A New Road Network Selection Approach Based on the Importance Criteria of Spatial Interactive Relationship

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Abstract—**After introducing the past research achievements in the field of automatic selection of road network, the advantages and shortcomings of how to select the road network were underlined, then a new road selection algorithm to fetch up the shortcomings was put forward. First, the assessment criteria of the importance of road network were summarized and classified on the basis of constraints in road network generalization selection. Second, the importance assessment criteria of road network were achieved by the spatial interactive relationship of road network which was analyzed with buffer analysis and cluster analysis algorithms. The enhanced road network importance criteria fetched up the lack of attribute information in data structure of road network, which was pivotal to road selection. Finally, examples were illustrated the advancement and scientificity of this new approach termed in this paper.**

Keywords-automated cartographic generalization; selection of road network; importance criteria of spatial interactive relationship; cluster analysis; buffer analysis

I. INTRODUCTION

Road network is one of the most important features of geographic elements, which reflects the geographical feature, social economy and human activities. It is pivotal to showing road elements correctly to reflect the real world objectively and convey cartographers' understanding of the real world correctly. Selection of road network has been a vital focus in the research of cartography [1] and automated cartographic generalization. In the past researches, the serious deficiency of automated cartographic generalization information has been a major reason that restricts the development of automated cartographic generalization itself because of the lack of information support. This problem has become more obvious in the automated selection of road network. Except the traditional geometrical information, how to obtain more spatial information to support the automated generalization of road network and make it more accurate has been the focus problem.

In the early research, the selection of road network manly considered the grade and length of roads. Now the following are the methods of auto selection. Topfer proposed a method based on the root square model. The Root square model is the law which is created by the large statistics and supports principles for the cartographers [2]. Mackaness proposed a method based on graph theory. On the basis of the scales of pre-generalization and post-generalization and the parameters of topology and road length, this method selects roads so that it can keep the connectivity of the roads and save the important roads [3]. In order to keep the good connectivity of roads, "Stroke" is put forward by the view of human visual impact. It regards some roads which have the best connectivity as a "stroke", and then the strokes are ordered. At last, the strokes are selected by their size. Y. Hu proposed a method based on the density of road grids. The method divides some small areas according to the density of road network. The roads in the small areas are selected by the density threshold which is determined by the attributes of geometry and semantics [4]. H. Qian put forward a method which combined the character recognition, stroke and polarization transformation. The method recognizes the character roads firstly, and secondly selects roads by stroke, and lastly selects the remaining short scattered roads by polarization transformation [5].

From the developing trend of road network selection, we can find that it pays more attention on the restricting factors. The existed methods still maintain a failure to get rid of the thinking pattern which mainly depends on road grade. Methods based on graph theory, which involves grade, length and topology, is a comprehensive method.

The selection of road network is a comprehensive task, and should consider grade, length as well as social values and military values as a whole. But the existing methods cannot factor in the social values, availability, military values, etc, which always leads to an unreasonable selection. In order to improve the road selection level, a new method is put forward in this paper. By using the methods, such as mathematical algorithms, spatial analysis, etc., more road spatial information criteria such as road availability, military significance, political meaning can be obtained, which is pivotal to measuring road importance comprehensively and give information support to road network automatic selection.

II. THE IMPORTANCE CRITERIA OF ROAD NETWROK DETECTED BY SPATIAL ANALYSIS

There is no doubt that road grade is an important and direct criteria in assessing the importance of the road. However, this criterion will usually take place of other criteria in the process

of road network selection. For example, in a desert area, the pathway road which leads to headwaters is more important than the common carriage road. Affected by the high speed development of the economy, influence of military activities, pursuit of a higher life quality, the assessment criteria of road importance have shown a trend of variety.

X. Li made a further study in the literature [6]. By analyzing the demand of the current cartographic generalization, this paper classified the assessment criteria of road importance. Table1 shows the seven aspects contained in the assessment criteria.

TABLE I. THE ASSESSMENT CRITERIA OF THE IMPORTANCE OF ROAD NETWORK

Assessment Criteria	Brief Illustration
1. Road Grade	The administrative grade of road
2. Road Length	The length of road
3. Road Availability	Whether the road is the only path among habitations
4. Road Political Meaning	Whether the road is the boundary of a country or district, or whether the road run across two districts
5.Road Military Values	Whether the road is a path to a military target such as headwaters, storage, airport, dock, army base, etc.
6.Road Economic Values	Whether the road is the key line of transportation
7.Road Special Function	Whether the road is built for a specific purpose, such as tourist, airstrip, etc.

Two steps are needed to assess the importance of road. Firstly is to rank the importance of the seven criteria, give each criteria certain weight according to their ranking. In series scale map, grade, availability, political meaning and military value of road network affect the military activities most.

Then the importance of the road in each criterion needs to be evaluated. The evaluation is made according to the certain conditions that the road is satisfied. Some importance can be calculated with its attribute value. For example, the road grade is namely the administrative grade. Generally, for a road, the higher the administrative grade, the larger social value, and the more important it is. Some other criteria need spatial analysis to evaluate its importance. For example, road availability, namely means whether it is the only road among inhabitants. Road political meaning means whether it is the boundary line of the country or the district or whether it runs across two districts. Road military value namely means whether it is a path to an important military target, such as headwaters, storage, airport, dock, army base. They all are needed to analyze the topologic relationship to evaluate the importance.

In order to obtain the above information, the methods of cluster algorithm and buffer analysis are adopted in this paper, and through the spatial analysis, the spatial relation information among the habitations, road network and so on, are achieved. Considering the importance of the road need to be evaluated through the spatial analysis of its connectedness between different habitations and its topologic relationship are considered the same for the habitations in a certain area. Thus, the habitations need to be clustered.

III. CLUSTER ANALYSIS AND BUFFER ANALYSIS ALGORITHMS FOR ROAD SELECTION

Cluster analysis, which is a branch of statistics, has a long research history as a method of unguided machine learning [7]. In recent years, cluster analysis has been a research focus in the field of spatial data mining and contain many achievements. Cluster analysis mainly clusters on the basis of the object characters and divides the objects into series of distinguishing groups by certain distance and similarity, which can lead to the maximum similarity in the same groups and the maximum difference in the different groups [8-10]. The distribution regularity of spatial data can be found by cluster. Nowadays, there are many cluster methods, including hierarchical cluster algorithm, graph theory cluster algorithm, fuzzy sets cluster algorithm, density cluster algorithm, division cluster algorithm, mixed cluster algorithm, etc. In automated cartography generalization, cluster algorithm is mainly used to detect the distribution of spatial elements, which contains the generalization of area target and selection of points group. Cluster algorithm has a significant effect on habitation generalization and selection of point groups.

Buffer analysis is one of the important methods of spatial analysis. Buffer zone, which is built automatically around point, line, area, is a polygon [11] which has certain width. Buffer analysis can obtain information from focused targets, and discover the relationship of dependence and restriction. Buffer analysis is widely used in civil engineering, geology analysis, environment engineering etc. In the cartographic generalization, it is also widely used in clash detection, feature displacement, line simplification, and so on.

The goal of this paper is to give a workable method of assessing road importance with cluster analysis algorithm and buffer analysis, which are used to detect the spatial relationships among road network and other features. In order to illustrate this method, this paper takes the road importance as an investigation object to design an algorithm and experiment. For the other criteria of road importance, it can also use this kind of method.

IV. THE METHOD OF ASSESSING THE IMPORTANCE CRITERIA OF ROAD AVAILABILITY BASED ON CLUSTER ANALYSIS AND BUFFER ANALYSIS ALGORITHMS

The availability of roads is the most pivotal criterion to assess the importance of road network because of the following aspects. Firstly, the availability of roads can reflect the movement orbit of human beings objectively. Secondly, availability of roads has great effects on keeping the topology similarity of road networks. The cartography specifications of series scale coordinate map make it clear that the corresponding scale of habitation must have the availability of roads. Table2 enumerates the basic demand of roads availability in habitation in the coordinate map at the scale of 1:250,000, 1:500,000 and 1:1,000,000.

TABLE II. THE BASIC REQUIREMENTS OF ROADS AVAILABILITY IN HABITATIONS [12-14]

Scale	The basic requirements of roads availability in habitations

1：250,000	There must be roads among the town-town, town-village and village-village
1：500,000	There should be roads among the town-town, and town-village.
1：1,000,000	There should be roads among the town-town.

It can be seen from the road selection requirements that there must be some roads among habitations, so the road availability has been the important criterion. If there is only one road between two habitations, then the only road must be selected. If there are many roads among habitations and the roads have the same availability, thus it should refer to other criteria such as grade, length, etc. for the continuing investigation.

The algorithm of assessing the availability of roads is illustrated as follows:

Firstly, habitations are clustered on the basis of the distance between two habitations. Center points of habitation can be obtained. If the distance between two center points is smaller than the threshold, we regard these two habitations as one cluster, namely a habitation unit. Secondly, the outlines of habitation units are designed based on the convex hull algorithm. Then, buffer zones of the outlines are built. If one road is the only road between two buffer areas, it must be selected.

There are 6 steps in total (Figure 1-6).

Step 1: Clustering the habitations according to the attribute name (Fig. 1).

Step 2: Obtaining the outline points of every habitation unit (Fig. 2).

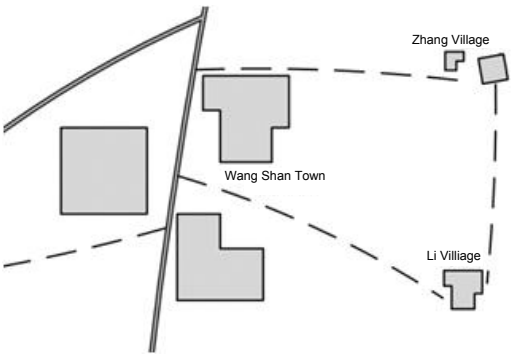

Figure1. Clustering according to the attribute

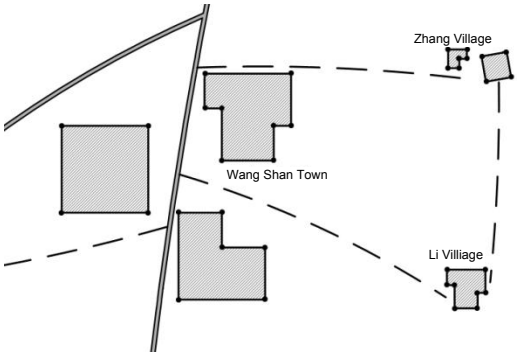

Figure2. Obtaining the outline points of every habitation unit

Step 3: For all the point groups, using convex hull algorithm to obtain area outlines (Fig. 3, Fig. 4).

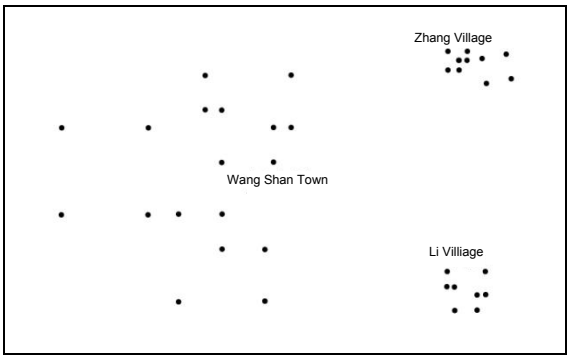

Figure3. Using convex hull algorithm

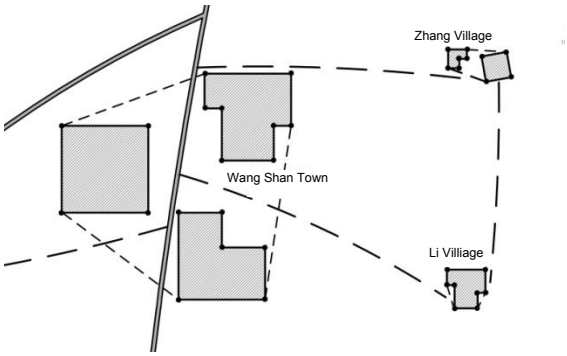

Figure4. Obtaining area outline

Step 4: Building buffer zones of the obtained habitation outlines according to the certain threshold (Fig. 5).

Step 5: Making buffer analysis and recording roads which are intersected with the corresponding buffer zone (Fig. 6).

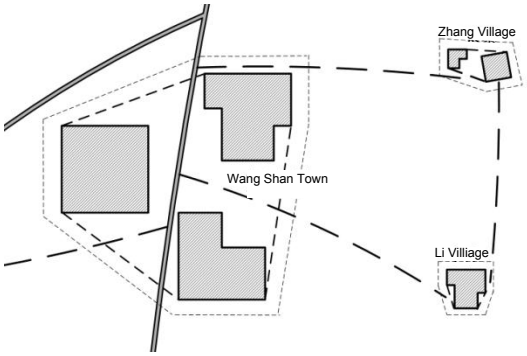

Figure5. Building buffer zone

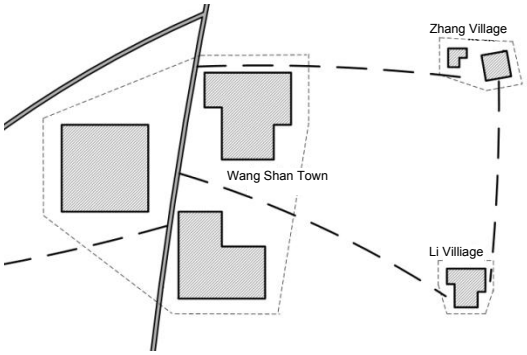

Figure6. Buffer analysis

Step 6: Calculating and analyzing the recorded roads.

(1) Finding out the roads connected with habitations.

(2) Finding out the only road between habitations and taking it as the necessary selected objective.

For the discrete point symbol habitations, the above methods are also workable. For the circle shape habitations in the small-scale map, it can do buffer analysis directly so as to get the spatial interactive relationship.

V. EXPERIMENT

Experiments to verify the advantages and scientificity of the algorithm created in this paper are done with the test data of part of the topographic map in our country. The scale is 1:100,000. Fig. 7 shows the original data consists of habitation and road network. In Fig. 8, the habitations are clustered and their buffer zones are built. For the area symbol habitations, the buffer zones are built with the convex hull algorithm, while for the point symbol habitations, the buffer zones are built directly. Then the buffer zones of habitations and road network are overlaid in Fig. 9. And at last, the only roads between buffer zones are selected, Fig. 10 shows the selection result of road network.

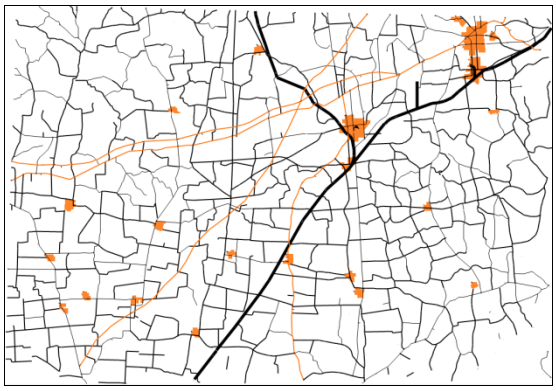

Figure7. Original habitations and roads data

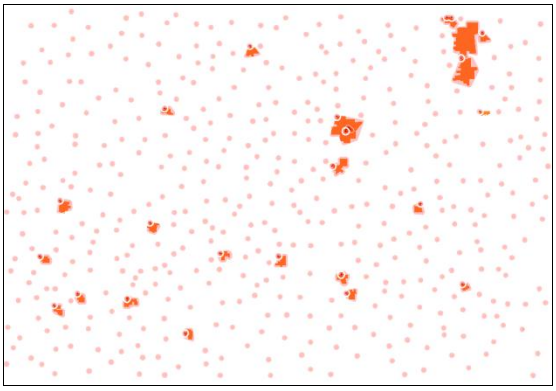

Figure8. Cluster and buffer analysis of habitations

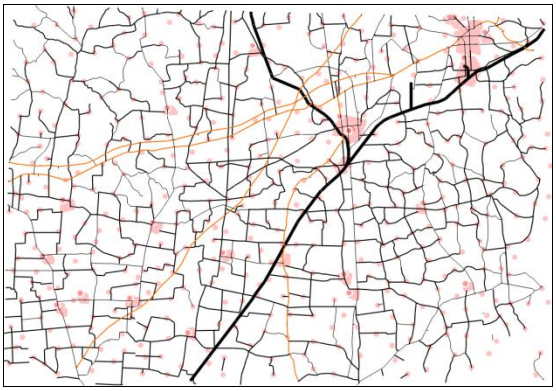

Figure9. Overlay the buffer zones of habitation with road network

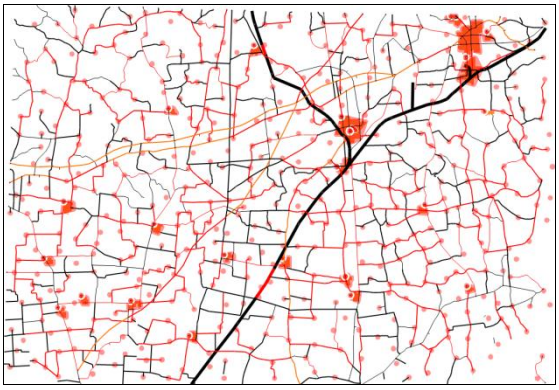

Figure10. Select the road network according to the overlay relations which are obtained with cluster and buffer analysis algorithms

From Fig. 10, it can be found that the only roads between habitations are all selected, so that the availability of roads is ensured.

The method which is based on the cluster algorithm and buffer analysis can be expanded in other fields. For example, combining the clustering and making buffer analysis about important military target, headwaters, storehouse with road grade, length and reasonable weight value used for measuring the military significance of roads, can give reference on roads selection. Making buffer analysis and considering road grade about boundary lines of country or area can measure the political significance of road. Clustering and making buffer analysis about cultural archeology, economic center etc. can measure the cultural and economic significance of roads.

VI. CONCLUSION

The method based on the cluster algorithm and buffer analysis to estimate the importance criteria of road network is a new approach to supply the data structure of road network by obtaining spatial interactive relationship from spatial data analysis. In the geographic information expressing mode, this method can obtain the important information of road spatial interactive relationship as much as possible by spatial analysis so as to estimate the importance criteria of the road synthetically. Tests illustrate the significant meaning on improving the accuracy and quality of roads selection.

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