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# A Method for Selecting Islands Automatically Based on Competitive Influence Domains

Lihua Zhang, Lulu Tang\*, Shuaidong Jia, Zeyuan Dai

Department of Military Oceanography and Hydrography & Cartography, Dalian Naval Academy, Dalian, Liaoning, 116018, China

\*Corresponding author's e-mail: world680@163.com

**Abstract.** Nowadays, the existing methods usually utilize the Voronoi diagram for automatically selecting the islands in chart. However, it is very hard that the selection results meet the actual requirement, of which the significant reason is that the Voronoi diagram is very difficult to represent the density and distribution of the islands in chart cartography generalization. Aiming at these drawbacks above, a method for selecting islands based on competitive influence domains is proposed in this paper. Firstly, the drawbacks of Voronoi diagram representing density and distribution of spatial data are analysed theoretically, and the island influence domain model is introduced to solve this defect. Secondly, the island influence domain model is defined and created. Thirdly, several islands are selected automatically through selecting the islands with the largest area of influence domain and deleting the islands whose influence domain have more overlap with the pre-selected islands. Finally, the experimental results show that: the proposed method improves the quality of the island selection which is obviously much higher than that of the methods based on Voronoi diagram, and it can be applied into more types of sea areas.

## 1. Introduction

Islands, being usually an important geographical feature in forms of points or areas are widely distributed on a nautical chart [1]. The quality of island generalization directly determines the quality of nautical chart. In the cartographic generalization, a series of steps for selecting islands are generally performed as follows: Firstly, the islands of which the areas are greater than a certain value should be selected in priority; Secondly, for the rest of islands, the number of the islands should be selected is calculated according to the square root model [2], and then the peripheral islands which reflect the distribution range and the extension direction are selected; Finally, the internal islands to reflect the regional density contrast and arrangement are selected until it reaches the index for selection [1,3].

For a long time, the island selection in cartographic generalization is usually operated manually by professional cartographers according to specifications requirements [3] and their own charting experience. On the one hand, this kind of manual operation method is inefficient, especially for some complex areas (e.g. the Zhoushan area, Paracel Islands area, etc.) would increase the operating time greatly; on the other hand, the quality of manual selection depends largely on the chart cartographers' professional ability and working attitude. In recent years, with the development of computer graphics technology, some scholars began to explore the methods for islands auto-selection. The basic idea of the existing methods for automatically selecting islands can mainly be divided into the following two types: (1) The human brain simulation method. This method tries to simulate the human brain thinking for automatic selection. Firstly, the larger islands are selected preferentially; then, Voronoi diagram is



used to calculate the density of each island, and the denser islands are preferentially deleted [4-9]. (2) The pattern-aware generalization method. Firstly, the islands that express the distribution range and distribution characteristics of the archipelago are identified and selected. Then, the denser islands are preferentially deleted in the remaining islands.

In short, most of these methods above delete the islands with higher densities priority for generalization purposes based on the evaluation of island density using Voronoi diagram [10,11]. However, it can be concluded that the Voronoi diagrams can not describe the density of features effectively in some special areas, which results in the difficulty of achieving the actual production requirements and restricting the automatic generalization of chart after systematic research.

Therefore, this paper will break through the basic ideas of above-mentioned methods. Firstly, the concept of island influence domain is introduced. Secondly, the island's influence domain model is defined and constructed. Finally, a corresponding automatic selection algorithm is designed and the automatic selection of islands is realized.

## 2. Material and Methods

### 2.1 Voronoi diagrams and influence domain model express spatial data denseness

#### 2.1.1 Shortage of the Voronoi diagram expressing spatial data denseness

For the group of point features (as shown in Figure 1a), the Voronoi diagram (as shown in Figure 1b) is mostly applied for expressing the density of these points. This is due to the polygon elements in Voronoi diagram exactly represent the generated space of the points it contains. The density of arbitrary point  $p_i$  can be calculated as follows:

$$\rho = \frac{1}{A(V(p_i))} \quad (1)$$

where  $A(V(p_i))$  represents the area of the polygon element in Voronoi diagram corresponding to the point  $p_i$ .

According to the general principle of cartographic generalization, some of the denser points should be deleted first after scale compression, which means two of the three points  $p_1, p_2, p_3$  should be deleted preferentially. However, owing to the definition of the density described above, it can be seen from Figure 1b that the density of the three points  $p_1, p_2, p_3$  is smaller than the point  $a_0$ . Considering the principle of deleting the features with larger density preferentially, the point  $a_0$  will be deleted first and  $p_1, p_2, p_3$  will remain. This is inconsistent with the actual principle of cartographic generalization.

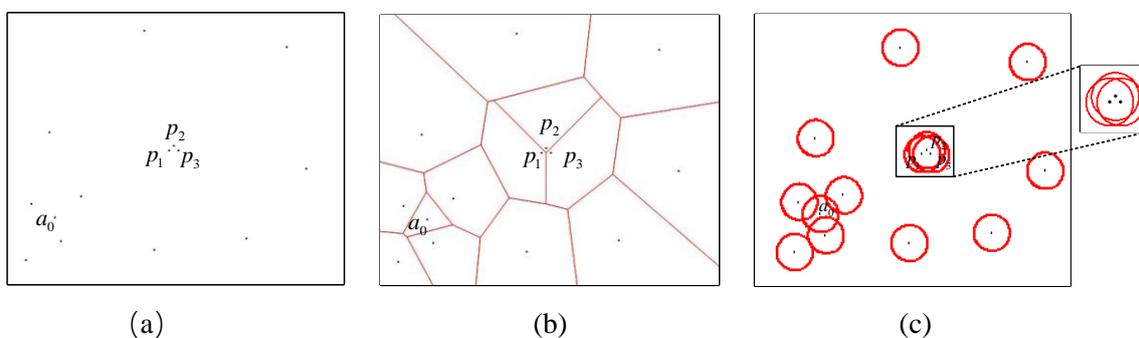


Figure 1. Express the impact of the spatial data by Voronoi diagram.

#### 2.1.2 Express the density of the spatial data by influence domain model

In order to cope with the drawbacks of the Voronoi diagram above, a buffer having a certain width can be set for the spatial features (there must be overlapping parts between the buffers). As can be seen from the Figure 1c, the overlap of buffers is very serious in the relatively dense areas (such as the region of they  $p_1, p_2, p_3$ ), and there is less or no overlap between the buffers for other sparse regions. This paper refers to the above buffer as the influence domain of the features, at the same time, this model is called the influence domain model. For the area feature, the model proposed can still be used to identify dense areas.

When using this model to describe the island's range of influence, it has the following characteristics:

- (1) The larger area of the island, the greater range of influence domain in the model;
- (2) The more isolated the islands are, the smaller overlapping areas with other islands' influence domains are.

These characteristics of the model make it possible to effectively identify these important islands that need to be selected priority. For this reason, the model proposed have the possibility of being applied to islands selection, and a method for selecting islands automatically based on competitive influence domains is proposed. That is, firstly, the influence domain is set according to the island's own attributes (shape, area, facilities on the island, etc.). Secondly, those islands with larger areas of influence domain are selected. Then, the islands with greater overlapping influence domains are removed. Finally, several groups of islands are selected automatically. The basic process of this method is shown in figure 2.

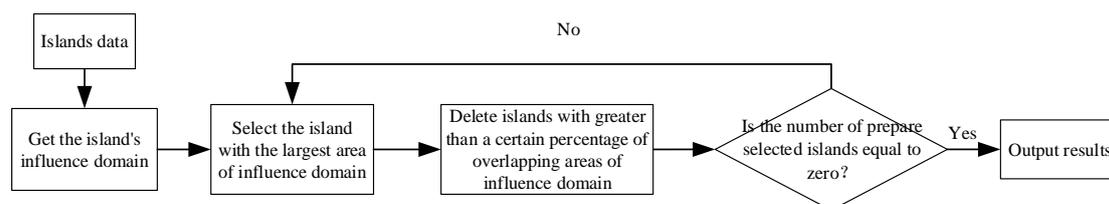


Figure 2. Flowchart of the basic process of the method.

## 2.2 Automatic selection of islands based on competitive influence domains

### 2.2.1 Construction of the model of influence domain

As an important geographical feature, the importance of islands is generally considered from the aspects of humanities, geographical location and ecological environment. However, considering the application requirements of the chart, the island's influence domain defined refers to the visual range of islands. The theoretical formula of the visible distance is used for reference, and the visible distance  $D_i$  of the island  $I_i$  can be expressed as follows:

$$D_i = K\sqrt{2rh} \quad (2)$$

where  $K$  represents the modulus,  $r$  represents the earth radius and  $h$  represents the eye height.

The area, that is defined by the points whose distances to the island  $I_i$  are less than  $D_i$ , is the influence domain of the  $I_i$ . Thus, the influence domain can be estimated as follows:

$$v_i(I_i, D_i) = \{P \mid d(P, I_i) \leq D_i\} \quad (3)$$

where  $v_i(I_i, D_i)$  represents the influence domain of  $I_i$ , and  $D_i$  represents the radius of the visible distance of  $I_i$ .

### 2.2.2 Interaction degree factor

In order to describe the degree of mutual influence between the two islands, the degree of influence between the two islands is defined as follows (▨ is the intersecting influence domain of the islands):

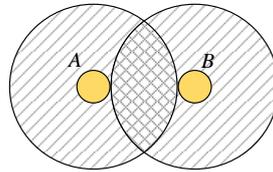


Figure 3. The influence degree of islands.

As shown in figure 3: The degree of influence of island  $B$  on island  $A$  is defined as follows:

$$\gamma_{B \rightarrow A} = \frac{S_{v(A) \cap v(B)}}{S_{v(A)}} \quad (4)$$

where the  $S_{v(A) \cap v(B)}$  represents the area of the overlap between the influence domains of island  $A$  and  $B$ , the  $S_{v(A)}$  represents the area of the influence domain of island  $A$ . On the contrary, the degree of influence of island  $A$  on island  $B$  is defined as follows:

$$\gamma_{A \rightarrow B} = \frac{S_{v(A) \cap v(B)}}{S_{v(B)}} \quad (5)$$

where the  $S_{v(B)}$  represents the area of the influence domain of island  $B$ .

### 2.2.3 Automatic selection based on the influence domain

#### (1) Basic idea of selection

The basic idea of the algorithm for automatically selecting island is to select the island with the largest area of influence domain priority, with to ensure that the selected island has the largest comprehensive influence domain. At the same time, those islands whose intersecting influence domain with the selected islands are greater than the selection threshold is removed.

#### (2) Main steps

The main steps are as follows.

Step 1: According to the above method, the influence domain of the island to be selected is obtained. According to equation (3), the weighted influence domains of islands are obtained.

Step 2: The first island that has the largest influence domain is selected. The comprehensive influence domain area of the currently selected islands is set to null ( $\Phi$ ). The influence domains of all islands to be selected are sorted by area size. The island with the largest area of island influence domain is selected, and it is marked as “selected”. Finally, that island’s influence domain is combined into the selected islands’ comprehensive influence domain.

Step 3: Those islands whose intersecting influence domain with the selected islands are greater than the selection threshold is removed. According to the equation (4), the degree of influence of selected islands on the island to be selected  $\gamma_{v \rightarrow I}$  is obtained. Then, compare  $1 - \gamma_{v \rightarrow I}$  with the selection threshold  $\gamma_d$ , and if it is less than, the island is deleted, otherwise, the island is retained.

Step 4: The effective influence domains of the islands to be selected are obtained and sorted by area size (the effective island’s influence domain refers to the partial area obtained after the difference between the island’s own influence domain and the selected islands’ comprehensive influence domain). Then, the island with the largest area of the effective influence domain is selected, and it is marked as “selected”. Finally, that island’s influence domain is combined into the selected islands’ comprehensive influence domain.

Step 5: Determine if the number of islands to be selected is equal to 0. If yes, stop selecting and output the result of the selection. Otherwise, go to step 3, and continue selecting the islands until the number of islands to be selected is empty.

In the process of sorting the islands' effective influence domains in step 4, if the size of effective influence domains of islands is equal, the distance summation between these islands and other selected islands are obtained. When sorting, the greater the distance summation, the more forward the location.

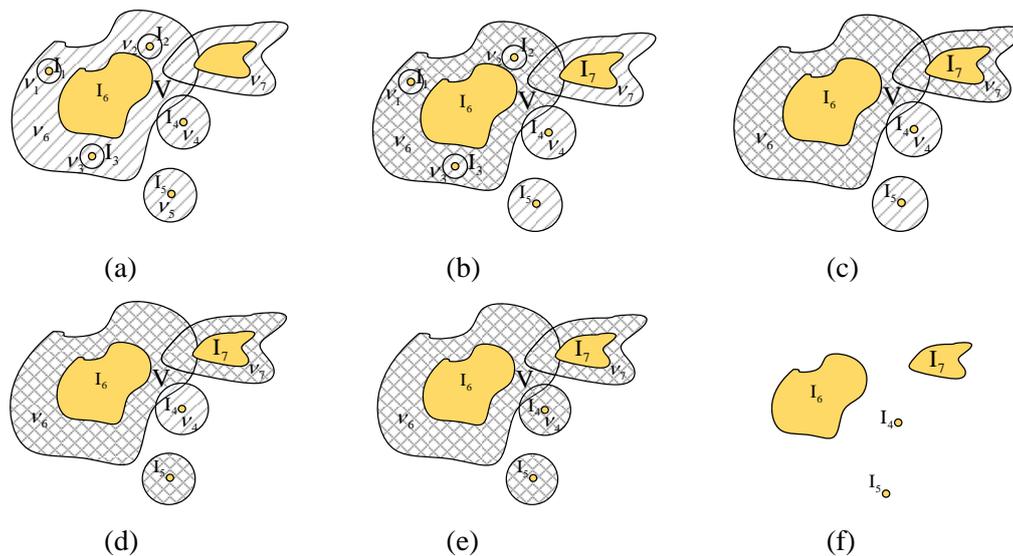


Figure 4. The flowchart of selecting islands automatically algorithm.

### 3. Results

In order to verify the feasibility of the proposed method, the charts of experimental data were selected from the vicinity of Zhongjieshan islands in chart 13300. In the experiment, the radius of the earth  $r$  is set to the average radius of the earth (6371 km), and the height  $h$  of the human eye is set to 5 m, which are used to calculate the spatial influence domain of the island.

This area, in which the distribution of the islands is striped and there are some isolated islands, can evaluate the effectiveness of the proposed method reasonably. And the island selection method based on Voronoi diagram [4] is set as the comparison method. The data map is scaled down to the target scale (1:500,000, as shown as figure 5a), and the result of the comparison method is shown as figure 5b. The modulus of the influence domain is  $K = 0.05$ , and the selection threshold is  $\gamma_d = 0.5$ . The selection result of proposed method is shown as figure 5c.

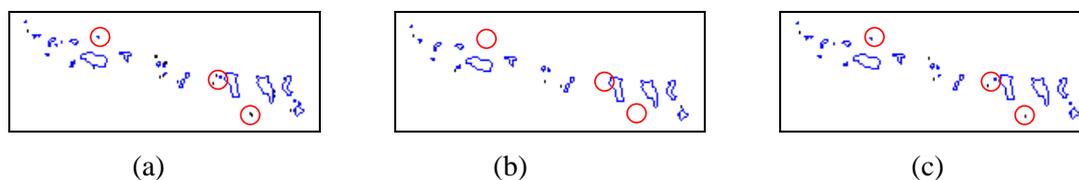


Figure 5. The selection results at Zhongjieshan Liedao waters.

In general, the isolated islands should be retained in selection process, at the same time, the point islands that are closer to the coast should be deleted. However, as can be seen from the figure 5b, the isolated islands (as shown by the circled area in the figure) are deleted, which causes errors. In contrast, as what can be seen from the figure 5c, the basic distribution characteristic of the region is maintained. Moreover, the important, peripheral and isolated islands are maintained well.

The island selection method based on Voronoi diagram regard the islands as the group of points, and use the Voronoi diagram to measure the density of the islands. However, because of the disadvantage of the Voronoi diagram expressing spatial data denseness, it is difficult to remove the

islands with higher densities during the selection process, but some isolated islands were deleted instead, which result in poor quality of the results. In contrast, the results of the method proposed in this paper are more reasonable.

#### 4. Conclusions

The following conclusions can be drawn from the theoretical analysis and experimental comparisons that were presented in this study:

(1) The proposed method can select islands automatically, whose results can meet the requirements of the charts.

(2) The proposed method improves the quality of the island selection which is obviously much higher than that of the methods based on Voronoi diagram.

The proposed method in this paper only considers the influence between islands. The influences of the other geographical features on the selection results need to be compared and analysed further.

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