SUITABLE REGION SELECTION ALGORITHM BASED ON MULTIPLE RESTRICTIONS

KE Xi-lin[a,b] , GUO Qing-sheng[a] , ZHANG Yue-peng[b] , HUANG Li-min[b] , LI He-yua[b] , JIN Cheng[b]

[a]School of Resource and Environment Science, Wuhan University, Wuhan, China, - chauchl@163.com,guoqingsheng@126.com
[b]Xi'an Research Institute of Surveying and Mapping, Xi'an China

KEY WORDS: Decision Support Systems, Topological Analysis, Image Understanding, Spatial Analysis, Geography, DEM

ABSTRACT:

Extracting the latent geo-information and provide decision support for the users is very important function in GIS(Geographic Information System). GIS is different from other mapping system (MS) in that topographical analysis is the main function of GIS. The common topographical analyses include slope analysis, visibility analysis, overlay analysis, buffer operation and overlay analysis. These analyses have played important roles in GIS by extracting the latent geo-information and helping the user to understanding the terrain. The vitality in GIS is that GIS can provide decision support for human being in planning their activity. Generally speaking, the activity of human being is often engaged in a certain region, so region selection is the support to boost the function and application of GIS. From above-mentioned thoughts, the authors investigate the suitable region selection analysis based on multi-restrictions and designs the algorithms to realize the region suitability selection. Under the algorithm, the experiment test is taken and has good effect in region selection.

1. INTRODUCTION

GIS can store, manage, visualize and analyze the terrain information. The kernel function of GIS is to make decision support for GIS user. Generally speaking, human's activities are engaged in some region. So region suitability analysis is very important for human being and their behavior.

Region suitability analysis means analyzing the terrain region and educing whether the region is suitable to engage some activity. For example when the flood occurs, mankind firstly analyze whether some region is suitable for evacuating the mass in order to avoid the huge loss of lives and properties. If helicopter is needed, the region need to be analyzed first to decide whether there is some place suitable for landing helicopter. Only with the accurate analysis, a series of activities can be scientifically planned.

The basic thought of region suitability is that whether the terrain is suitable for human activity is determined under the topographical acquirement of activity and topographical character. The topographical characteristics cover terrain, water-system, vegetarian, and resident. So the analysis of the terrain is based on the analysis of these features.

2. SUITABLE REGION SELECTION PROBLEM

As to the topographical character, DEM data is needed. Besides DEM data, other topographical features, such as vegetation, water system, terrene character, and so on, are necessary to be analyzed. With above mentioned geo-information, the region suitability can be engaged with overlay analysis algorithms.
In order to analyze the topographical character of the terrain, slope raster matrix should be built on the basis of the DEM data of the terrain computing the slope value of each DEM grid.
On the basis of slope value matrix, other value matrixes, such as other feature values are created, in which the value of the potential grid is TRUE otherwise is FALSE. In creating the binary matrix of the terrain, other features, involving the terrain, are considered. In this paper, the algorithm is on the foundation of the built-value matrix.

0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	1	1	0	0	0	0	0	1	1	0	0	1
0	0	0	0	1	1	0	0	0	0	1	1	1	0	1	1	1	1	1	0	1	1	0	0	0	1	1	1
0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1	1
1	1	0	1	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
1	0	0	1	1	0	0	1	1	1	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1
0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1
0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	1	1
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1
1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0	1	1
1	1	1	1	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	1	1	1
1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0
1	1	1	0	0	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
1	1	1	0	0	0	0	0	1	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	0	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1
1	1	1	0	1	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	1

Figure 1. Binary data matrix

After the binary value matrix is built, the area of each appropriate connecting region is computed. When the area of the region is not less than the threshold area value, the region is a likely suitable one. The edge line and the reference coordinate point of the region will be calculated out.

3. DESIGN OF THE SUITABLE REGION ALGORITHM

The region suitability analysis algorithm, which is based on the raster data shown as in Figure 1, is involved with the steps as follows:

1) To eliminate the potential binary value grids where the width is less than the width threshold using the erosion algorithm of mathematical morphology.

2) To seek a first valid grid as seed grid and searching for the connecting region from the eight adjacent grid of the seed grid. If all the potential grids are sought, the connective region is established. From the connective region, the area of the region can be calculated. If the region area is larger then the threshold area value, then the next steps will continue. Otherwise the algorithms come to the end, and give the conclusion that the terrain is not suitable for the activity.

3) To compute the edge line of the connective region according to the suitable region. The edge line of the region defines the region domain. And the edge line of the region can make human comprehend where the suitable region is.

4) To compute the suitable region coordinate. The suitable region coordinate is set to be the average of the whole of the region grid coordinate. If the suitable region has a vain amongst region, the region coordinate point may be located in the vain region. So the region point, if in the vain region, should be shifted to the valid region.

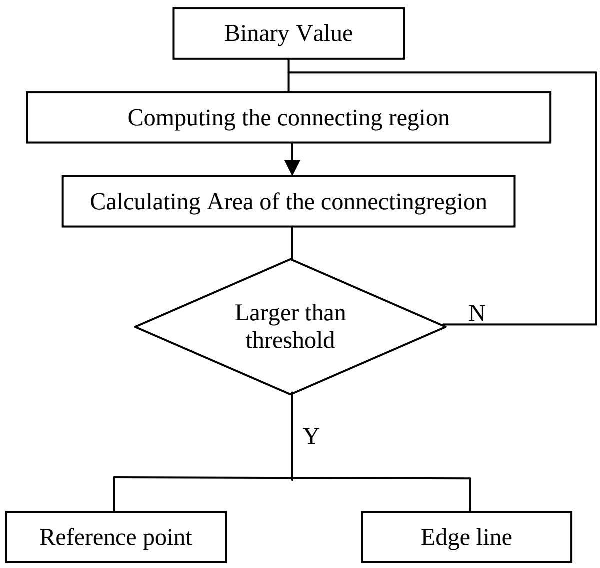

Figure 2. Process of the algorithm

Mathematical morphology is a kind theory of non-linear im age or signal processing and analyzing, with a set of integrated theories, methods and algorithms. After the creation of mathematical morphology by Matheron and Serra, French mathematician, it is widely used in the fields, such as image buildup, partition and edge line extracting and shape analysis and image compression.

In the paper, we implemented some operations of mathematical morphology to realize the algorithm, such as Erosion Operation and Hit-or-Miss Transform.

3.1 Eliminating the grids of narrow belts

In binary value matrix, some grids are connected with other grids into a connecting region. But the belt width is less than the threshold width which is important for human activity. Then these grids should be eliminated firstly for precision analysis.

In mathematical morphology, two basic transformations are defined: dilation and erosion.

The definition of erosion operation is as follows:

A and B are two sets in n dimension O-Space E^n.

That set A is dilated by B can be defined as:

$$A \oplus B = \{ c \in En \mid c = a + b,\ a \in A,\ b \in B \} \quad \text{or}$$

$$A \oplus B = \bigcup_{b \in B} A_b$$

That set A is eroded by B can be defined as:

$$A \ominus B = \{ c \in En \mid c + b \in A,\ \forall b \in B \} \quad \text{or}$$
$$A \ominus B = \{ c \in En \mid Bc \subseteq A \}$$

Erosion operation is useful for eliminating the narrow belts in binary value matrix.

Before the operation, the area of each binary grid in the binary value matrix is calculated on the geo-information of the whole terrain region and the grid number. The eliminating width can be computed with the threshold belt width. Then using the erosion operation of mathematical morphology, the grids in the narrow belts can be eliminated.

3.2 Seeking the connecting region

After the binary value matrix is optimized by eliminating the grids through step 3.1, the connecting region would be sought.

In the algorithm, an array will be built to store the grids in a connecting region, including the position information of the grid.

The first valid grid (its value is TRUE), as the original grid, would be sought. If no valid grid is found, the algorithm is ended with no suitable region.

If existing, the original grid is put into the array, its eight neighboring grids are determined whether they are in the same connecting region or not. If the neighboring grids are neither in the same region, a connecting region computation ends. If some neighboring grids are of the same connecting region, they are put into the array and set to be original grid respectively and their neighboring grids are determined as to the end. With the recursive operation, each connecting region will be found.

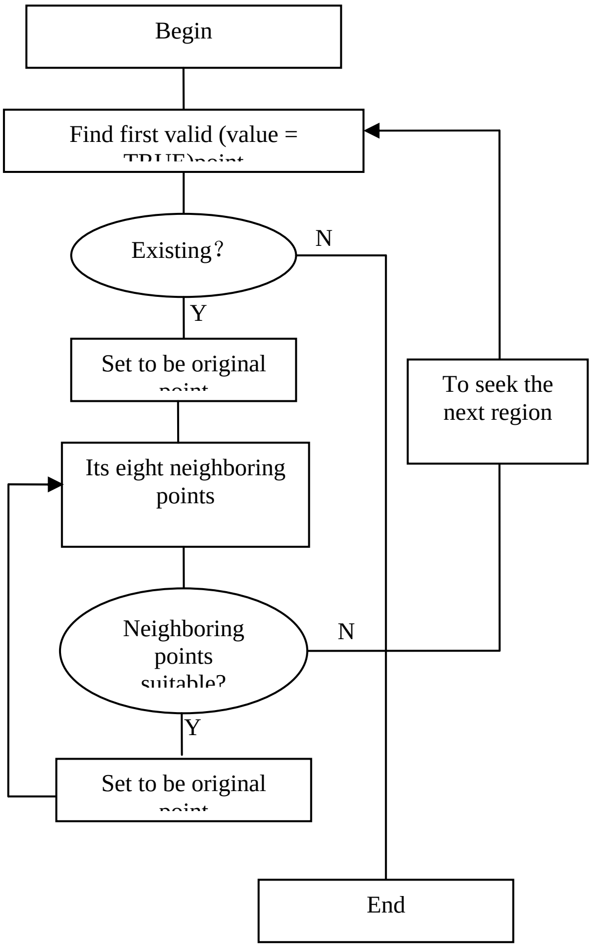

Figure 3. Process of the seeking connecting region

The connecting region is sought and then the algorithm goes to the next step. Before computing the area of each connecting region, the grids that encircle the connecting region and are eliminated by erosion operation should be added into the connecting region. After this, the connecting region is finished to be sought.

Whether the connecting region is suitable for human activities is a kernel question. What is the criterion to determine that? Area! If the area of the connecting region is larger than the threshold area, then the connecting region is suitable and activities can be engaged in this place. So the area of the connecting region will be calculated. Just to enumerate the number of the grids in the connecting region and the area of the connecting region can be acquired.

3.3 Calculating the reference coordinate of the suitable region

As in step 3.2, the connecting region is confirmed. The position and range of the connecting region should be calculated in order to tell human where the region covers and its scope. To know the position of the connecting region is to calculate its reference position, that is X value and Y value of the region.

Generally speaking, the reference position of the region can be calculated as the average value of X value of all the grids and the average value of Y value of all the grids.

Provided that $X = \{X_1, X_2, \cdots\cdots, X_n\}$

$$Y = \{Y_1, Y_2, \cdots\cdots, Y_n\}$$

Then the reference position of the connecting region (X,Y) can be attained as :

$$X_{total} = \sum_{i=1} Xi$$

$$Y_{total} = \sum_{i=1} Yi \qquad i = n$$

$X = X_{total} / n$;
$Y = Y_{total} / n$;

The position getting with this method will not fit for the need, for sometime the reference point is not in the connecting region as shown in Figure 4.

Figure 4. Region and its reference point

On this condition, the reference point is not appropriate. It would be rectified to be fit. The method to rectify the reference point is how to move the reference point into the connecting region.

Hit-or-Miss transformation of mathematical morphology can solve this question. Hit-or-Miss transformation can capture the internal or external flag. In the transformation, two basic elements are needed: E and F. they can make a structure B:

B＝（E，F）。One can detect internal part and the other detect external part.

$A \times B = (A \ominus E) \cap (Ac \ominus F)$
Here $E \cap F$ = NULL, that is E and F disjoint.
$A \times B = \{x : E+x \in A ; F+x \in Ac\}$
When F = NULL, $F+x \in Ac$
$A \times B = \{x : E+x \in A\} = A \ominus B$

In the paper, we use Hit-or-Miss to thin the binary value connecting region S.

B＝（E，F）

We thin the region S using strcture B.:

$S \otimes B = S \setminus (S \times B)$

And here we apply a structure queue B1，B2，……Bk to recursively output a region quenue S as：

S1 ＝ S⊗B1，……，Sk = Sk-1⊗Bk or
｛Si｝ = S⊗｛Bi｝= （…（（S⊗B1）⊗B2）…⊗Bk）

With the operation recursively, the set becomes thinner and thinner, if the input region is limited, the output image will be a thinned image. Through this the framework line of the connecting region is acquired.

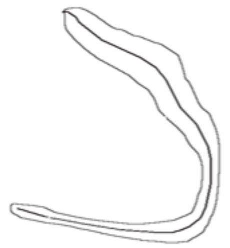

Figure 5． Thinned image with Hit-or-Miss Transformation

After thinning the connecting region, the framework line is gained as the line shown in Figure 5 in the polygon region. This paper, we move the reference point to its nearest point in the framework line, then we can get the appropriate point to define the location of the connecting region. The appropriate point is shown as Figure 6.

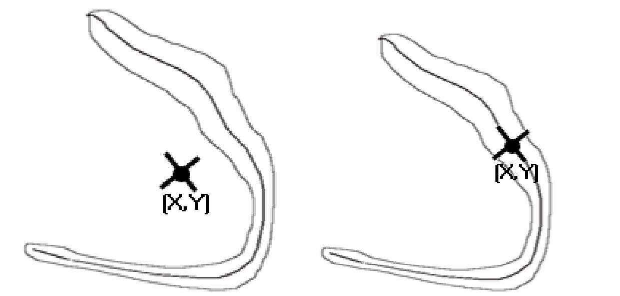

Figure 6． Original reference point and rectified reference point of the connecting region

After rectification, the reference point of the connecting region will be in the region in all case. From the reference point man can know the location of the suitable place for man to engage some activities.

3.4 Extracting the edge line of the suitable region

To extract the edge line of the connecting region, edge points of the region should be sought and join the edge points to get the edge line.

According to the feature of the edge grid, first the binary value of the edge grid is TRUE and not all the binary values of its eight neighbouring grids are TRUE. That means at least one neighbouring grid is invalid with the value of FALSE. So when the grid (I,J) is valid, A(I,J) = TRUE, if the following is TRUE, then grid (I,J) is one edge grid.

S = A(i-1,j - 1) + A(i-1,j) + + A(i-1,j+1) + A(i,j-1) + A(i,j+1) + A(i+1,j-1) + A(i+1,j) + A(i+1,j+1)
A(i,j) = 1 && S < 8

According to the above formula, the discrete edge grids can be acquired. Putting these grids together makes the edge line. The method is like the one that seeking the connecting region. Finding a valid edge grid, and seeking its neighbouring grids. When some grids are sought, they are put into an array storing points that makes the edge line.

In seeking the neighbouring grids, there is a problem to handle. The problem is that when a grid has two neighbouring grids maybe are edge grids simultaneously, how to select the better one as shown in Figure 6.

0	1	0	0	0
0	1	0	0	0
0	1	1	1	0

Figure 7． Potential edge grids in edge line

As shown in Figure 6, the current grid is enclosed by ○, but it has two neighbouring grids enclosed by ◎. In the case, which one is better to be the next edge grid is a problem to deal with.

To solve this problem, we utilize two methods. One is to adopt the angle-closing principle. That means that when to determine the next grid, the grid in the closing angle is in the priority. The another one is that pre-processing the potential edge grids to eliminate this question. Through the test, the latter one is easy to realize with better effect.

As show in Figure 7, the edge grid enclosed by ○ has two neighbouring grids enclosed by ● on upright direction. Then the grid enclosed by ○ can be deleted from the edge grids. Through this step, the edge line can be gained easy and in high speed.

0	0	0	0	0	0	1	0
0	0	0	0	0	0	1	0
0	0	0	0	0	0	1	0
0	0	0	0	0	0	1	0
0	0	0	0	0	0	1	0
1	1	1	1	1	1	1	0
0	0	0	0	0	0	0	0

⇒

0	0	0	0	0	1	0
0	0	0	0	0	1	0
0	0	0	0	0	1	0
0	0	0	0	0	1	0
0	0	0	0	0	1	0
1	1	1	1	1	0	0
0	0	0	0	0	0	0

Figure 8． Eliminating the confusing edge grid

4. EXPERIMENT AND CONCLUSION

We have implemented the algorithm in Region-selection Analysis. In the experiment, we analyze a region covering 5× 4sq.km to determine whether it is suitable for rendezvous in anti-terrorist manoeuvre. The original data is DEM of this region, other feature data and some requirement parameters of rendezvous operation. From DEM data we get the slope value of this region and through this we make out the potential valid grids for rendezvous operation so as to build a binary value matrix. Also on the basis of terrain features and the rendezvous operation another binary value matrix can be built. We overlay the two binary value matrixes and gain the binary value matrix for analysis. By the algorithm proposed in this paper, we got a satisfying result in less than 15 seconds.

In the experiment test the binary value data built from terrain analysis and other restriction is shown in Figure 9a. The valid data is in the black area.

Using the algorithm proposed in this paper, we make the suitable region and calculate the edge line of the suitable region and its reference point as shown in Figure 9b.

Figure 9a．Original raster data　9b．Experiment result

Topographical analysis become more and more important in GIS, and the original data are diversified. Especially with the integration of RS and GIS, some raster data are integrated into GIS and topographical analysis is engaged on the basis of RS data. Many new theory and methods should be used in GIS such as microwave analysis and geometrical transformation.

REFERENCES

[1] Barrera, J. , Banon,G,J,F: “Expressiveness of the morphological language”. Image Algebra and Morphological Image Processing III, SPIE, San Diego, California,(1769), pp. 264–275, 1992

[2]Heijams,H. ：Theoretical Aspects Of Gray-Level Morphology，IEEE Trans. Pattern Analysis and Machine Intelligence.vol.13.No.6,pp.568-582,1991

[3]Serra J.，Image Analysis and Mathematical Morphology，New York: Academic，1982

[4]Serra J.，Image Mathematical Morphology and its Applications to image Processing，
Kluwer Academic Publishers，1994

[5]MarrD.，Theory of edge detection，Proc Roy Soc，980，(27):187 一 217