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Algorithm of symbol generation and configuration of land polygons in present land-use map

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Abstract: The symbolization of land polygon is an important part of cartography. In the mapping of traditional present land-use maps, the symbol of land polygons was usually filled by the method of filling or plotting, but these methods can't solve the spatial conflicts of the symbol. According to the principle of cartography, the rule of how to symbolize the land polygon was summarized, and a new method that can generate and deploy the land symbols was presented. By making use of C# programming language and Arc Engine developing components, the algorithm can generate land symbols presenting triangle and adjust the coordinate of the symbol. Through mapping the present land-use map of Honghe county, this algorithm can reduce 88.84% of the spatial conflicts error rate compared with the traditional methods. It improves the accuracy and efficiency of the map symbolic.

Key words: land symbol; present land use map; symbol configuration; spatial conflict

1 Introduction

As the language of maps, the map symbol is a basic method to express the geographic things [1], and a basic tool to visualize the geographic information. The configuration of the map symbol can convert the map elements to hieroglyphs and intuitive symbols that can be identified by the map users. It can also transmit more abundant map semantic information for map users. Using the symbolic algorithm based on the map symbol library, the map elements were drawn [2]. The land symbol is an important part of the map symbol; it plays an important role in expressing the content of present land-use map. In a present land use map, the symbolization of the land symbols is often realized by the filling or plotting methods, namely, drawing particular patterns in a closed polygon area according to the standard space [3]. But in the practical applications, these traditional methods of filling and plotting [4] have some problems as follows: 1) some land symbols are incomplete because they are intersected or covered by the land boundary and linear matters; 2) land symbols are intersected by the map annotation; and 3) land symbols are lack in some small, complex or irregular land polygons. The problems are shown in Fig. 1.

In order to effectively solve the above problems, a new method based on C# programming language and ArcEngine developing components to generate and deploy land symbols is presented in present land-use map with scale of 1:10000.

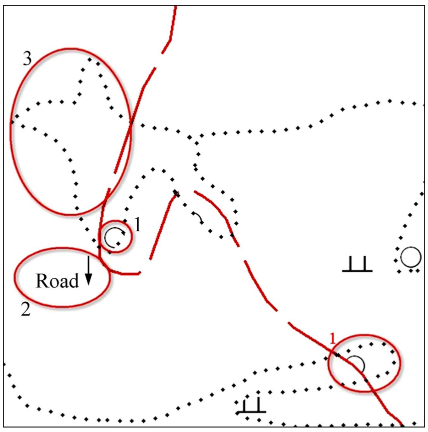

Fig. 1 Problems in traditional symbolic methods

2 Filling of land symbols

At the present, most GIS softwares such as MapInfo and Arc/Info use map symbol library and comparison tables to symbolise the land symbols. The land symbols are created and packed within the land polygon by filling or plotting methods. The methods can't solve the

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overlaying problems between the land symbols and land boundary, linear matters and map annotations. Besides, it is not easy to adjust the positions of symbols. So, these technologies always cause spatial conflicts between the land symbols and other spatial elements. It reduces the readability and the exactness of the map.

2.1 Filling pattern of land symbols

With the long-term experience of the map graphics experts, a set of standardized filling patterns of land symbols has formed in the present land-use map. For different land polygons, the land symbols can be divided into three patterns, that is triangle fill, single-point fill and unsigned fill.

1) Land symbols filled with triangle patterning. Triangle symbols are used in the land polygons that stands for the cultivated land, garden land, woodland, grassland, beaches, glaciers and permanent ice, saline land, sand, bare land, and so on. The symbols on the map are generally at the horizontal spacing of 20 mm, vertical 10 mm.

2) Land symbols filled as single point. The single point land symbols are used in the land polygons as traffic area, mining sites, scenic and special sites. It means we should simply place one symbol in these land polygons.

3) Unsigned filling. Unsigned filling is used in land polygons as city, town, water, and land for water facilities. The land use is expressed by filling with the shading and colorful background in these land polygons.

2.2 Position rule of land symbol

Space conflict refers to the phenomenon that the map elements fighting for the space during symbol allocating [2]. It is mainly caused by the increasing charge capacity of the symbolized map elements, which will lead map coverage, which is not accordant with the specifications of cartography [7]. The phenomenon of space conflict must be considered in the symbol allocation. Concretely speaking, it includes the following points.

1) The land symbol cannot be covered with land boundaries, linear features and administrative boundaries.

2) The land symbol cannot be covered with the annotations of the map.

3 Basic idea of algorithm

Firstly, the symbol point of triangle layout and single point symbol are generated by the algorithm according to the land nature and graphic shape of the land polygon. Secondly, the coordinates of the symbol are adjusted to solving the spatial conflict between the symbol and other map elements. Lastly, the missing land symbols are added. The algorithm process is shown in Fig. 2.

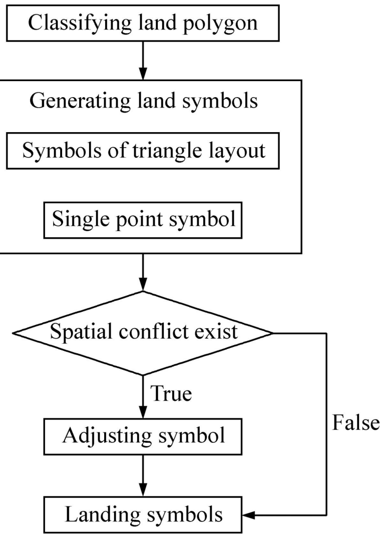

Fig. 2 Algorithm process

The basic ideas of this algorithm are as follows.

1) Symbol generation. Traverse the land polygons needing triangle layout land symbols. Obtain the Minimum Bounding Rectangle (MBR) of the land polygons, then create buffer at 25 m within the polygon basing on the land polygon’s boundary. Generate the triangle layout symbols according to the triangle layout symbols generating algorithm. And then, judge whether the symbol is in the polygon which erases the buffer. If the symbol is in the buffer erased polygon, retain it, of not, delete it. Then, traversing the land polygons of single symbol, generate symbol at the center if it is in the land polygon, else, generate label point.

2) Symbol adjustment. Space operations are made to adjust the coordination of the an ideal status according to the distance between the eight neighborhoods of the symbols and linear feature and annotation. At last, check the land polygons which needs to be filled with symbols but don’t have a symbol, generate a symbol in it to make sure that every polygon has a symbol.

4 Algorithm implementation

4.1 Generation of symbolic point

1) Classify the land polygons according to the symbolic rules on the present land-use map. First, traverse the land polygons which need triangle layout symbols, create buffer at 25 m within the polygon basing on the land polygon’s boundary, obtain the minimum bounding rectangle (MBR) of the land polygon. And then obtain the buffer erased polygon, as shown as Fig. 3(a). Second, loop from the upper left corner of the MBR, X

direction variable is 50 m in odd line, 100 m in even line, *Y* direction variable is 100 m. When the *x* coordinate is beyond the maximum *x* coordinate of the MBR, the program loop into the next line. When the *y* coordinate is beyond the minimum *y* coordinate of the MBR, terminate the program loop, as shown in Fig. 3(b). At last, sift the symbols, and keep the land symbols in the buffer erased polygon. The symbols after sifted avoid the spatial conflict with the land boundary, as shown in Fig. 3(c).

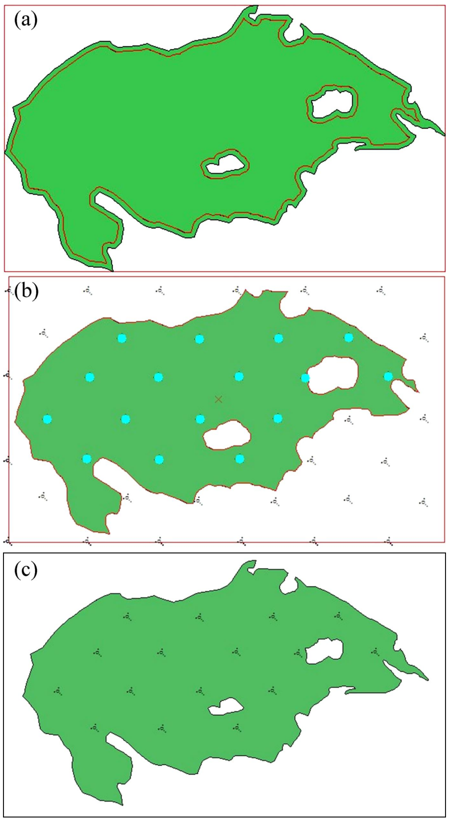

Fig. 3 Generation of triangle layout symbols: (a) Obtaining minimum bounding rectangle (MBR) of land polygon and creating buffer within it; (b) Generating triangle layout symbols; (c) Shifting symbols

The main code of the program is as follows.

//Comments: define p_x, p_y as the coordinates of the stay generated symbol points.

//Comments: FHIDS is the symbols' space

double $p_y = y_2 - \text{FHDIS} / 4$

while ($p_y > y_1$)

//Comments: y_1, y_2 are the minimum and maximum coordinates of MBR in *y* direction

{

if (!b) //Comments: define *b*=false

Comments: {$p_x = x_1 + \text{FHDIS} / 4$;}

//Comments: p_x is the variable in *X* direction

else

{$p_x = x_1 + 3 * \text{FHDIS} / 4$;}

While ($p_x < x_2$)//Comments: x_2 is the maximum *x* coordinates of MBR

{

IPoint pPoint = new PointClass();//Comments: Define a new point feature

pPoint.PutCoords(p_x, p_y);

//Comments: judge whether the point fall in the buffer erased polygon.

If (PointIsPolygon1(pPoint, pGeometryBuffer))

{

//Comments: generate point and give its DLBM property.

insertGeoMetry(pPoint,DLBM, InsertFeatureCursor, FID);

}

$b = !b$;

$p_y = p_y - \text{FHDIS} / 2$;

}

}

2) Extract the land polygons which is needed to fill the single point. Determine whether the geometric center of the polygon is in the polygon itself. If it is in it, generate the symbol point, else, generate the land polygon's LablePoint. This method guarantees every land polygons which needs to be filled with symbol has a symbol point.

4.2 Symbol adjustments

After the land symbols generation, we need to calculate the distance between annotation, linear feature and land symbols. We need to adjust the symbol if the distance is less than threshold. For example, the spatial conflict of land symbol covers with annotation, the procedures to the symbol is presented as follows.

1) Obtain the MBR of text annotation, obtain the distance(define as mind) between the symbol and annotation by using the ReturnDistance method of IProximityOperator interface in ArcEngine. The mind should be negatived if the center of the symbol were within the annotation.

2) Set the symbol as point $A(x, y)$, x, y are the coordinates of *X* direction and *Y* direction of the point. The threshold of the minimum distance between symbol and annotation is ZJDIS (here we set it 25 m).Set neighborhood point $A_i(x_i, y_i)$,and the distance between the symbol point and its neighborhood point is d. d=ZJDIS−mind+5. Obtain the eight neighborhood of the land symbol, and then save it in the List of initList (ref dx, ref dy, d). The order is bottom, left bottom, left, upper left, above, upper right, right, bottom right. x_i, y_i can be calculated by equations (1) and (2). The calculate process shown in Fig. 4.

$$x_i = x + d\cos\theta \tag{1}$$

$$y_i = x + d\sin\theta \tag{2}$$

2) Traverse every neighborhood point from

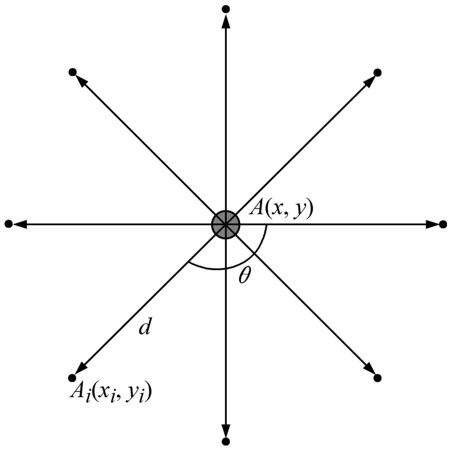

Fig. 4 Calculation of eight neighborhood points

neighborhood point A_1. Judge whether its distance with the annotation rectangle is greater than threshold ZJDIS. If the distance between point A_i and annotation is greater than that of the threshold ZJDIS, and the coordinates of A_i is still in the buffer erased land polygon, then coordinates of symbol point can be changed to $A_i(x_i, y_i)$. If point $A_i(x_i, y_i)$ which is satisfied couldn't be found, namely symbol can't be adjusted, delete the symbol. Algorithm adjust process can be shown in Fig. 5.

The Algorithm's main code is as follows.

```
double mind = MinDistance(pPoint, pGeometry);
//Comments: The MinDistance function using the ReturnDistance method of IProximityOperator interface to calculate the shortest distance between Graphics
double d = (ZJDIS − mind) + 5;
initList(ref dx, ref dy, d);
for (int i = 0; i < dx. Count; i++)
{
    IPoint newPoint = new PointClass();
    //Comments: save neighborhood point Ai into newPoint
    newPoint.PutCoords(x+dx[i], y+dy[i]);
    //Comments: judge whether the point is in buffer erased land polygon
    if(PointIsPolygon1(newPoint, pTBDLGeometry))
    {
    if(MinDistance(newPoint, LineGeometry)≥ZJDIS)
        {
        PointFeature.Shape=newPoint; pFeatureCursor.UpdateFeature(PointFeature);
        }
    }
}
```

In Fig. 5(a), irrigated land symbol is covered with the text annotation. In Fig. 5(b), we obtain the symbol's eight neighborhood points of the symbol. In Fig. 5(c), the cultivated land symbol is adjusted to the neighborhood point and A_2.

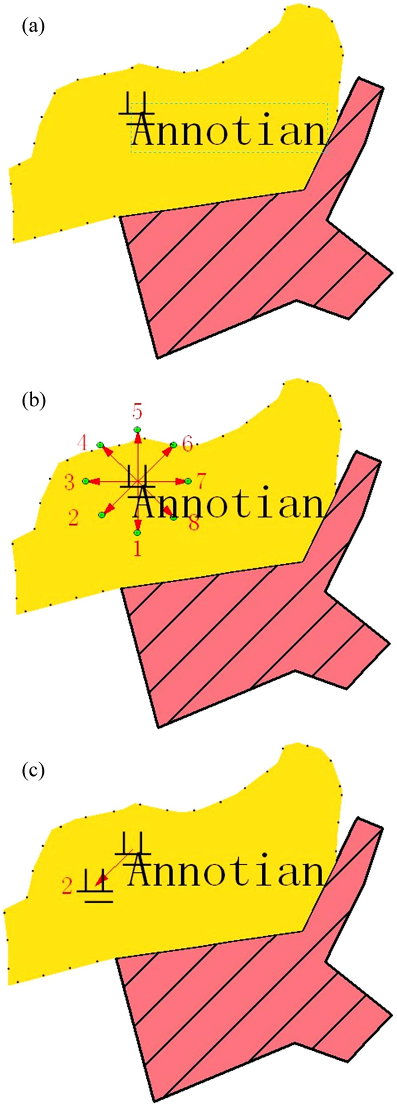

Fig. 5 Symbolization of map using traditional filling method

4.3 Check and addition of symbol

After processes 1) and 2), there is no land symbol in some small or complex graphics land polygons. It is because the symbol and its eight neighborhood points all intersect with the land boundary, linear feature or map annotation. So, the symbol was deleted after the symbol adjustment. So, we need to check all land polygons after symbol adjustment and add a symbol point in the land polygon which needs a symbol, no matter whether the spatial conflict exist or not.

5 Experimental analysis

Land-use map is a thematic map to express the distribution and area of land-use polygons, and the land use structure. For the land use map, the specifications and accuracy of the symbol configuration are very important. It directly affects the accuracy, readability and aesthetics of the map. However, in the mapping of traditional land-use map, spatial conflict is widespread. It is hard to adjust the coordinates of the symbol because of the symbol is encapsulated in the land polygon. Therefore, a new method to generate and deploy symbols is presented based on ArcEngine. This algorithm was used in mapping the land use map of the second rural land survey, and the experiment shows it can achieve a satisfying effect. The compared results of the symbolized map between the traditional algorithm and this algorithm are shown in Figs. 6 and 7.

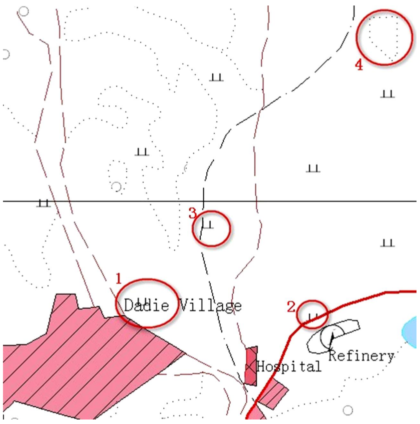

Fig. 6 Symbols of traditional filling method

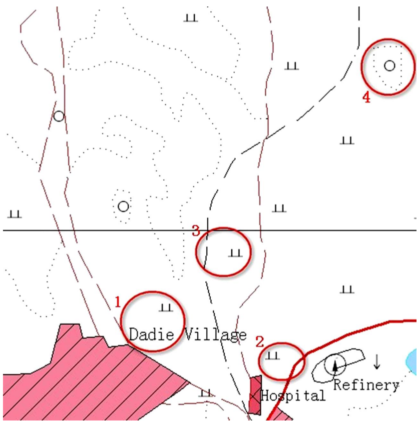

Fig. 7 Symbolization of map using method mentioned in this paper

It can be seen from Fig. 6 that, in location 1, the land symbol cover with the annotation, in location 2, the land symbol covers with the high-way, in location 3, the land symbol is intersected with administrative boundaries. The most of these mistakes is solved after this algorithm processing.

In the mapping of Honghe country in Yunnan province, total of 2028.74 km^2 and 96 maps at 1:10000 scale are drawn. The percentage of spatial conflict is 23.3% and 2.6% by using the traditional method and the new method advanced in this paper.

6 Conclusions

1) A symbol generation algorithm was presented according to the symbolic rule of the land symbol. This algorithm generates triangle layout symbols which satisfy the spatial relationship that the land-use symbol must be included in the land use polygon. The minimum outsourcing rectangular of the land use polygon is the critical condition of the program's loop.

2) A symbol intelligent configuration algorithm was presented to solve the spatial conflict problem between the land use symbol and other map elements, it adjusts symbol's coordinates to the right position according to the distance relation between symbol's eight neighborhood and the other map elements.

3) The spatial conflict between the land symbols and land boundary, linear feature, administrative boundaries in some GIS software like Arc/Info was solved. This method is proved to be feasible and effective to improve the accuracy of the map symbolization through the project of the mapping of the second rural land survey of Honghe in Yunnan. This method can be popularly used in the present land use map, basic farmland distribution map, farmland slope grading map, land planning revision map.

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