DESIGN AND IMPLEMENTATION OF DECISION-MAKING SUPPORT SYSTEM FOR THEMATIC MAP CARTOGRAPHY

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ABSTRACT:

Thematic map symbol is a basic component of thematic map language and it plays an important role in expressing the thematic content. However, the extensity of users leads to the diversity and complexity of the thematic symbols and expression methods, and most of the thematic maps do not have a fixed format and norms like topographic map. At the same time, we can not require all the users to be very familiar with GIS Mapping knowledge. Thus, it is needed that the system can provide a decision-making support system which can produce high-quality maps for the general GIS users while the geographical information is visualized. Moreover, the decision support system must be built on the basis of map design software. That is to say, there should be a decision support system for thematic map cartographic in GIS. It can combine cartographic knowledge with the map design module and mapping module together. This paper first discusses the necessary and results of the usage of decision-making support system for the thematic mapping application. And then it is followed by a thematic analyse the decision problems in the process of the thematic mapping. The system uses the different decision-making model or different reasoning method according to different issues. In the final, it focuses on the structure and function of decision support system for thematic mapping which is designed and programmed based on JBuilder2005 introduced and SQLServer2000.

1. INTRODUCTION

1.1 Motivation

Today, in the process of map's rapid development, the great advantages of thematic maps in the information transmission, storage, conversion and display have become essential tools and means in investigations and studies, analysis and evaluation, forecasting, planning and design, command and management. And thematic map symbol is the most basic and important component of the thematic language and plays an important role in the expression of the thematic content.

With the development of GIS (Geographical Information System), map designer is also a map reader. However, it is found through research that the extensity of users leads to the diversity and complexity of the thematic symbols and expression methods and most of the thematic maps do not have a fixed format and norm as topographic map. At the same time, we can not ask all the GIS users to be very familiar with cartographic knowledge. Thus, it is needed that the system can provide a decision-making support system which can produce high-quality maps for the general GIS users while the geographical information is visualized. Moreover, the decision support system must be built on the basis of map design software. That is to say, there should be a decision support system for thematic map cartographic in GIS. It can combine cartographic knowledge with the map design module and mapping module together. It also allows users to produce a better map by operating the system.

1.2 Related Work

Decision Support System (DSS) was mainly used in the field of management science earlier. It is a special kind of viewpoints and methods in developing decision-making support. Although the theoretical research of the decision support system overseas has exceeded it in our country, it is blank overseas as the same as our country in some applications, or it just begins. In the Seventh Auto-Cartography International Colloquium held in Washington, DC in 1985, many articles pointed out that the basic features of the next phase of computer-aided mapping would be the establishment and development of "intelligent" system. Intelligent system should include expert systems and intelligent database. In the 15th ICA meeting held in September 1991 in the United Kingdom, the formal map theory and cartographic knowledge were set as the theme of the 16th session (1993) of the ICA.

With the proposal and support of Professor Zhizhuo Wang in our country, a succession of the application of artificial intelligence expert system for mapping in the application of mapping seminar series greatly promotes the research in this area. In the national mapping Development Fund and the National Natural Science Foundation Youth Fund, Bo SU(1993) carried out artificial intelligence expert system research based on the application of theoretical research, development tool and application development of mapping expert system. He established a mapping expert system development tool and developed an intelligent cartographic production system MAPKEY which can be used in the area of thematic maps and

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successfully resolved a series of major problems in the thematic map design process.

2. KEY DECISION-MAKING PROBLEMS IN THEMATIC MAPPING

The main idea of designing decision-making support system of thematic mapping is using all kinds of technologies and methods to solve the decision-making problems in thematic mapping in order to favoringly make a perfect map through operating this system by users (Qingsheng GUO, 1993). To design a good decision-making support system, key decision-making issues referred to the thematic map design should be analyzed clearly at the beginning, and then propose corresponding decision-making models and reasoning methods according to different problems. Fig1 is the structure of decision-making support system of thematic mapping.

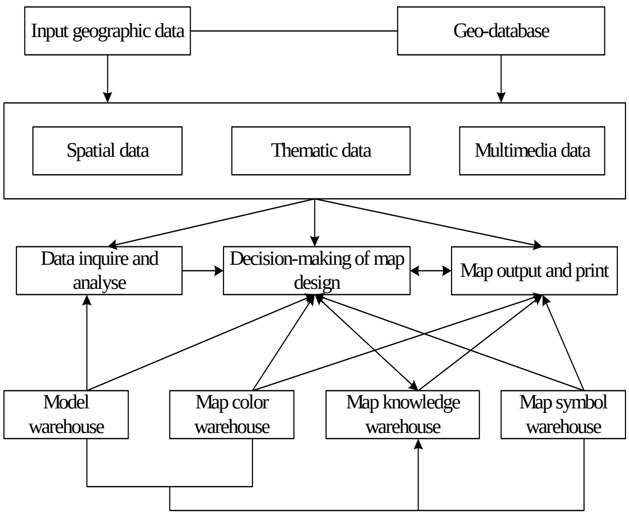


Figure1. Structure of decision-making support system of thematic mapping (Qingsheng GUO, 1993)

2.1 Determine the content of thematic maps

Map design work is the core of cartography and determining the content of thematic maps which task is to make sure which features to be expressed in the thematic map according to the map users, their needs and data information is an all-important job during the map design process. As long as the elements which will be drawn in the map are identified, the methods and symbols design can be carried out. In order to transfer map information effectively, it must reduce the noise hidden behind the map information and prevent over much map information. That is to say, on one hand, only features referred to the usage of map can be presented and on the other hand, only the important elements can be shown when there are too much features. This is the main idea of how to make sure the thematic map content (Yixin HUA, 1993).

The factors are taken into account when choosing map elements including: map types, map themes, characteristics of the cartographic region, map scale, special needs of users and so on. The map types and themes to a large extent represent map use, so according to the map types and themes which elements will be chosen can be initially identified. For the same region, the greater scale, the more elements can be shown and vice versa. These notes, the contents of the choice of thematic maps need a large number of geographical knowledge (thematic elements experts in the fields of knowledge) and cartographic knowledge.

For the common map or the map of which type has been existed, analogical reasoning is carried out based on the a priori knowledge. The prior knowledge of the thematic map is understood as the features and contents chosen on exited maps. That knowledge organized in a special data structure (such as the framework) is stored in the database (Jing Tian, 2007). When the map is a completely new type of map, computers can only provide a reference. Below is the use of a framework explains resources map:
Framework name: basic elements.
Map type: resources map.
Map Scale: 100,000 (on a scale denominator).
Map region: the scope of longitude and latitude.
Basic elements: [Ocean, coastline, residents, the island, railways, rivers, bourn].

2.2 Thematic Map Data Processing

There are many map data sources. Regional and point statistics, and observation station data can be used to cartography after processing simply. Some data root in the map of balance. Map data pre-processing can be roughly divided into qualitative and quantitative data processing.

Qualitative data mainly refers to the elements on geographical maps and thematic regional boundaries, including all annotations. Its major operation is to select and graphics. Selection is divided into two steps: whether this element is needed, and which elements are selected among the required elements. Graphics generalization only needs to determine the minimum size of bending standards.

Quantitative data processing is defined as a pretreatment which services for kinds of map representation, including simple statistics computation, such as the absolute quantity, density, relative quantity, percentage growth rate and growth rate; calculation of the basic statistical features. These basic statistical characteristics are as follows:

- Identify two or three kinds of different sizes of the interval value, compute the frequency of data and draw distribution histogram curve;
- Calculate the difference between adjacent data and draw distribution histogram curve;
- Compute average, median and mode of all kinds' data;
- Make sure split points according to distribution of the natural curve or histogram;
- Calculate the extreme value and difference of data.

2.3 Selection and Reasoning about Map Representation Methods

There are commonly more than 10 thematic map types, namely point diagram maps, linear diagram maps, chorochromatic mosaic maps, soline maps, stereoscopic perspective methods, nominal point symbol maps, proportional symbol maps, dot methods(dot mapping), classification ratio method (choropleth maps), statistical maps (areal diagram methods) , cartographic arrowhead methods, triangle charts law. Every method should be corresponding to geographic data characteristics and particular types of map graphics to be expressed.

representation	Data characteristics to be expressed						
	Spatial distribution	quantity	grade	summation	Comparative	direction	Sequential
point diagram map	point	√	√	√	√	√	√
Linear diagram	line	√	√	√	×	√	×
chorochromatic mosaic maps	area	×	√	×	×	×	×
isoline maps	surface	√	√	√	×	×	×
nominal point symbol maps	point	√	√	√	√	×	√
Area filled maps	Discrete surface	√	√	√	×	×	×
dot methods	point, area	√	×	√	×	×	×
choropleth maps	Statistics region	×	√	×	×	×	×
areal diagram methods	Statistics region	√	√	√	√	×	√
triangle charts law	area	×	×	×	√	×	×
cartographic arrowhead methods	line	√	√	×	√	√	√

Table1. Map representation selection rule table (Qingsheng GUO, 2003)

Different methods will emphasize differently on different map data characteristics. And some data characteristics can only be expressed by particular methods. As long as judging the current data characteristics, we will know which method to choose. Its reasoning process is simple. Table 1 is a map representation selection rule table (Qingsheng GUO, 2003).We can select different map representation according to the spatial distribution of quality, quantity, grade, combined, compared, direction and temporal options. The reasoning process of map representation selection is shown in Figure 2 (Qingsheng GUO, 2003).

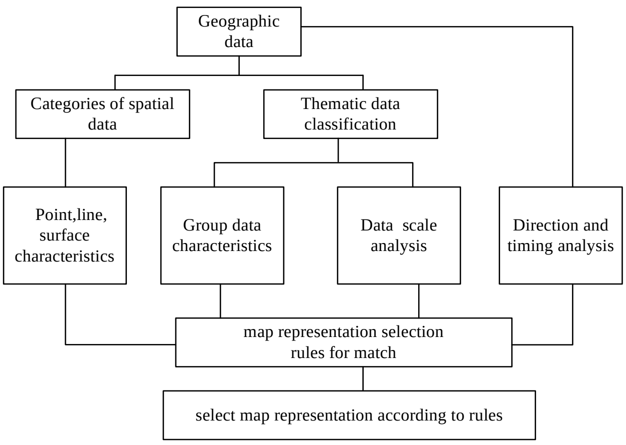


Figure2. Reasoning process of map representation selection (Qingsheng GUO, 2003)

2.4 Charts selection in statistical maps

The main factors that affect charts selection in statistical maps include data types and characteristics, data positioning characteristics and data difference. The selection rules relating to the data difference as follows:

- Difference between 1 / 2 and 1 / 50: When using absolute ratio, apply lineal symbols, such as cylindrical, the cumulative value of maps, polyline plans.
- Difference between the 1 / 40 and 1 / 500: When using absolute ratio, apply areal symbols, such as round, square, triangle, etc.
- Difference greater than 1 / 400: generally use conditions ratio and apply lineal or areal symbols.
- Difference between 1 / 40 and 1 / 4000: apply volume symbols, such as the sphere, cube, etc.

Selection charts based on different kinds of data, that is to say, statistical data is divided into the total indicators, compared indicators, structural indicators, the dynamic combination of indicators. The paper establishes those knowledge such as the links and relations between map graphs and statistical data mainly by using the form of tables which will be explained in next section.

3. DESIGN OF THEMATIC MAPPING DECISION-MAKING SUPPORT SYSTEM

3.1 General design

The thematic mapping module is considered as a separate component of which the data acquisition and display is carried through interface. Input parameters, and show the thematic mapping results at the location that the parameters specified and generate legend synchronously to achieve flexible thematic mapping function. The system specific objectives are as follows:
(1) The system can draw all kinds of thematic maps including point diagram maps, linear diagram maps, chorochromatic mosaic maps, isoline maps, stereoscopic perspective methods, nominal point symbol maps, proportional symbol maps, dot methods(dot mapping), classification ratio method (choropleth maps), statistical maps (areal diagram methods) , cartographic arrowhead methods, triangle charts law.
(2) The system can draw point symbols by function methods (dynamic effect of the earthquake, the dynamic effect of combustion point, the dynamic effect of the explosion, with the direction of landslide), linear symbol (single, two-lane arrow, and multi-arrow) and areal symbols (supporting to fill map by line, point and images).
(3) The system has a unified interface through which we can choose thematic elements. The system can automatically draw a thematic map according to thematic elements type and characteristics. Modify the design parameters of various charts through interface to gain satisfaction results.

3.2 System Structure

According to the overall aims and design principles, as well as thematic mapping methods, combining the characteristics of the development of components, the whole system will be divided into 8 modules which are data processing, district mapping, statistical classification maps, points of mapping, and dynamic symbols drawing, perspective and contour mapping, special thematic symbols, interactive mapping interface and legend mapping. Each module is composed of several sub-modules.

3.2.1 Data organization and comparison table design: Based on the analysis about the special geographical data storage in the relational database SQL Server and all kinds of thematic data in multiple industries and fields, the thematic data are classified and a thematic mapping data storage format and a data structure are proposed which can meet the needs of multi-cartographic requirements to achieve the data integration of thematic maps with base maps and spatial data reasonable storage and organization.

According to the characteristics of thematic elements and thematic map representation, we design a comparison table between thematic elements attributes form and thematic map representation table, as shown in Figure 3, Figure 3 (a) is a code table of thematic map representation, Figure 3 (b) is a thematic elements of the code name attribute table, Figure 3 (c) is the correlation table of (a) and (b), that is to say, thematic maps representation corresponding to certain thematic statistics can be found in Table (c).

方法代码	表示方法名称	指标类型ID
1	分级统计地图法	1
2	点值法	1
3	等值线法	1
4	透视图法	1
5	动线法	<NULL>
6	范围法	<NULL>
7	质底法	<NULL>
8	定点符号法	<NULL>
9	定位图表法	<NULL>
10	圆柱图	3
11	三維饼图	3
12	扇形图	3
13	正方体图	1
14	百分格图	3
15	柱状图	3

(a)

表格名称	代码
1999年全国各省人口	1
2000年全国各省人口	2
1999年全国各省农业构成	3
2000年全国各省农业构成	4
1999年全国各省产业结构	5
2000年全国各省产业结构	6
2000年7月台风路径	7
各省绿地状况	8
各省受教育程度构成	9
各省性别年龄构成	10
1997年-2000年全国各省粮食和家禽产量	11
1999年-2002年全国各省三大产业构成	12
1997年-2000年全国主要农产品产量和销费量	13
各省各教育水平人均收入情况	14
全国植被覆盖情况	15

(b)

专题要素属性表标	专题地图表示方法代码
1	1, 2, 3, 13, 53, 54
2	1, 2, 3, 13, 53, 54
3	10, 11, 12, 14, 15, 22, 23, 24, 25, 26, 30, 34, 35, 36, 45, 48
4	10, 11, 12, 14, 15, 22, 23, 24, 25, 26, 30, 34, 35, 36, 45, 48
5	10, 11, 12, 14, 15, 22, 23, 24, 25, 26, 30, 34, 35, 36, 45, 48, 56
6	10, 11, 12, 14, 15, 22, 23, 24, 25, 26, 30, 34, 35, 36, 45, 48, 56
7	5
14	33
3, 4	16, 49, 17, 19, 20, 21, 51, 37, 38, 39, 40, 50, 41, 46, 32
5, 6	16, 49, 17, 19, 20, 21, 51, 37, 38, 39, 40, 50, 41, 46, 32
3, 5	27, 29, 28, 52
3, 6	27, 29, 28, 52
4, 5	27, 29, 28, 52
4, 6	27, 29, 28, 52
8	10, 11, 12, 14, 15, 22, 23, 24, 25, 26, 30, 34, 35, 36, 45, 48
3, 8	27, 29, 28, 52, 32
4, 8	27, 29, 28, 52, 32
9	10, 11, 12, 14, 15, 22, 23, 24, 25, 26, 30, 34, 35, 36, 45, 48, 31

(c)

Figure3. Comparison table. (a) is a code table of thematic map representation, (b) is a thematic elements of the code name attribute table, (c) is the correlation table of (a) and (b)

3.2.2 Thematic mapping data processing: In thematic maps, symbol size generally indicates the number of objects. The system deals with chart size by using grading and relative ratios. Grading means divide thematic values into a number of hierarchical values. Values only at the same level are represented as a symbol of the fixed size. There generates a jump between different level symbols. Relative ratio processing means the symbol size is in direct proportion to values of thematic elements, but is not in absolute proportion with restrained conditions. Both methods have advantages and disadvantages, users can choose their own situation according to the statistical data chrematistics. So, the system defines the largest, smallest size of the chart and the minimum length of the chart in order to generate each chart size with its statistic data.

When dealing with the symbol size with classification method, it is necessary to grade statistical data. Data classification primarily consists of two aspects, namely determining class intervals and class boundaries. According to experience, for areal diagram methods, statistic data are usually classified into three or no more than five to seven classes. To determine the class boundaries refers to data types and distribution. This system realizes four classification methods, equal steps, standard deviation, arithmetic progression and clustering method.

3.2.3 Areal diagram mapping:
Charts selection which is used in areal diagram maps are affected by many factors including data types and characteristics, data characteristics, positioning data and the difference between the maximum and minimum. Here we only consider data types and characteristics and group symbol chart into five types: the overall total symbols, segmentation symbols, contrast symbols, the development of symbols and a combination symbol, and so on. Two-dimensional point symbols such as round circle, round ring and sector symbols which are the most widely used are often applied to represent some complex phenomenon's internal structure. And the two-dimensional development point symbols are used to reflect the dynamics of things by changing colors and area. The inscribed circle, concentric circle or other concentric symbols are used to express the different changes at different periods. Three-dimensional symbols can effectively increase the people's feelings, and this system provides the sphere and prismatic symbols.

In this module, the system completes a large number of related charts mapping. When users select the information they want to see, the system will automatically judge their data type (or types of statistics), and then gives the corresponding chart type. The users can choose the default charts and can also choose according to their own preferences option. In addition, users will be able to change symbols colour to enhance the symbol level.

3.2.4 Choropleth mapping: Classifying data according to statistics within each distinct, choropleth map is used to reflect the concentration of geographical phenomena or the distribution of different levels of development by using the appropriate color spectrum or the halo lines with different density.
Choose users' own interest topics, see directly the default choropleth map system gives, or click on the change button in the toolbar to enter the modification interactive interface to change class methods, class intervals and boundaries. Users can change the initial or terminal color and a color sequence used to fill the choorpleth map will be automatically generated which indicate the value difference between each district.

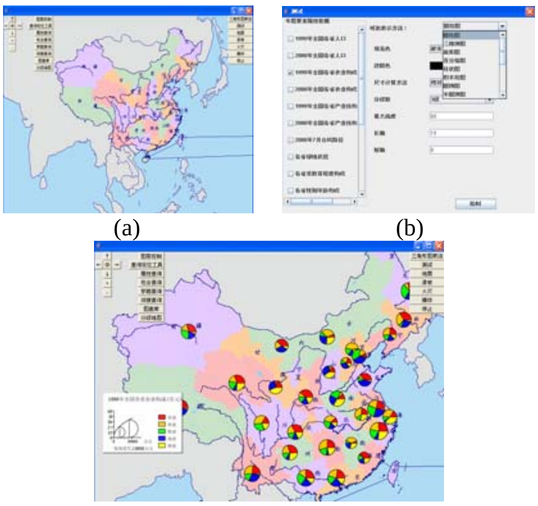
3.2.5 Dot mapping: Dot map is a relatively simply map form to represent map quantitative data. As long as a certain size and the same shape of the dot have been identified, the point diagram map can used to express the distribution area, quantities characteristics and distribution density of the phenomenon. The system achieves two methods of point collocation: uniform method (statistical method) layout and specified location layout (geographic methods). Besides, dot parameters such as dot size, dot values and dot color can be modified by an interactive interface.

3.2.6 Cartographic arrowhead mapping: Cartographic arrowhead method is generally used arrow symbols of the movement and direction of the road, such as population migration routes, current and freight routes. And arrow and the upper arrow direction should be consistent; the arrow should remain symmetrical wings. The thickness or width of the arrow indicates the speed of ocean currents strength or the amount of cargo. The length of the arrow indicates the wind direction, current stability; Arrows of which start point is connected with end point represent the convergence movement routes.

3.2.7 Isoline maps and stereoscopic perspective methods: Isolines are connection lines of the same data. The system establishes grid DTM model on the basis of discrete points which are used to draw three-dimensional contour map and perspective map. On the assumption that discrete points is the true geographic coordinates points within the province. Discrete points attribute values are obtained from the table access. According to discrete points to build a Delaunay Triangulation of non-conditions, then TIN model will be transformed into grid model Grid through interpolation operation. The final step is to draw isoline map and stereoscopic perspective map in accordance with principles of visualization model using Grid model.

4. IMPLEMENTATION

The thematic mapping decision-making support system uses SQLServer2000 and JBuilder2005 development platform. Figure 4 is the system interface and thematic mapping dialog. When users select the data "agriculture of the provinces in 1999" in the check box on the left, the drop-down list box on the right lists all suitable map and chart types for the selected statistical indicators for users to choose. After a particular statistical table is selected, the system presents all default parameters of this chart, but users can also modify these parameter settings, such as revising colour filled with, frame colour, size calculation method of classification, symbols, such as maximum so as to develop their own thematic maps. Then click on "mapping" button users will gain the corresponding statistical maps and diagrams. Figure 4 is a areal diagram which uses round circle to show the production agriculture in 1999.



(a) (b) (c)

Figure 4. System interface. (a) is the initial interface, (b) is the interactive dialogue box, (c) is an example of statistics map

5. CONCLUSION

The thematic mapping decision support system is designed and implemented in this paper which has been proved to be a useful feature map production software. Based on expert knowledge, the system can automatically give a smart choice about map methods and map symbols as a kind of GIS decision support for common users to map a thematic map.
With computer hardware, software, technology development, visualization of changes in technology, our next goal is to study the help of some powerful graphics, animation technology to achieve the dynamic modelling and display the phenomenon, and will enable each representation to enhance the dynamic visual experience.

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