CO-449

AN INTELLIGENT DEFORMATION METHOD FOR IMPROVING THE CLARITY OF SCHEMATIC NETWORK MAP

TI P., LI Z.

The Hong Kong polytechnic university, HONG KONG, HONG KONG

ABSTRACT

Recently, some methods of automated generation of schematic map are proposed. However, no specific method is given for expansion of congested area on a map in the process of schematization. In fact, it is a key to produce a schematic map with great clarity. For instance, for a line network map, if there are many lines in a small area on a map, although the shape of these lines is simplified by process of schematization, it is still not easy to recognize such an area for human. In order to solve the problem, a method for enlargement of congested area is developed in this project. Two steps are involved to realize the method: the first step is automated detection of congested area. The second step is automated selection of most appropriate model for magnification of congested area. In this paper, the London tube network map is used as test data. The preliminary result by using the method shows that the readability and clearance of schematic map are improved apparently.

INTRODUCTION

Automated production of schematic map is a fairly complex task which includes not only abstraction of representation of map contents, but also preservation of topological information and consideration of aesthetic aspects. In 1988 Elroi defined three basic steps for schematization process, (1) Simplification of lines to basic shape, (2) Re-orientation of lines to restricted regular grid, (3) Enlargement of congested areas to spread density of network. However, no specific algorithm is given in this paper.

Later, many cartographers have done an amount of research work relating to automated generation of schematic map and proposed some algorithms to realize the task (Neyer 1999, Barkowsky et al. 2000, Cabello et al. 2001, Avelar and Mueller 2000, Ware et al. 2006). However, the proposed algorithms focused on the simplification of lines, preservation of topology and consideration of aesthetic aspects in network maps and don't consider the expansion of congested area on a map. Li and Dong (2010) indicate that the congested area on a map should be expanded in the process of schematization. However, no magnification method is given in this paper. From the design of London Tube map we can see that the scale in the map is not consistent if comparing with its original map. The scale in centre area is greater than the other area on the map. This effect of enlargement makes the representation of schematic map clearer and improves also the readability of map. Therefore, for congested areas on a map, the space should be expanded in order to improve the clearance of representation of map. In this paper, a method is developed for realization of the aim.

EXPANSION OF CONGESTED AREA ON NETWORK MAP

If there are congested areas on a map, the space should be expanded in order to improve the readability of map. To achieve the aim, there are two steps involved in the magnification process: firstly, a searching is performed in order to determine whether there are congested areas on the map. Secondly, if exist, the congested area should be expanded by most appropriate method. Certainly, if no congested area can be found, the process of magnification can be ignored.

Searching congested area

In this project, a method should be provided for automated searching congested area on a map by considering the distance of two lines. If the distance of two lines is less than a threshold, the space between lines should be considered as congested area. However, the distance among vector lines is computed by points of a line to points of other lines. If there are many lines in a network map, the amount of calculation is quite huge. And the result of calculation depends on also the point density on a line. Therefore, the method of rasterization is used to quicken the process of searching. Only twice traversals along the horizontal and vertical direction of maps for all pixels, the searching can be finished. The process is represented in figure 1.

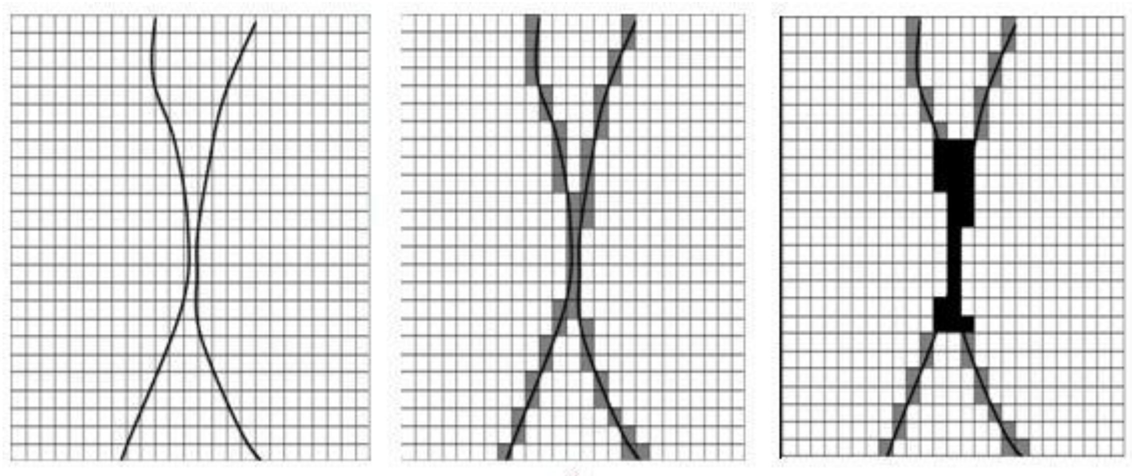


Figure 1 (a) original lines (b) rasterization of lines (c) finding the congested area

The pixel size is set as 0.5 mm according to the value of smallest visible object (SVO), which is proposed by Li and Openshaw (1992). The value of SVO is determined from 0.5 mm to 0.7 mm. In my research 0.5 mm is chosen as basis pixel size. If more than one line is in a pixel, this means that they are too close and can't be discriminated. Certainly, we must consider the distance between lines which are in adjacent pixels. If it is less than 0.5mm, the space between these lines should also be marked as congested area. By analysis of distribution of all congested areas on a map. A coordinate transformation can be used to expand the region which includes many congested areas.

Expansion of congested area

Polyfocal projection

The technique of variable-scale map can be used to realize the magnification of congested area. The variable-scale mapping indicates that the change of scale in different area on a map is realized according to a defined mathematical formula. In 1978 kadmon proposed polyfocal projections which realize a "magnification" effect for one or several area in a map. The projection formula is expressed as follows (Kadmon 1978):

$$x' = x + f(R)(x - x_1) = x + \Delta x$$
$$y' = y + f(R)(y - y_1) = y + \Delta y$$

P(x, y) is an arbitrary point on original map. P' (x', y') is new coordinate of the point on variable-scale map. P(x1, y1) is the coordinate of center of focal. R is the distance from the arbitrary point to the center of focus and f(R) is a function of distance.

$$f(R) = \frac{A}{1 + CR^2}$$

By using the function, the effect of expansion in an area is related to distance to centre point and parameter A and C. As seen from the formula, when R = 0, S = S0 (1 + A). That is, the scale of centre is increased by (1 + A) times. Therefore, parameter A can be considered as magnification coefficient. And the function f (R) is in inverse ration with C when A is a constant. So the value of C can influence the change of scale for entire map. According to the characteristics of polyfocal projection, in order to obtain a better magnification effect, the area should approximate circle or rectangle best. And the application of these methods is easy because only a centre point is determined and the computational complexity is O (n), where n is all points on a map.

From the projection formula we can see that the new coordinate P' comprises of its original coordinate and the radial increment. Therefore, by the coordinate transformation method, a focal zone can be expanded from the centre of the focal (shown in figure 2).

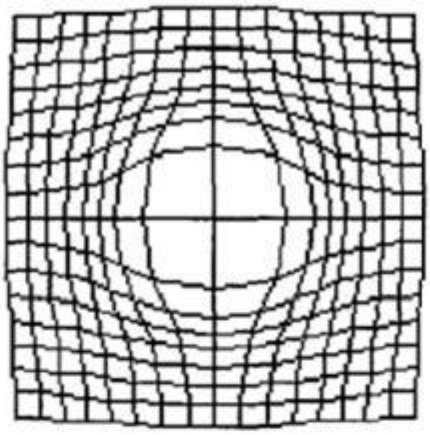


Figure 2 Polyfocal projection

(Source: http://www.infovis-wiki.net/index.php?title=Polyfocal_display)

Considering the possibility of multi-focus, the coordinate formula of these polyfocal projections can be written as follows:

$$x' = x + \Delta x_1 + \Delta x_2 + \cdots + \Delta x_n = x + \sum_{i=1}^{n} \Delta x_i$$

$$y' = y + \Delta y_1 + \Delta y_2 + \cdots + \Delta y_n = y + \sum_{i=1}^{n} \Delta y_i$$

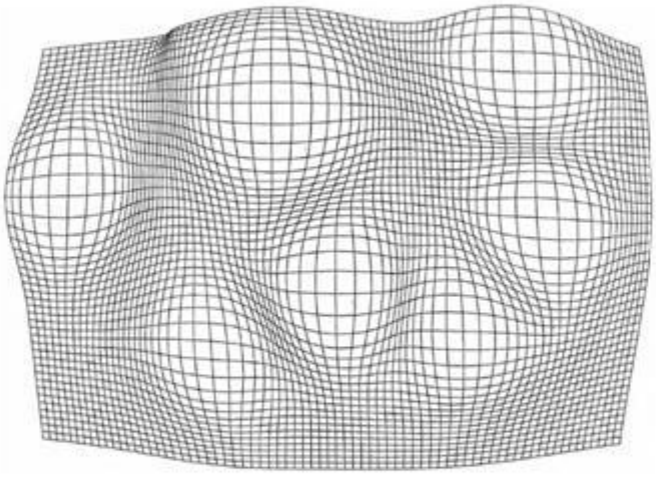


Figure 3 Multi-focus (kadmon 1978)

Multiquadric interpolation method

By using Multiquadric interpolation method, the effect of magnification for areas on a map can be also obtained. Hardy (1971, 1975) proposed the method for approximation of two-dimensional geographical surfaces and gravitational and magnetic anomalies. Franke (1982) compared 29 scattered data interpolation based on accuracy, stability, efficiency, memory requirement and ease of implementation. The Multiquadric interpolation method was rated one of the best methods. Beineke (2001) used the method to construct the distortion grids in order to visualize the geometric distortion between ancient map and modern map. The basic function is defined as follows:

$$f(x) = \sum_{j=1}^{N} a_j \, g_j(x - x_j)$$

Where g_j is a radial basis function.

The basis function of multiquadric interpolation is written in the form:

$$u = Da, \; v = Db$$

If there are n control points on a map, the basis function can be described as follows:

$$u_1 = d_{11}a_1 + d_{12}a_2 + d_{13}a_3 + \cdots + d_{1n}a_n$$

$$u_2 = d_{21}a_1 + d_{22}a_2 + d_{23}a_3 + \cdots + d_{2n}a_n$$

$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$

$$u_n = d_{n1}a_1 + d_{n2}a_2 + d_{n3}a_3 + \cdots + d_{nn}a_n$$

$$v_1 = d_{11}b_1 + d_{12}b_2 + d_{13}b_3 + \cdots + d_{1n}b_n$$

$$v_2 = d_{21}b_1 + d_{22}b_2 + d_{23}b_3 + \cdots + d_{2n}b_n$$

$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$

$$v_n = d_{n1}a_1 + d_{n2}a_2 + d_{n3}a_3 + \cdots + d_{nn}a_n$$

Where:

a_i is parameter of interpolation in x direction.

b_i is parameter of interpolation in y direction.

u_i is displacement of control point i in x direction.

v_i is displacement of control point i in y direction.

d_{ij} is distance between control point i and j.

D is the coefficient matrix which consists of dij and the main diagonal is zero because of $d_{ij} = d_{ji}$.

The multiquadric interpolation method can be used to realize the enlargement of congested area by using grid points and the process of implementation is described as follow:

1) Grid points are selected as control point.

2) The grid, which contains congested area, is expanded by displacement of grid point.

3) The interpolation parameter a and b can be calculated by the displacement:

$$a = D^{-1}u, \; b = D^{-1}v$$

4) The parameter a and b are obtained. Then, the displacement of points on a map can be computed by following equation:

$$u = as, \; v = bs$$

Where $s = \{s_1, s_2, \ldots, s_n\}$. s_i is the distance between a point on the map and control points.

5) The new location of point i on the map can be calculated by displacement u_i, v_i.

A characteristic of the method can be obtained from process 4 of implementation as follows: If the point on the map has same location as control point, the displacement of the point is same as control point. For other points on the map, the displacement can be interpolated by displacement of all control points. Comparing to polyfocal projection, multiquadric interpolation method can be used to realize magnification for congested area with any shape. However, the computational complexity is O (n^2N), where n is number of control points and N is number of all points on a map. This means the method need much computation time.

In implementation of magnification, some lines in network must have distortion. However, in this project we focused on improvement of representation of schematic network map and don't hopes that the resultant schematics map have significant change so as to result in false cognition of map. Therefore, before using a method to enlarge the congested area, two issues must be considered:

• If the lines have significant distortion, the schematized results should also have great variety comparing to their original shape and direction, e.g. the schematized direction of a line is 0 degree. However, because of distortion, the direction becomes 90 degree. This may influence the cognition of schematic map.

• Because of the enlargement of congested area, the map features which are near the area are perhaps squeezed. This may cause that a new congested area comes into being.

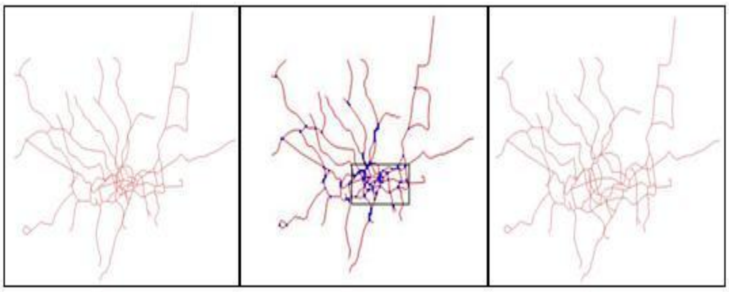
Therefore, in the process of enlargement of congested area, the two issues should be avoided as soon as possible by selection of an appropriate magnification method and adjustment of the magnitude of expansion.

RESULTS AND CONCLUSION

In this paper the London tube map is used as test data and its display format is 5 cm * 4 cm (Normal PDA screen size). In this paper, the process of expansion will be divided into following two steps and the results are presented in figure 4:

• First, the congested area on a map should be found by setting minimum distance between lines.

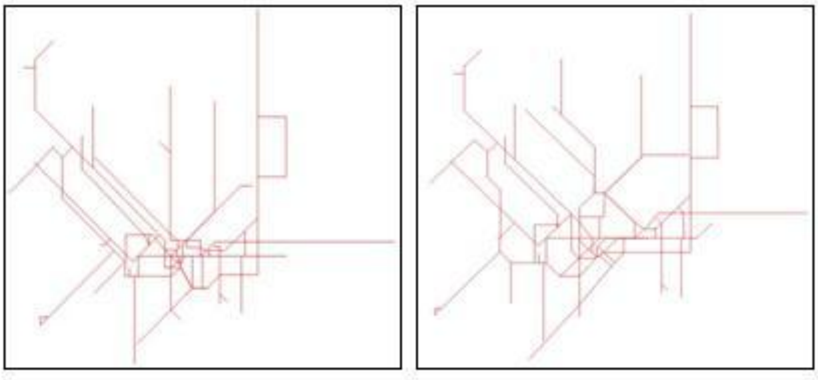
• Second, according to the distribution of congested area, the polyfocal projection is selected as expansion method in order to improve the readability of schematic map.



a b c

Figure 4 Original network map (b) Search congested area (c) Expansion Result

The result of schematization is shown in figure 5. The schematization method is based on stroke which proposed by Li and Dong (2010). The left picture is the schematic map of London tube map and the right picture is the schematic map of corresponding distorted network map. By comparing the two pictures, the readability and clearance of right one is improved apparently because of the magnification of congested area. And the right schematic map has not significant distortion comparing to the left one and don't influenza recognition of map. Therefore, the enlargement of congested area is necessary for production of schematic map with great clarity.



a

b

Figure 5 Schematic network map (b) Schematic distorted network map

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