A STUDY ON GEOMETRIC CORRECTION OF HISTORICAL MAPS

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ABSTRACT

Historical maps are precious materials which show spatial distribution of land use, streets and so on at the time when the maps were produced. They might be peerless ones through which we can grasp the concept of city planning at that time. In analysis of historical maps, the most efficacious method is to compare them with the present ones by overlaying them. However, the low precision, in the geometrical sense, of the historical maps makes the task of comparison very difficult. On the other hand, the latest techniques of Geographic Information Systems (GIS) might offer an excellent opportunity to overcome such a difficulty. The objective of our study is to construct a method for geometric correction of historical maps provided the environment of GIS is given in the field of historical studies. This paper shows the conditions required in the geometric correction of historical maps and proposes a possible method in which Triangulated Irregular Network (TIN) model and Affine transformation are employed. This paper also shows some applied examples which demonstrate the significance of the geometric correction of historical maps.

1. INTRODUCTION

Historical maps are precious materials which show various spatial distribution of land use, streets and so on at the time when the maps were produced. They might be peerless ones through which we can grasp the concept of city planning at that time.

In analysis of historical maps, the most efficacious method is to compare them with the present ones by overlaying them. However, the low precision, in the geometrical sense, of the historical maps makes the task of comparison very difficult. So far, overlaying historical maps on present maps have been done subjectively by hand (*Kodama*, et al, 1994). Such a method, however, has following drawbacks:

(a) the work is not efficient;
(b) the information on historical maps is lacking;
(c) the method is not objective.

On the other hand, the latest techniques of Geographic Information Systems (GIS) might offer an excellent opportunity to overcome such drawbacks. Using GIS technique, geometric correction of historical maps becomes possible.

The objective of our study is to construct a method for geometric correction of historical maps provided the environment of GIS is given in the field of historical studies. Geometric correction makes the task of comparison between a historical map and a present one easier than before. And geometric correction gives scale and compass to historical maps. Moreover, it makes overlaying of contour lines on historical maps possible. As a consequent, historical maps can be analysed quantitatively. And then, value of historical maps as historical materials much increase.

2. GENERAL METHOD FOR GEOMETRIC CORRECTION

The most popular method for geometric correction is to employ Ground Control Points (GCPs). This method has been applied when maps are overlaid on other projected maps, or when satellite's pictures and aerial photographs are overlaid on maps. Geometric correction can be summarized as follows:

(1) GCPs are specified as reference points which should be clearly perceived and whose coordinates should be known;
(2) GCPs determine a coordinate transformation (u=f(x,y), v=g(x,y)) to correct coordinates (x,y) (image coordinate system) into coordinates (u,v) (map coordinate system) by the Least Squares Method.

In general, Helmert's transformation, Affine transformation, projective transformation and polynomial transformation are selected as coordinate transformation.

We applied this method to geometric correction of historical maps. In this case, coordinates (x,y) are coordinates of the historical map, and coordinates (u,v) are coordinates of the present one. GCPs are set as reference points which have not moved along history, for instance, temples, shrines, parts of castles and so on. A coordinate transformation to coincide these GCPs should be determined by the Least Squares Method. The geometric correction by employing Helmert's transformation or Affine transformation is, however, not very precise (*Ryo*, 1996). If the level of precision increases by employing high degree polynomial transformation or neural networks, straight streets and moats are deformed unnaturally. Moreover, polynomial transformation is not homeomorphic in some case.

Hence, the coordinate transformation for geometric correction of historical maps have to satisfy following three conditions:

(a) should be one-to-one mapping (homeomorphism) ;
(b) should coincide GCPs (temples, shrines and castles) of a historical map and those of a present one;
(c) should transform specific segments (the straight streets and moats) of a historical map into those of a present one.

3. GEOMETRIC CORRECTION APPLYING TIN-MODEL

3.1 TIN-model

The Triangulated Irregular Network-model (TIN-model) is a vector-based topological data model that have been used to represent terrain data (Bonham-Carter, 1994). In the TIN-model, sample points are joined by lines to form a mosaic of triangles. Each triangle is treated as a plain surface. A Delaunay triangulation is used, which produces triangles that are as close to being equilateral as possible (*Kishimoto*, 1978).

3.2 Application of TIN-model to Geometric Correction of Historical Maps

We first applied the TIN-model to geometric correction of historical maps.

(1) TIN was produced by the Delaunay triangulation on a historical map and a present one respectively.
(2) A coordinate transformation was determined for each corresponding triangle.

Using this method, we could geometrically correct the distortion which vary from place to place. We determined that the coordinate transformation was Affine transformation (Fig. 1). This method has been used as a method for texture mapping. The Affine transformation expresses scaling, rotation, translation and correction of skew distortion. The Affine transformation which is a linear expression will keep straightness, topology and ratio in a segment.

Employment of the Affine transformation is an extension of interpolation of heights in the TIN-model, namely to extend a linear expression z=ax+by+c to u=ax+by+c, v=dx+ey+f. The GCPs of the historical map and the present one are coincided perfectly, so that the parameters have unique solutions. If the following premises are satisfied, the geometric correction will satisfy the conditions listed in Section 2.:

(a)TIN on the historical map and the present one are homeomorphic;
(b)The specific segments which should be straight are lines to form TIN.

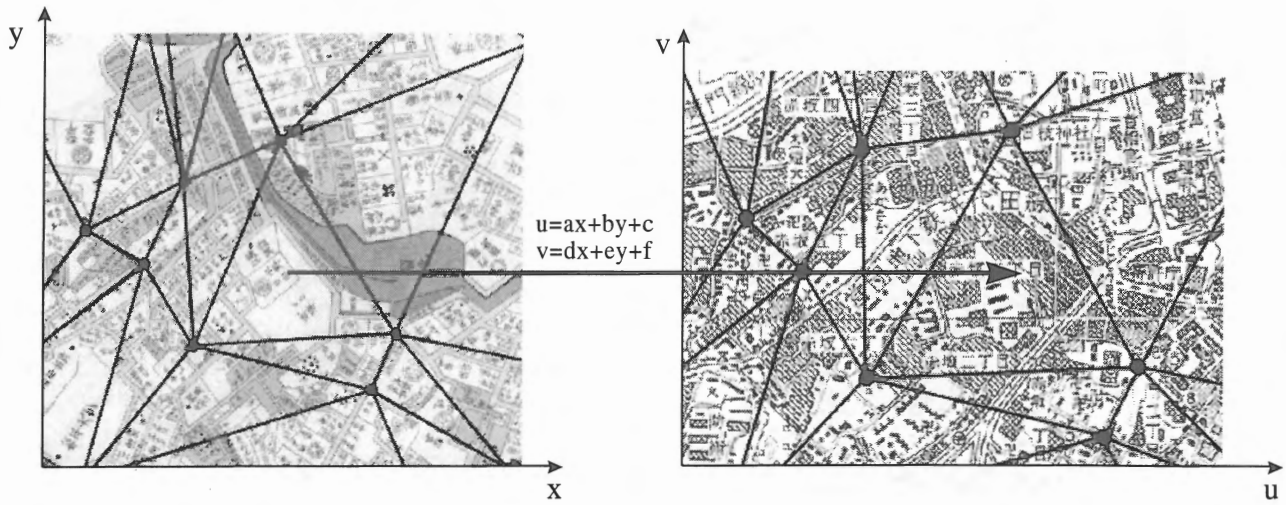


Figure 1: The method for geometric correction of historical maps which integrating TIN-model and Affine transformation.

If the TIN does not satisfy above premises, TIN is reformed manually (*Nishio*, 1990).

The way of specifying GCPs is as follows:

(1) Comparing historical maps and present ones, we first picked up GCPs which had not moved along history;
(2) We then confirmed reliability of GCPs from documents;
(3) Transforming a historical map by Helmert's transformation, we finally removed inappropriate GCPs.

4. EXPRIMENTS

4.1 Comparison of a same place at various times

We applied the method integrating TIN-model and Affine transformation to some historical maps. We used following maps:

(a) *Genroku-Edo-Zu* map (1693) (*Genroku* era: 1688～1703);
(b) *Tenpou-Edo-Ezu* map (1843) (*Tenpou* era: 1830～1843);
(c) *Jissoku-Tokyo-Zenzu* map (1892);
(d) 1:25,000 topographic map published by the Geographical Survey Institute (1996).

We specified 25 GCPs for each map and corrected the historical maps geometrically. Figure 2 are examples of outputs which are at *Tameike* in *Minato* ward, Tokyo. *Tameike* was a pool.

The examples show that the geometric correction makes the task of comparison between a historical map and a present one easier than before. Moreover, it makes the task of comparison between some historical maps possible. For instance, the center of the pool of that time is the Patent Office and the *Tameike* intersection, which is an intersection of the *Sotobori-dori* Avenue and the ring superhighway, at present. And comparing *Tenpou-Edo-Ezu* map (b) with *Jissoku-Tokyo-Zenzu* map (c), a change in the pool can be recognised. Changes of land use caused by the disappearance of the pool can be also recognised.

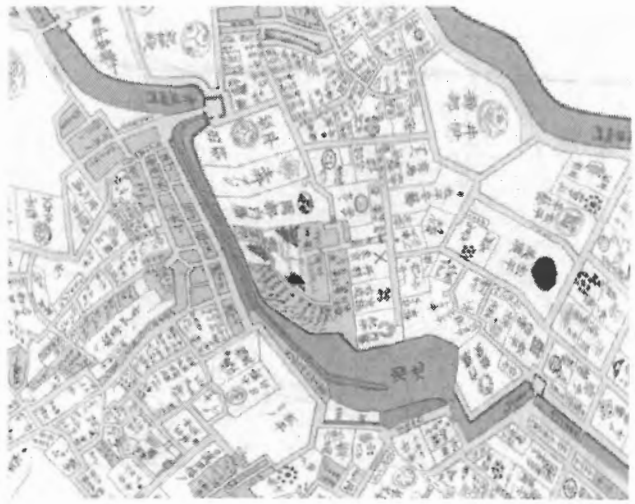
4.2 Measurement of an area from historical maps

Geometric correction can make the task of quantitative analysis more accurate, so that geometric correction gives scale and compass to historical maps.

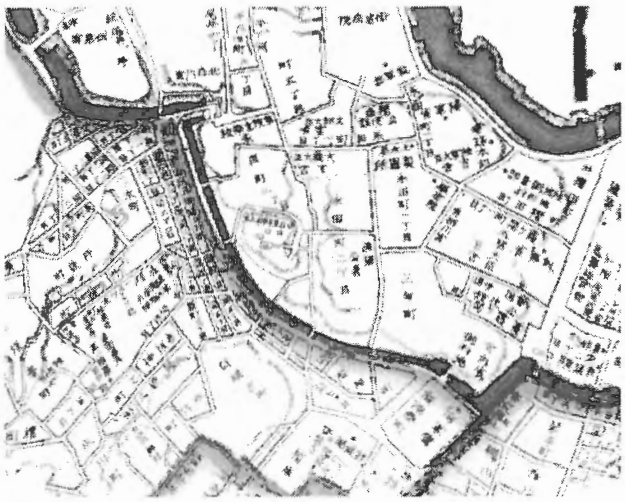
Figure 3(a) shows the historical map which expresses the damage at the war known as *Shougitai*-War (1868). In *Edo* era maps which expresses the damage by disaster, war, and so on as red zone were handed out. This map is one of that type of maps.

A dark zone on the historical map represents an area damaged by the war. It is difficult to directly measure the area of damage from the historical map, and make a comparison between the place of the damage at that time

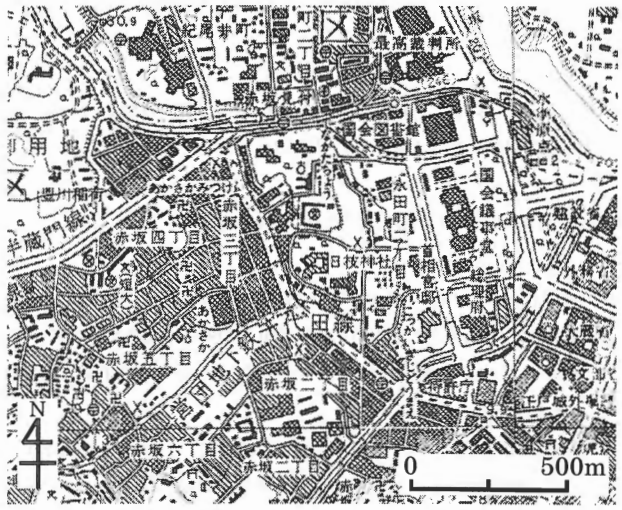
(a) *Genroku-Edo-Zu* map (1693)



(b) *Tenpou-Edo-Ezu* map (1843)



(c) *Jissoku-Tokyo-Zenzu* map (1892)



(d) 1:25,000 topographic map (1996)

Figure 2: Geometric correction of historical maps of various times

and the place at the present time. With the proposed method we corrected the historical map against the present map geometrically, which is an 1:10,000 topographic map published by the Geographical Survey Institute. Figure 3(b) shows the result and the region is from *Asakusa* to *Koishikawa* in *Taito* ward and *Bunkyo* ward, Tokyo. From the corrected map, the measurement of the exact area became possible. The area of the damage is 470ha.

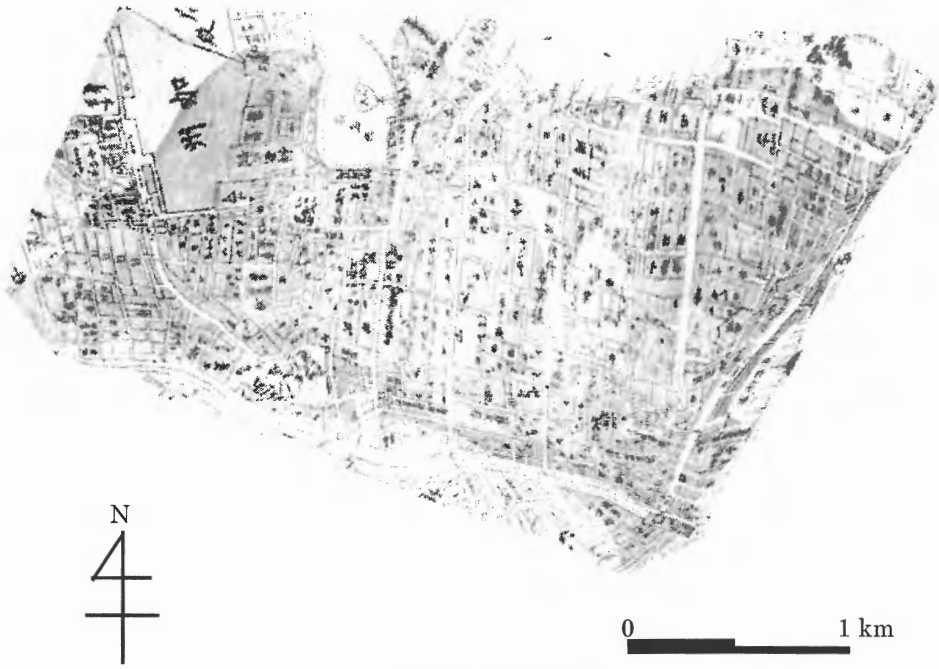
4.3 Expression of topography (contour lines) on historical maps

There are no contour lines on historical maps. In Japan, contour lines on maps appeared in *Meiji* era. Overlaying a corrected map on a present map with contour lines, the topographical analysis of the historical map became possible.

We corrected the historical map, which is *Bannen-Edo-Zu* map (1860) (*Bannen* era: 1860), against a present map, which is an 1:2,500 topographic map published by the City of Tokyo. Figure 4 shows the result. The region is *Mejirodai* and *Kohinata* in *Bunkyo* ward. We also produced contour lines (5m intervals) on the present map employing TIN technique. Finally, we transfer those contour lines to the corrected historical map. However, the inclusion of various other graphical information in the final map has made the topographical observation difficult.

Figure 4 shows that great feudal lords (*daimyo*), for instance, the *Hitotsubashi* family, the *Mito* family and the *Hosokawa* family, had their residences at good environmental slope which faces south. Many of the

(a) *Edo-Taika-Zenzu* map (1868)



(b) The corrected historical map

Figure 3: Measurement of the area from the historical map

residences of feudal lords, temples and shrines were at slope. Especially all of temples and shrines in this region were at slope. Moreover, we can observe that the main trails, for instance the trail (*Otowa-dori* Avenue at present) running from north to south in the center of this figure and the trail (*Mejiro-dori* Avenue) running from east to west in the north of the river (the *Kanda-gawa* river) in this figure, are aligned parallel to contour lines. The *Otowa-dori* Avenue also runs through the valley.

There are several other historically significant information in the historical maps. For further graphical illustration, please visit Home Page:

http://planner.t.u-tokyo.ac.jp/index/thesis/fuse.html

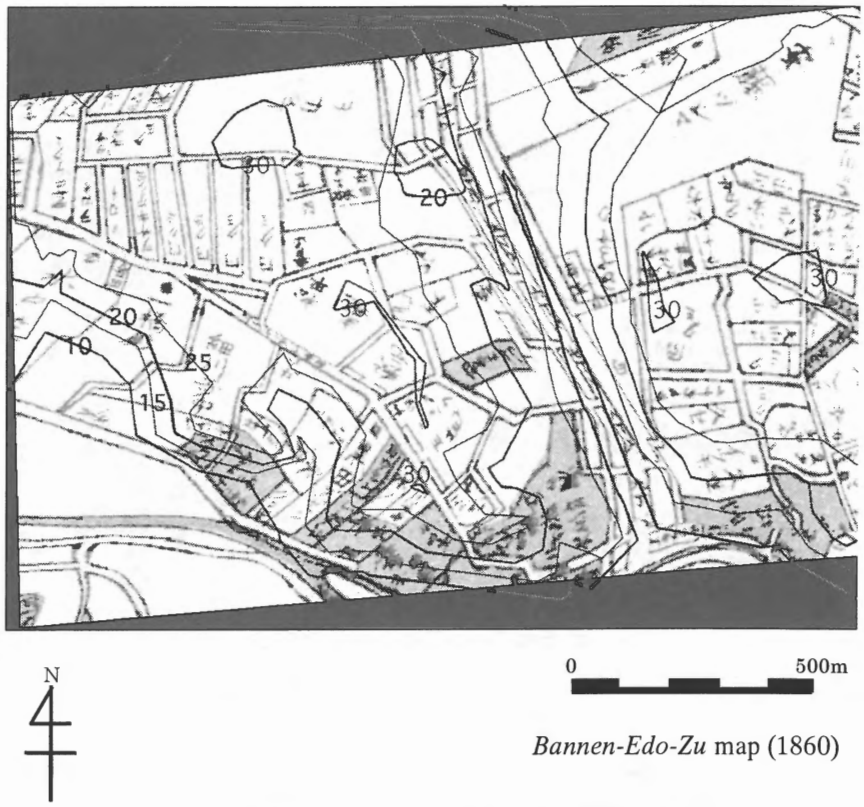


Figure 4: Overlying contour lines on the historical map

5. CONCLUSION

The implications of this study are:

(a) the evaluation of possibility that existing methods may be applied, and the arrangement of necessary conditions of geometric correction of historical maps;
(b) the suggestion of a method which integrates TIN-model and Affine transformation;
(c) the confirmation of the significance of the geometric correction of historical maps through some applied cases.

Correcting historical maps against the present ones geometrically, value of historical maps as historical materials increases. We can employ GIS in order to analyse historical maps. The method for geometric correction of historical maps is thus worth using as a component of GIS.

There are many attractive ways to apply the method for geometric correction:

(a) the analysis of changes of streets and canals;
(b) the analysis of changes of land use;
(c) the confirmation of more exact locations of rivers, damp grounds and precipices;
(d) the reproduction of landscape of historical days;
the presumption of locations of cultural assets lain underground.

REFERENCES

Bonham-carter, G.F., 1994. Geographic Information Systems for Geoscientists: Modelling with GIS. Pergamon, Ontario, pp.150-152.

Kishimoto, K., 1978. An Algorithm for the Optimum triangulation. Journal of Information Processing of Japan, 19(3), pp.211-218.

Kodama, K., Yoshihara, K., Tawara, M., and *Nakagawa, K.*, 1994. The Map with Information in *Edo* Era. Asahi Newspaper, Tokyo.

Nishio, T., 1990. A Study on Expression of Topography in Digital Elevation Model. Graduation. Thesis, University of Tokyo.

Ryo, T., 1989. Study on Accuracy of Old Maps. Master. Thesis, University of Tokyo.