

ON POINT FEATURE AUTOMATIC ANNOTATION PLACEMENT IN 3D ENVIRONMENT

Jingwei Shen*, Yongning Wen, Yongjun Wang, Min Chen, Hongjun Su

Key Laboratory of Virtual Geographic Environment, Nanjing Normal University, Ministry of Education, Nanjing, Jiangsu Province 210046, P.R.China - jingweigis@163.com

KEY WORDS: Geography; Cartography; Three-dimensional; Visualization; Virtual Reality; System

ABSTRACT:

Based on the research of the automatic annotation placement in two-dimensional (2D) domain, automatic annotation rules of point feature in the three-dimensional (3D) field are proposed. In this paper, the quad-tree index is used to organize the 1:250 thousands vector map attributes data of China. Backing culling, view culling and overlap culling are introduced to decide whether the annotation is display or not. This method can reduce the displaying annotation in a great extent and improve the efficiency of this system. A 3D earth system is developed as a prototype. Annotation position is determined by the billboard technology which is widely used in 3D domain. Backtracking algorithm are employed to figure out the automatic annotation placement.

1. INTRODUCTION

Annotation is an important part of the map. Annotation position and direction are related to the map readability and the map practicability. If the annotation is placed in a suitable position, the map can be nicer. Automatic annotation placement is that using arithmetic to simulate the manual work to place the annotation in a suitable location on the map. The result of the annotation position should be readable, rational and nice^[1]. The high quality of the map must answer for this requirement. The automatic annotation placement hasn't been solved in an excellent way up to now. The latest research shows that finding out the optimal position of the annotation is impossible from the limit time cost, because the algorithm designed is expired to cost the lesser time but get a preferable result.

Readability, fairness, harmonious, unambiguousness and compatible with other object are the target of the high performance of the annotation^[2]. The researches of the annotation placement include the automatic annotation placement rule, overlapping theory, optimum methods and so on^[3-4]. Du Shihong studied the automatic annotation placement including point, line and polygon feature. Point feature annotation is usually surrounding the point feature. Line feature annotation is placed along the line feature according to the line shape. Polygon feature annotation is located in the position mainly depended on the area and shape of the polygon. Yoeli (1972) worked over the relation of the point feature and its annotation, and reckoned the annotation position has different priority.

In recent years, many algorithms about the automatic annotation placement were studied and developed. The researches on automatic annotation placement have made great advancement. Genetic algorithm was used to solve the annotation placement. Genetic algorithm expression of the solution of the problem into chromosomes which passed on the choice, exchange and variation, a more responsive to the environment of the new chromosome is produced^[5-7]. The key problems of the annotation including annotation parameters, priority, relationship of the annotation and map symbol, collision of the map symbol and annotation, the size of the

annotation and so on are analyzed^[8]. Voronoi graph was introduced to locate the annotation placement of the polygon feature^[9]. Fan Hong discussed the line feature annotation rule and designed the parallel line algorithm^[10]. Wang Zheng extracted main skeleton line of polygon water system to locate annotation placement^[11]. Tabu search arithmetic is used in the point feature automatic annotation placement^[12-13]. Expert system^[14], heuristic algorithm^[2], simulated annealing algorithm^[15] and so on were also used to study the point feature automatic annotation placement.

In the GIS, the geography objects are usually abstract into point feature, line feature and polygon feature. In the research of annotation placement, the research objects also refer to the point, line and polygon. At present, the research on point feature automatic annotation placement is most. The amount of point annotation is more than other two types and the point annotation is implied more easily. In recent years, virtual reality technology, Internet technology and 3D visualization technology developed rapidly. Google Earth, World Wind and Virtual Earth came forth and had a rapid development in the world. Virtual city, virtual community and virtual university emerged in endlessly. Geography language had begun the conversion from map to GIS and virtual geographic environment^[16]. The tradition map and GIS have expanded to 3D domain. Automation annotation placement also existed in the 3D environment. In the 3D environment, automation annotation placement had become an urgently problem to solve. The point feature automatic annotation placement in 3D environment was the major research content in this paper.

2. THE RESEARCH OF THE ANNOTATION IN 3D ENVIRONMENT

2.1 Annotation placement rules in 3D environment

Annotation can be placed in many different positions and usually surrounds the point feature. The position can be summarized into eight types which are separately in the right, top, left, bottom, top right, top left, bottom left and bottom right^[9]. Fig.1 shows out the priority of point feature. In the fig.1, the

black point represents the point feature which is used to depict the point geography object. The positions from 1 to 8 are the priority of the annotation placement. The 1 position is the most preferred position. If the overlapping situation exists, the placement is adjusted from 1 to 8.

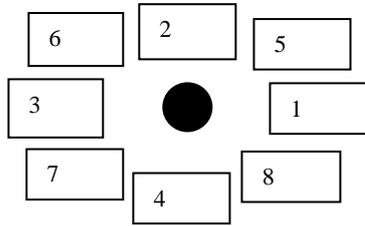


Figure.1. Priority of the annotation

Many geography objects can be expressed by point feature, so the point feature should be classified into different level according to its attributes. The 1:250,000 vector map attribute data of China can be classified into six kinds (Table 1). If different of class data collide with each other, the lower class data can't overlap the higher class data. In the map, the data with high class has priority to display and the lower class data display only when the map zooms in to a very large scale.

| Administrator name | Priority |
|--|----------|
| Capital | 1 |
| Provinces, autonomous regions and municipalities | 2 |
| Provincial cities | 3 |
| Counties, autonomous counties, county-level cities, the urban area | 4 |
| Towns | 5 |
| Villages | 6 |

Table 1. Administrator name and its class of China

The most prominent character in the 3D space is that z-buffer is introduced. The depth of the annotation decides whether the annotation discards or not if the annotations overlap each other. If two annotations overlapping phenomenon exists and the annotations have the same priority, the greater z-buffer depth will not display.

2.2 The Calculation of the annotation overlapping

The boundaries of the annotations should be calculated by the length and width of the annotations. The rectangle structure can be expressed in the struct AnnotationBound. If the LabelBound1 and LabelBound2 are defined by struct AnnotationBound, whether the annotations collide with each other or not can be express in the following pseudocode.

```

struct AnnotationBound
{
    double x;
    double y;
    double width;
    double height;
}
    
```

Struct of the AnnotationBound

```

if (LabelBound1.y < LabelBound2.y + LabelBound2.height &&
LabelBound1.y + LabelBound1.height > LabelBound2.y &&
    
```

```

LabelBound1.x + LabelBound1.width > LabelBound2.x &&
LabelBound1.x < LabelBound2.x + LabelBound2.width)
    The rectangles overlap;
Else
    The rectangles don't overlap;
    Pseudocode of the whether the rectangles overlap
    
```

3. THE DATA ORGANIZATION OF THE ANNOTATIONS

In the 1:250 thousands of China Vector map attributes data, there are more than 680,000 records. If annotation positions were calculated every time and annotations were displayed in the map, time cost is very high, so the data should be organized in a reasonable way. The following paragraphs will discuss the data organization.

3.1 Organize the data in quad-tree index

Quad-tree index is an index that is used to divide the space. The space is separated into four equal subspaces every time. The subspaces can be separated if we need further precision data. If we want to build the quad-tree, the boundaries of the space should be prior acquired. The boundaries of China in the 3 degrees north latitude and 55 degrees north latitude and 70 degrees east longitude and 130 degrees east longitude. The depth of the quad-tree is six, and the attributes data are inserted into the quad-tree nodes according to the geographic coordinates of the relevant point feature. Data area should be acquired first, and the service required the data according to the data area then. RequestBound is defined data area. The quad-tree nodes are calculated with the relationship between annotationBound and the RequestBound. If the quad-tree node boundary is in the boundary of the RequestBound, all data in the node are acquired. If the quad-tree node boundary intersects with the boundary of the RequestBound, the data in the quad-tree node are pop out one by one and compared with the boundary to decide whether display or not. If the quad-tree boundary is outside of the RequestBound, the quad-tree node wouldn't be considered. Figure 2 shows the required data process.

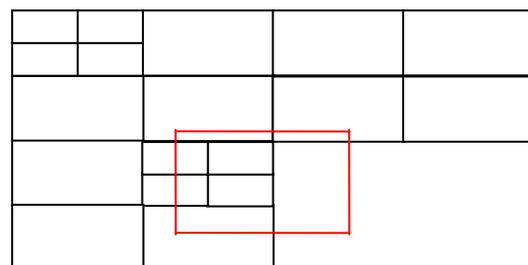


Figure 2 Quad-tree structure and requiring data boundary

3.2 The visibility of the annotation

In the 3D environment, the annotations should display in real-time. If the number of annotation is large, the time cost is very high. The annotation visibility includes back culling, view frustum culling and occlusion culling. Back culling is used to discard the annotation that behind the view angle. Those annotations aren't visible, so the transformation to those annotations has no meaning. If annotations are outside of the viewing volume, the annotations will be discarded. Occlusion culling is introduced to delete the elements that are occluded by

other opacity elements. The depth of the annotation, the easier it is occluded.

4. DEVELOPMENT OF THE PROTOTYPE AND AUTOMATIC ANNOTATION PLACEMENT ALGORITHM

4.1 The development of the prototype

Because the functions implementing the 3D object transformations are in the Cartesian coordinates, the function between geography coordinates and Cartesian coordinates transforming should be design. The equation 1 implements the conversion between the two different coordinates.

In the function, r is the earth radius; Lat and lon represent respectively latitude and longitude; X , y and z are the coordinates in the Cartesian coordinates.

$$\begin{cases} x = r \times \cos(lat) \times \cos(lon) \\ y = r \times \cos(lat) \times \sin(lon) \\ z = r \times \sin(lat) \end{cases} \quad (1)$$

Earth longitude is divided evenly in the 360 parts from -180 degrees to 180 degrees. -180 degrees is 180 degrees west of Greenwich and 180 degree is 180 degrees east of Greenwich. Earth latitude is divided evenly in the 180 parts from -90 degrees to 90 degrees. -90 degrees is 90 degrees north of equator and 90 degrees is 90 degrees south of equator. From north to south, from west to east, the geographic coordinates are calculated in the Cartesian coordinates. The corresponding texture coordinates is calculated and the indices of the texture coordinates is store in an array. Surface model is constructed by series of triangles which are joined by the points calculated in the Cartesian coordinates. Then, a texture mapping is mapped to model surface according to the indices. The prototype is named 3D earth system.

4.2 Making certain the position of the annotation

One method making certain annotation placement at present is 3D texture mapping^[19]. The annotations are converted into bitmap. Then, the bitmap data is created to texture mapping. The annotations are mapping to the surface of the models as texture. This technique makes the annotations cling to the model surface. But the viewers can not look at the annotation from any aspects conveniently. In this paper, the billboard is used in the annotation placement. The billboard in the 3D domain is a geometry polygon which always faced to the viewer. Billboard technology is introduced to express annotation in the 3D environment. The annotations are placed horizontally and this style makes the viewer observe the annotation easily. The following will discuss the course of making certain of the annotation position.

- Step1. Read the geographic coordinates of the point feature.
- Step2. Make sure the center of the annotation position. Convert geographic coordinates to Cartesian coordinates and make this coordinate as the center of the billboard.
- Step3. Make certain the size of the billboard. The size of the billboard is decided by the length of the annotation font number and font size. The four corners of the billboard can be calculated by the equation 2.

- Vertex 1: $Center + V3 * Length / 2 - V2 * Width / 2$,
- Vertex 2: $Center + V3 * Length / 2 + V2 * Width / 2$,
- Vertex 3: $Center - V3 * Length / 2 - V2 * Width / 2$,
- Vertex 4: $Center - V3 * Length / 2 + V2 * Width / 2$.

Where $Center$ is the coordinates in the Cartesian
 Eye is the view point, up is the direction of the up vector
 $V1 = Center - eye$
 $V2 = up$
 $V3 = V2 \times V1$.

If the four corner coordinates are calculated out, the space position of the billboard is made sure. When the users are roaming in the 3D environment, the view angle is changing every time and the billboard is recalculated, so the annotations always face to the viewer.

4.3 The automatic annotation placement algorithm

The course of automatic annotation placement algorithm is introduced. Firstly, acquire the viewing geographic coordinate boundaries named $ViewBound$ and the displaying levels according to relationship between the view point and 3D earth system. The distance of view and 3D earth system decides the levels of the administrator data and the view angle determines the boundaries. Secondly, make use of $ViewBound$ to get the quad-tree nodes and the geographic coordinates. Convert the geographic coordinates to the Cartesian coordinates. Thirdly, get the annotation boundaries by the billboard technology and store the information including the annotations level and annotations name to struct $AnnotationInfo$. Then, all the struct $AnnotationInfo$ are stored in an array. The finally information that is displayed is stored in $CompleteList$ array. Backtracking algorithm course is follows.

- Step1. Get an element from $PlaceList$ named $Label$.
- Step2. Get element from $CompleteList$ one by one, determine if the element intersects with $Label$. If intersection phenomenon doesn't exist, $Label$ is pushed into $CompleteList$ array, then return to step1. If intersection phenomenon exists, go to step3.
- Step3. If intersection phenomenon exists, make certain the new position of the $Label$ according to the position priority. If the new position is suitable, update the $Label$ information and push the $Label$ into $CompleteList$ array, then return to step1. If all the candidate positions are not suitable, then go to step4.
- Step4. If the annotations belong to the different levels, the annotation with the high level will save and the lower level will be discarded. If the annotations have the same levels, then compare the $Label$ $zbuffer$ with the element $zbuffer$ that overlapped with the $Label$. If the $Label$ $zbuffer$ value is the bigger, $Label$ is discarded. If the $Label$ $zbuffer$ is the smaller, the element collides with the $Label$ will be discard and the $Label$ is pushed into $CompleteList$ array.
- Step5. Repeat the step from 1 to 4 until the $PlaceList$ is null.
- Step6. Display all the annotation in the $CompleteList$ array.

```
struct AnnotationInfo
{
    int level;
    string name;
    double x;
    double y;
    double width;
    double height;
    double zbuffer; }
```

4.4 The algorithm running result

Based on the research content above, 3D earth system is developed. This algorithm solves the automatic annotation placement perfectly. Figure 3 shows the result.

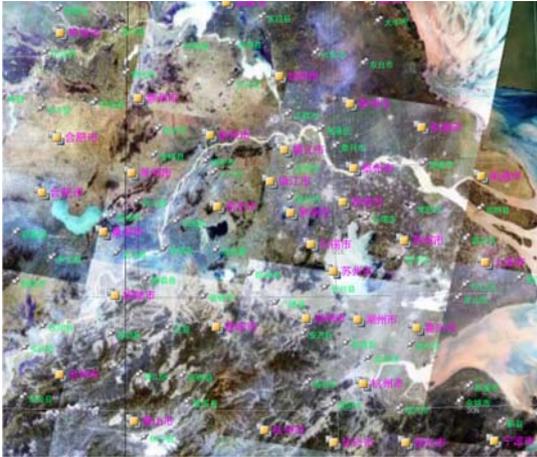


Figure3. The result of the automatic annotation placement

5. CONCLUSION AND DISCUSSION

This paper researches the point feature automatic annotation placement in 3D environment. Automatic annotation placement rules are proposed and mass data organization is touched upon. 3D earth system is developed and annotation is displayed in the 3D surface perfectly.

There are also many problems to discuss in the next steps. The time cost of this algorithm isn't very high. The paper doesn't consider the point feature annotation whether have ambiguity with other point features.

ACKNOWLEDGEMENT

This work was supported by a grant from the National Natural Science Foundation Project of China (No. 40730527), and a grant from the National High Technology Research and Development Program of China (863 Program)(No. 2007AA12Z207).

REFERENCES

[1] Du Shihong, Wang Qiao, Du Daosheng, etc. Research on name automated placement [J], Geography and Territorial Research. 2002, 18(4), 14-18.

[2] Liu Yong, Zhou Zhiwu, Chen Feixiang. Research on point features label automated placement [J]. SCIENCE & TECHNOLOGY PROGRESS AND POLICY, 2003, S1, 250-251.

[3] Fan Hong, Du Daosheng, Zhang Zuxun. The study on the principles of automated placement of map name and its implementation Approach[J]. Journal of Wuhan Tehcnical University of Surveying and Mapping, 1999, 24(2), 154-157.

[4] Cheng Kongzhe, Zhu Xinyan, Zhang Yinzhou, etc. Study on automatic Chinese-Label placement [J]. Journal of Wuhan

Tehcnical University of Surveying and Mapping, 1997, 22(2), 136-141.

[5] Shawn Edmondson. A general cartographic labeling algorithm[J]. Cartographic, 1996, 13(4),13-23.

[6] Dijk S. Genetic algorithms for map labeling[D]. Utrecht: Utrecht University, 2001.

[7] Liu Shuan, Lv Shuai. Map text label placement with genetic algorithms[J]. Control engineering of China,2007,14(2),129-131.

[8] Du Shihong, Wang Qiao, Du Daosheng, etc. The key technology study of name automated placement[J]. Geography and Geo-Information Science,2003,19(1),20-24.

[9] Luo Guangxiang, Xu Bin. The study on automatic name placement around point feature based on voronoi[J]. Journal of Chan'an University(Earth Science Edition) ,2003,25(6),63-69.

[10] Fan Hong, Zhang Zhuxun, Du Daosheng. The algorithm design and implementation of adding annotation to map for linear feature automatically[J]. ACTA GEODAETICA et CARTOGRAPHICA SINICA, 1999, 28(1),86-89.

[11] Wang Cheng, Li Lin, Zhu Haihong. Automatic name placement for area water features on small scale maps[J]. Geomatics and Information Science of Wuhan University, 2007, 32(6),544-547.

[12] Zheng Chunyan, Guo Qingsheng, Liu Xiaoli. Automatic placement of point annotation based on tabu search[J]. Geomatics and Information Science of Wuhan University, , 2006, 31(5), 428-431.

[13] Yamamoto M, Camara G, Lorena LAN. Tabu search heuristic for point feature cartographic label placement [J]. GeoInformatica, 2002, 6(1),77-90.

[14] Luo Guangxiang, Wang Jinlin, Ma Wentao. The expert system of the map labels[J]. Mapping technology and equipment, 1999, 1, 24-25.

[15] Luo Guangxiang, Ma Zhimin, Tian Yongrui. The Study of automatic cartographic name placement based on simulated annealing algorithm. DEVELOPMENTS IN SURVEYING AND MAPPING, 1999, 2, 11-16.

[16] LIN Hui, Gong Jianhua, Shi Jingjing. From maps to GIS and VGE-A discussion on the evolution of the geographic language[J]. Geography and Geo-Information Science, 2003, 19(4), 19-23.

[17] Mason Woo, Jackier Neider, Tom Davis, etc. The official guide to learning of OpenGL, Version 1.2 [M]. Addison Wesley Longman Press.

[18] Jiang Shui, Sheng Yehua, Yao Yong. Implement of converting coordinate and querying for geographic object in the digital earth [J]. GeoSpatial Information, 2007, 5(1), 43-45.

[19] Jiang Wenliang, Li Lin, Hu Jingyan, etc. Research on point annotation of hill shading map [J]. Science of Surveying and Mapping, 2005, 30(4), 74-75.