A CARTOGRAPHIC DATA MODEL
FOR BETTER GEOGRAPHICAL VISUALIZATION BASED ON KNOWLEDGE

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ABSTRACT:

Firstly, this paper makes analyses on the geographical visualization and mapping functionality in GIS software which have some shortcomings. So, the idea of geographical information cartographic representation is presented to improve the quality of the geographical information visualization and to satisfy rules of traditional cartography. The digital cartographic representation, which tries to make a model of the mapping procedure based on traditional cartographic knowledge, creates a template-mapping model for cartographic symbols. This template-mapping model achieves the transformation from cartographic specifications to products. Meanwhile, it can well consider characteristics of respective geographical feature, the relations between this feature and other features, the relations between this feature and cartographic region. These three kinds of relations are described with quantity parameters which can be used to map a symbol template to a symbol instance responding to some one geographical feature. With this template-mapping model for cartographic symbol, we can visualize the respective feature’s property in detail and improve the quality of geographical visualization. Hydrology and transportation features are taken as two examples to verify the availability of this cartographic representation model.

1. INTRODUCTION

Maps are the essential tools for geographical information visualization. Geographical information could be efficiently transmitted to users who are capable of capturing the knowledge on location, shape, quantities and qualities traits and the change information with maps helping. A set of cartographic theories and methods are founded within thousands of years. Furthermore, a great deal of cartographic knowledge and experience are gradually accumulated, which guides traditional mapping procedure. In 1960s, maps were digitized and saved in the computer. So geographical information system was created to process and analyze geographical information. So far, GIS have been fast developing, which is advanced from two-dimensional to three-dimensional, from static to dynamic. Now, geographical information science has been achieved an integrated theory system. However, cartography is an important role in geographical information science. Cartographic data model is used to save and manage geographical information. Cartographic generalization principle is the base of multiple scales spatial database in GIS. Moreover, cartographic symbol system is the key point for geographical information visualization. Consequently, cartography is one of the essential bases for GIS.

Geographical information system becomes a functionality system for geographical information saving, managing, analyzing and representing instead of recording maps in digital form with computer technology and application requirements rapidly developing. These new functionalities, which include spatial data model, spatial database advance the theory of GIS. Geographical information visualization is the combination of geographical information representation and scientific visualization. The fundamental type of the geographical visualization is a map. The target of GIS visualization is to finish cartographic representation for geographical information. According to the quality of mapping, GIS visualization has three stages which are graphics, symbolization and cartographic representation.

The basic theme of geographical information visualization is to display geographical features on screen, which can represent all features, features in one layer or features in some region. Graphical representation enables the users to distinguish where the geographical features are and distributed pattern, as the figure 1 shows. This representation, which uses computer graphics to make the digital geographical information visible, is the most basic level of geographical visualization. Its shortcoming is that it can not efficiently transform level and quantities information of geographical entities to users, because of neglecting the traits of human’s spatial cognition and geographical phenomenon.

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Figure 1. Graphics Representation of Geographical Information

Symbolization is an important aspect of geographical visualization, which symbolizes geographical information. As a result, that can display geographic features on screen to perform the visualization, as figure 2 shows. Existing map symbol system which can effectively represent quality and quantity properties of geographical information is generated through long term cartographic work based on professional knowledge. However, symbolization has a little bit difference from cartographic representation. Spatial relations and properties comparison are not considered in geographical information symbolization with GIS software, which can not effectively transform the geographical features and their relations to users.

Cartographic representation is the topmost level of geographical visualization. Cartography makes a comprehensive representation of distribution, combination, connection, quality and quantity of spatial entities. Cartographic representation displays macro structure of the whole cartographic region besides respective quantity and quality characteristics of one geographical feature.

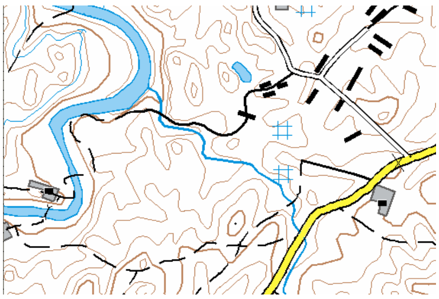

Figure 2. Symbolization of Geographical Information

According to the three stages of geographical information visualization above, most of GIS software belongs to the symbolization stage which just symbolizes single geographical feature rather than considering the spatial relations and attribute comparison among features. Nevertheless, ArcGIS 9.2 launched by ESRI has presented the concept of cartographic representation and provides tools for map editing. In this case, geographical visualization is going to become the stage of cartographic representation.

It is important to have a research of theories and methods of cartographic representation for digital geographical features because of the trend of geographical visualization development. Basically, cartographic representation of geographical information is the simulation of traditional mapping procedure in digital environment. Consequently, traditional cartography is the theoretical base of cartographic representation. Cartographic symbols managed by cartographic symbol function module in GIS software are tools for representation. The symbol function module is key point to the quality of geographic visualization. Moreover, the method and procedure of geographic information symbolization have an impact on the rational representation of geographical relations and cartographic region's traits.

2. TEMPLATE-MAPPING MODEL FOR CARTOGRAPHIC SYMBOLS

This paper presents a template-mapping model for cartographic symbols, which is based on the improvement of existing map symbol model. As the figure 3 shows, cartographic symbol template corresponds to geographical feature type, while symbol instance is related to geographical feature instance. This model analyzes every feature instance's properties from three levels including single feature, relative features and all features in whole cartographic region. Then, these properties are specified as mapping parameters which can represent the details of geographical feature instance and finish better cartographic representation. The template-mapping model for cartographic symbol not only simulates the transformation process from symbol template in specifications for cartographic symbols to symbol instance in map-making procedure, but also defines the visual variables of cartographic symbols which are used to describe the symbol template and instance. This description of visual variables is called symbol primitive-parameter method.

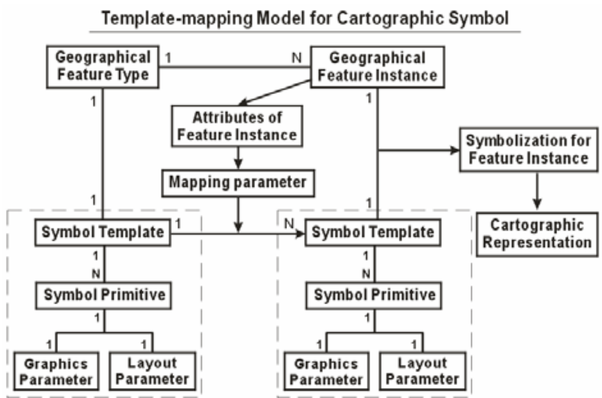

Figure 3. Template-mapping Model for Cartographic Symbol

In the template-mapping model above, symbol template focuses on the style definition of specifications for cartographic symbols. Graphics parameters of symbol primitive are used to specify the shape, size, colour of a symbol. Furthermore, layout parameters of symbol primitive define the density, structure, direction of s symbol. These six properties are visual variables for cartographic symbols. In this case, managing a symbol is just to manage these six visual variables in digital environment. Symbol instance, which is also specified by six visual variables, makes a model for the representation result corresponding to geographical feature instance's characteristics. Among the two types of symbols, symbol template is mapped to symbol instance during cartographic representation procedure. Mapping parameters determine the mapping process from template to instance.

Symbol template is unique to geographical feature type defined in the specifications for cartographic symbols in topographic maps or other cartographic rules. For example, transportation features are classified into standard railway, narrow railway, high way and so on. Every type is related to some symbol which is used symbolized this type of geographical features. This symbol template is on behalf of graphic style and normal traits of features belonging to the same class.

Symbol instance, whose graphics and layout parameters are specified by every feature's attributes, relation with features spatially related to current one, relation with the integrated cartographic region, is unique to geographical feature instance. For example, while symbolizing the village road features using the dash line, the intersection part of village roads should be drawn with the solid part of the dash line instead of the hollow part of the dash line intersecting. This rule for intersection representation ensures that the connection point can be distinguished by map readers. To satisfy this requirement, the symbol instance used to symbolize some village road feature should be adjusted so as to draw the solid part of the dash line symbol across the intersection part among some roads. One feature type has numerous feature instances. At the same time, one symbol template corresponds to a number of symbol instances. In cartographic process, a symbol template will be mapped to a symbol instance which can display geographical feature instance's properties.

This paper tells the differences between symbol template and instance. The symbol template is oriented to the normal attributes of the geographical feature type, while the symbol instance is oriented to respective properties of the feature instance. Moreover, the template-mapping model for cartographic symbols realizes the automated transformations from the symbol template to the symbol instance through map-making. One of the two key points of this model is to define the visual variables for the symbol template and instance. Another one is to model the mapping procedure from template to instance.

3. CARTOGRAPHIC DATA MODEL BASED ON KNOWLEDGE

This section presents a cartographic data model based on the template-mapping model for cartographic symbols introduced in the previous section. The cartographic data model can calculate the mapping parameters according to the respective characteristics and relations. Then, this model transforms the symbol template to symbol instance displaying the details of geographical feature instance. This method advances geographical visualization in detail and improve the better visualization which is accurate to one feature instance. Finally, the cartographic representation is finished with this model. Hydrology and transportation features will be taken as examples to indicate that how the cartographic data model works.

3.1 Cartographic Representation of Hydrology

Hydrology is one of the most fundamental features, which has an important impact on natural environment and social economy activity. It is very essential on maps. This paper has studied the cartographic representation of hydrology in three aspects.

Fundamental geographical information database is digital results which save spatial information, attribute information and spatial relations. However, fundamental geographical database fails to provide necessary information for cartographic representation of hydrology. As a result, some pre-process have to be taken to retrieve necessary information. In fundamental database, spatial topological information, which breaks the integrated hydrology features into some arcs connected with each other, has been saved as the coverage format (ESRI). Nevertheless, the integrated river feature is regarded as one object handled in cartographic representation. This paper presents an approach to retrieve the single feature and structure of information hydrology and founded a cartographic data model available to hydrology features' representation, as figure 4 shows.

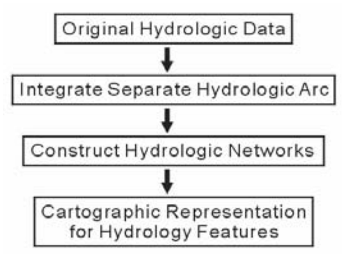

Figure 4. Hydrologic Data Process

Hydrology structured organization, which is an old problem in geography, was studied by geographers and hydrologists such as Horton (1945), Starchier (1957) and Shreve (1966). Cartographer has also researched how to organize the hydrology features with some specific structure such as Richardson (1993), Hehai WU (1996), MarcoMoreno (2002). Cartographic data model introduced in this paper is the key point of performing better representation of hydrology features instead of symbolizing single feature without considering relations among features. An automated method of founding hydrology structure with river's level and length is created, which retrieves the backbone of hydrology using the river level code firstly and constructs the level structure of all rivers.

Mapping parameters of symbol instance is an important step to achieve cartographic representation of hydrology. Cartographic data model can make a calculation for the symbol instance responding to the feature instance based on the context of every hydrology feature. In detail, this model must specify the start width and end width of the hydrology symbol and widen-gradually procedure. These accurate parameters can help cartographic representation visualize every single hydrology feature in this cartographic region. Feature instance level visualization can represent hydrology structure attributes with every single hydrology feature symbolized using different widths corresponding to different levels. Cartographic data model has three parts including the foundation of hydrology structure, calculation of mapping parameters for feature instance and symbolization of feature instance, as figure 5 shows. In these three parts, hydrology structure is the base of cartographic representation. Mapping parameter is the key point.

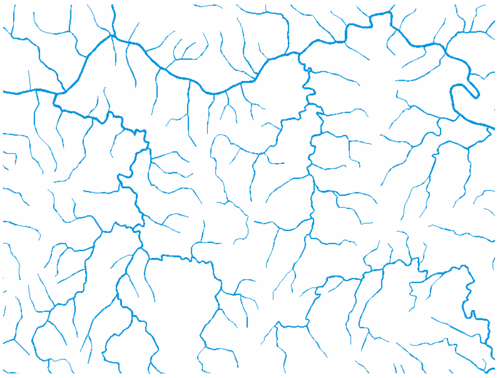

Figure 5. Cartographic Representation for Hydrology

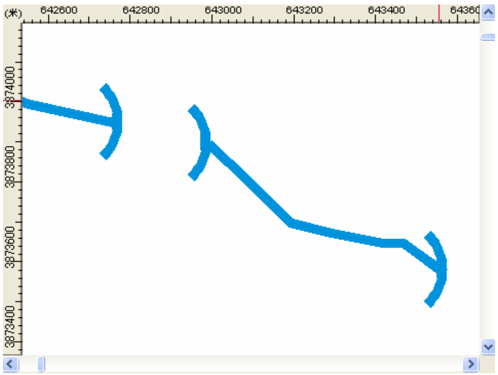

Figure 6. Symbolization of ports of underground rivers

Figure 6 above displays the symbolization result of port symbols for the underground rivers. Obviously, the directions of these symbol instances are incorrect. Figure 7 shows the appropriate representation of these port feature instances.

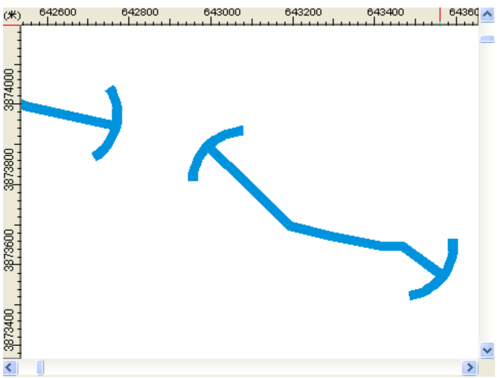

Figure 7. Cartographic Representation of ports of underground rivers

3.2 Cartographic Representation of Transportation

Transportation is a general concept which contains land, marine, air transportation. On maps, transportation types, levels, location and shape should be correctly and appropriately represented. Existing GIS software simply symbolizes every single transportation feature to make geographical information visualization. However, this simple symbolization can not display transportation structure or satisfy the cartographic rules. Current research on the visualization of transportation features concerns how to drawing the symbols corresponding to the features. These studies finish symbolizing features with symbol templates, which represent the visualization of common properties of transportation. Furthermore, cartographic data model for transportation creates a structured transportation features. In this case, mapping parameters retrieved from this structured transportation data model indicate single feature's characteristics on three aspects. Based on the mapping parameters, the transportation symbol templates can be adapted to symbol instances. Symbolizing the transportation features with these symbol instances could represent the minor differences among the feature instances. There are three steps to found the cartographic data model for transportation features. The procedure includes structured-handle, mapping parameters assignment and feature instance symbolization, as figure 8 shows.

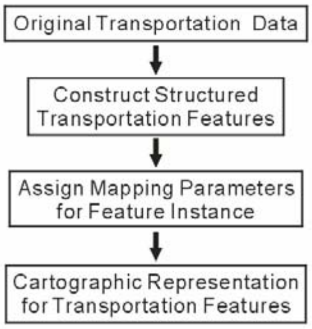

Figure 8. Transportation Data Process

In geographical information data model, topological vector data format disjoints the road or railway which is integrated logically. But symbolization of this topological model can incorrectly represent the relations among features. To avoid this incorrect representation, the transportation features should be structured before symbolization. The task is to combine the road arcs into an intact feature instead of symbolizing two separate arcs, which leads to a gap between two symbolized connecting roads. Moreover, it is necessary to create a linear reference system based on the cartographic data model. This linear reference system save the intersecting points along the integrated road or railway feature.

Mapping parameters assignment for transportation symbol instances is to represent feature instance's properties, spatial relations among features and cartographic rules by adapting the symbol template to specific style. For example, adjusting the drawing orders of symbol primitives is needed to display the intersection and connection relations. The dash symbol template should be adjusted to ensure that the solid parts will be drawn in any joint point. The symbol instance mapped with mapping parameters can move the solid and hollow part along the feature. These methods can perform better cartographic representation, as figure 9 shows.

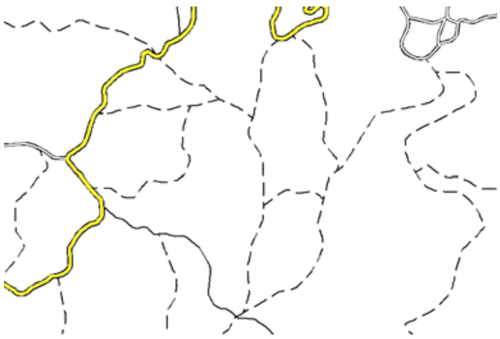

Figure 9. Cartographic Representation for Transportation

4. CONCLUSIONS

This paper summarizes existing theories and methods of cartographic symbols and cartography. The visual variables such as shape, size, colour and direction are defined to describe the symbols. This method is called primitive parameters. Then, after analyzing the symbolizing procedure, this paper distinguishes the symbol template oriented to geographical feature type from the symbol instance oriented to every single feature. The template-mapping model presented in this paper is created to simulate the procedure of the transformation from symbol template to instance while symbolizing. Furthermore, structured-handle for geographical feature data is the key point of the cartographic data model because it is structured geographical information that can provide all level properties of respective feature. Finally, the single feature's characteristics, relations with other features and whole cartographic region, all of the information, can be used to specify the mapping parameters for accurately symbolizing feature instance. In this case, cartographic representation is accomplished.

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