through third-party software. The experimental results are shown in Fig 2.

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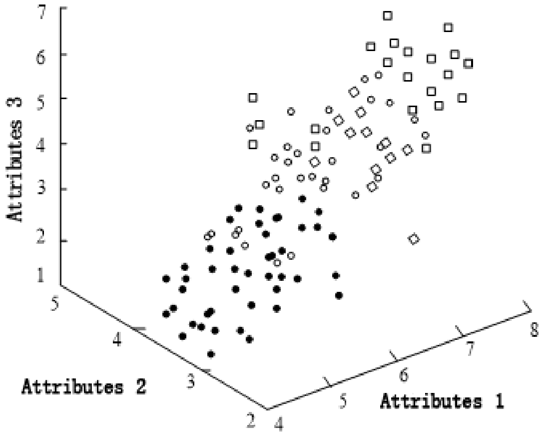
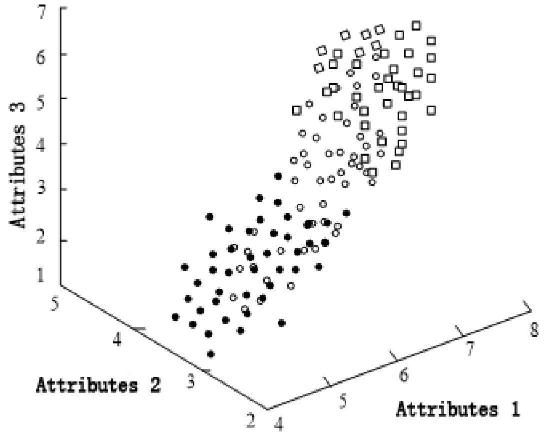
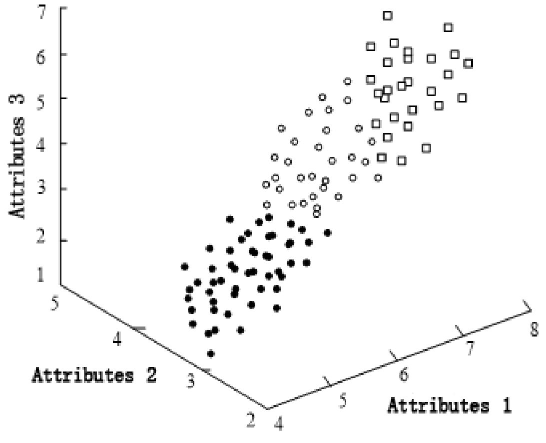


(a) Methods and experimental results in Literature [8]



(b) Methods and experimental results in reference [9]



(c) Experimental results of the method proposed in this paper

Fig 2: Experimental results of spatial data clustering effect of different evolution models

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Compared with the results in the figure, it can be seen that in the data clustering results of the method in Literature [8], there is data hybridity at the boundary of data blocks, and the data clustering effect is average; in the experimental results of the method in Literature [9], the three groups of data are mixed together, and there is no obvious data boundary. The data distribution is extremely dense, so the clustering effect is very poor; the experimental results of the method proposed in this paper show that the data distribution is uniform, and there are obvious boundaries between data blocks. There is no data hybridity, and the clustering effect is obvious. This shows that the proposed spatial difference and evolution model of agricultural parks is more reliable for spatial data processing and has better data clustering effect.

3.3 Experimental Results and Analysis of Model Synergy

There are many ecological spaces in the agricultural park, with numerous cultivated species in each ecological space. These species are all in different spaces. In the process of spatial differential evolution in the agricultural park, some reactions will take place among these species, which will affect the change of spatial state. Taking the spatial change of each species as an index, it is scored according to its change characteristics. And the change of the evolution model is also scored to analyze whether the change trend of a single index is consistent with that of the model. At the same time, the discrimination of each evolution model is calculated, and the detailed degree of model evolution is studied. The calculation formula of the discrimination is:

$$s = \frac{\left[\sum_{i=1}^{n} \left(x_i - \overline{x} \right) \Big/ n \right]^{1/2}}{\overline{x}} \tag{16}$$

In the formula, s indicates discrimination, and $\overline{x}$ indicates the average value of index scores. n indicates the number of indexes, and x_i indicates the score of the i-th species index in the ecological space of the agricultural park. The higher the discrimination, the more detailed the evolution of spatial differences. Based on the above, the experimental results are shown in Fig 3.

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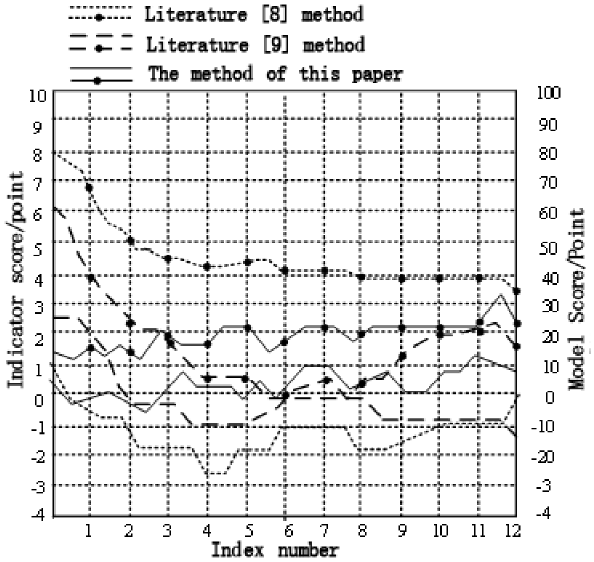

Fig 3: Experimental results of synergy of different evolution models

In Fig 3, the curve with dotted graphs indicates the model score, while the curve without dotted graphs indicates the index score. When the model score changes steadily, the scores corresponding to the methods in Literature [9] and Literature [8] show an upward trend, indicating that the coordination between them is poor; in the experimental results of this method, the change trend of the model score curve is basically consistent with that of the index score curve, and the synergy is good. Moreover, there is a good synergy between the indicators and the model, and the evolution is more detailed.

To further illustrate the synergistic effect of this method, the running time is taken as the experimental index. On the basis of the above experimental results, different evolution models are used to deal with different spatial units, and different features in spatial data sets are marked. After the evolution results are obtained, the synergistic effect of the models is analyzed. The experimental results are shown in Table I.

TABLE I. Experimental results of running time of different evolution models

Model name	Number of bins/one	Number of labels/one	Running time /s
The method in Literature [8]	5804	3	0.1
	8996	2	0.21
	19521	4	0.45
	43400	5	5.03
	84325	6	16.91
The method in Literature [9]	6055	1	0.08
	9265	3	0.46
	21654	4	1.22
	42546	2	4.81
	82134	5	18.24
Method proposed in this paper	6243	5	0.05

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9154	3	0.11
25321	4	0.17
43914	4	0.84
81343	8	2.76

According to the data distribution in Table I, there is little difference in the number of bins processed by the three models. With the increase of the number of bins, the running time is also increasing. Compared with the results of the three groups, the running time of this method is shorter and the number of salient feature bins is larger, which indicates that the model has high efficiency and can ensure evolution accuracy and efficiency, and that the modeling analysis of spatial differences and evolution of agricultural parks based on topological segmentation and cluster analysis has better generalization ability than the general evolution model.

IV. CONCLUDING REMARKS

In this paper, taking the spatial difference and evolution of agricultural parks as the research focus, and combining with the actual situation of agricultural park development, an evolution model based on topological segmentation and cluster analysis is designed, and the generalization ability of the model is further verified, which proves that the model has very good generalization ability, and is practical to a certain extent in the research of related fields.

However, in the process of practical application, it is found that the spatial change of agricultural parks has a great relationship with regional development. Facing the evolution of spatial differences, the study should also combine with local development. In the future research, we should take the development of local agricultural parks as the starting point to further study the spatial differences of agricultural parks.

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