Digitization of Ancient Maps Based on GIS Technology:
The Yu ji tu Map

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Abstract:
Digitization of ancient maps is always a challenge. This article introduces in detail the steps of digitizing the ancient map Yu ji tu using GIS technology and discusses the progress of digitization of ancient maps and its significance.

Keywords: digitization, ancient maps, GIS technology

Map culture is an indispensable part of Chinese culture. The ancient maps have scientific, cultural and artistic value, so they receive more and more attention. There are many people now who attempt to protect, research and recycle ancient maps through digitization.

According to the traditional charting technology, ancient maps of China can be divided into three kinds. The first kind is traditional Chinese maps with visual brushwork. In these maps, the terrain and other features are visually and realistically drawn. Maps were then seldom directly used for production and construction, therefore there was no high request for accuracy. The map content expressed by landscape painting is intuitive, stereoscopic and readable. The second kind is maps with a grid scale. With the “six principles of cartography” by Pei Xiu of Western Jin Dynasty as theory, the orientation of geographical factors is controlled by the gridding. Compared with the traditional Chinese maps with visual brushwork, these maps have an extremely high accuracy. The grid scale is the most scientific cartography method in China, before the map projection method was introduced into China [1]. The third kind is maps with latitude and longitude which was introduced into China at the end of the Ming Dynasty and at the beginning of Qing Dynasty.

At present, based on its special cartography, digital protection of ancient maps mainly refers to scanning, photography, text and image databases, etc., but lacks database administration and utilization to its
content and spatial information. However, with the development of electronic maps and geographic information systems, ancient map databases based on GIS already have become the inevitable way to continually improve the preservation, research and service of the geographical information found on ancient maps.

1. Introduction of Yu ji tu

Yu ji tu is the extant earliest map with cartography of Ji li hua fang (The landscape is covered with a scaled grid, every square represents one hundred li, 1 li = about 500m.), holds an important status in Chinese map history, and objectively reflects the cartographical level in the Song Dynasty. The famous British scientist Dr. Joseph Needham commended in his work Science and Civilization in China that “Yu ji tu is the most outstanding map in the world at that time.” Yu ji tu consists of two stone tablets which are preserved separately in the Steles Museum in Jiaoshan, Zhenjiang and in Xi’an.

The map in Zhenjiang was engraved in the 12th Year of the Shaoxing Reign (1142) in the Southern Song Dynasty with corrections of the publication of the 3rd Year of Yuanfu Reign in the Northern Song Dynasty year (1100), while Yu ji tu in Xi’an was engraved in the 6th Year of Shaoxing Reign in the Southern Song Dynasty year (1136). The contents of the two maps are basically consistent. The landscape is covered with a grid scale, every square represents one hundred li(1 li = about 500m). The map direction has north at the top and south at the bottom. With more than 500 geographical names, this map reflects the panorama of China in the Song Dynasty. Especially the river system is engraved in great detail. [2]

This article uses the red rubbing of Yu ji tu from the Steles Museum in Xi’an, but the age of the rubbing is unknown. The frame of the map is 79 cm long and 78 cm wide, nearly a square. It was inscribed that “each square grid represents one hundred li and there are names of mountains and rivers, ancient and modern states and counties.” This map includes countrywide about 380 names of administrative districts, nearly 80 river names, more than 70 mountain names and 5 lake names. Its accuracy is quite high, e.g. the outline of the coastline and the shape of the Yellow River and so on are extremely similar to those of the modern map. Other features and their expression are also similar to the modern cartography, and river lines are engraved clearly and fluently. Lines of the middle and lower reaches of the Yellow River and the Yangtze River are thick, their trends are near to trends in modern maps. “River” in the names of most rivers is replaced by “Water”, for example, Fen Water (now Fen River), Jialing Water (now Jialing River) and so on. The Yellow River is named “The Great River”(pinyin: da he), the Yangtze River is “The Big River” (pinyin: da jiang). According to the historical records, more than 1700 years prior to the 2nd Year of Jianyan Reign (1128) in the Southern Song Dynasty, the Yellow River always joined the Haihe river system and flowed into Bohai Sea. In this map, the Yellow River entered the sea in the Haihe Estuary of the Bohai Gulf. The shortcoming of this map is that there are some warps by the river trends and curves and most of big rivers in south China are not drawn. [3]

It is obvious that Yu ji tu provides precious materials for the studies of Chinese cartographical history. Its historical value and scientific significance are preserved for posterity. But at present, this map and the others are merely preserved in paper form. How to protect these ancient maps better, how to use them effectively and how to serve the reader conveniently, are the main aims of the construction of a map database and map information system.
2. Digitization of *Yu ji tu*

2.1 Analysis of *Yu ji tu*

*Yu ji tu* chiefly includes river systems, mountains and place names of administrative districts. River systems and coastlines are represented in form of lines, while names of mountains and administrative districts are expressed in the form of labels. Every grid in the map represents one hundred *li*, with 71 horizontal grids and 73 vertical grids. There are 5110 grids in all.

2.2 Digitization project

Based on the contents of *Yu ji tu*, a digitization project is outlined.

Polygons: Rivers, lakes. Shown as polygon features; attributes include river and lake names.

Lines: Rivers. Shown as linear features; attributes include river name.

Points: Places. Shown as point features; attributes include name and type. Used to query map.

Labels: Shown as point element, attribute includes name. Used to display and represent the original appearance of the map factually.

2.3 Digitization results

2.3.1 Display

Fig. 1: Overlay effect of original map and vector map, rivers in blue are vectorgraph;
Fig. 2: Vectorgraph of rivers and labels;
Fig. 3: Partial map, including original map, vector map and labelling.
Fig. 2

Fig. 3
2.3.2 Querying

With GIS software, according to the names of rivers and places, elements or factors of the map can be queried.

3. Digitization process of ancient maps

3.1 Raster map from paper map

Transforming paper maps to raster maps is the basis of digitizing paper maps. At present, there are generally three types of raster maps: first, JPG files produced by digital camera with high resolution; second, image files produced by a large scanner; and third, high resolution electronic maps produced using GIS technology. The first way is the most economical. But it is impossible to capture a large map on one digital image. The splicing of pictures increases the difficulty of digitization.

Scanning technology is only an initial stage of digitization. Raster maps can be conveniently stored in the computer, so the ancient maps can be preserved effectively for a long time. But it is insufficient, because the preserved information is not linked to other relevant information included on the original map. In addition there are other disadvantages, such as large storage files, bad display effect, difficult to query, etc. So the digitization of maps requests the following step: vectorization of maps.

3.2 Vector map from raster map

The vectorization of raster maps refers to the raster images (in form of BMP, JIF and so on). With special map digitization software (MapInfo Professional), grid arrays in the raster image are identified as vector objects and preserved in a certain form.

In a vector map the goal is to create a separate layer for each type of feature (point, line, or polygon) or
integration of several vector units. Based on such a data structure, we can very conveniently edit and classify all the objects on the map, and then obtain the spatial relationships between them. It is also advantageous for browsing and outputting the map.

3.2.1 Analysis
Ancient maps are hand-painted and don’t have coordinates and contents and manifestations vary. For example, *Yu ji tu* uses the method of *ji li hua fang*, includes more than 500 geographical names, and the river systems are depicted in great detail. But in the *Complete atlas of Jiangxi province*, the topographical and cultural features, such as mountains, waterways, towns, and villages are drawn visually. Therefore, maps should be analysed before vectorization. The analysis refers to identifying the various components of the map. Based on the map analysis, and combined with the demand of electronic map application and characteristic of vector maps, the project of map vectorization is established, i.e. the contents and form of vectorization.

3.2.2 Criterion
According to the project of map vectorization based on the map analysis, concrete and operable criterions are as follows established:
1. Definition of map database
   1) Layers of the map and the content of every map layer
   2) Type of spatial elements of every map layer: points, lines, polygons
   3) Type and evaluation standard of attribute fields of every map layer
2. Process of map vectorization
   Includes approaches, precision request and aesthetic request, etc. of the vectorization
3. Criterions for back-check
   Includes contents that should be checked after vectorization against check methods

3.2.3 Matching
Matching means that raster maps should be matched to the geographical coordinates in the same district and includes the following aspects: geometrical correction, projection transformation, and scale unification. Map matching is an important step in the vectorization of raster maps.

3.2.4 Vector and attribute evaluation
After the step of matching, the vectorization of raster maps and attribute evaluation can be carried on according to the criterions. We need to interpret the map, extract elements and through the method of vectorization transform them into points, lines, or polygons. Then the vectorization should be checked against the criterions.

This article takes *Yu ji tu* as an example and introduces the process and significance of ancient map digitization. The application of a single digitized ancient map is relatively simple, but when several or many ancient maps that have correlative relations have been produced, their application can become more extensive. On the basis of digitization of ancient maps in quantity and with help of GIS, we can carry out the search and display the contents of ancient maps, produce special historical maps, realize the analysis and comparison of different maps, and serve the reader better.
Map digitization is the foundation for establishment of geographical map databases. Afterwards, we can construct ancient map information systems and network ancient map information systems based on the geographical database of ancient maps.

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