Information Organization and Visualization Mechanism of Electronic Map

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Abstract  Based on research on information organization and visualization mechanism of multimedia electronic map, this paper proposes an organization method about spatial information and multimedia information of multimedia electronic map: seamless spatial data were organized and managed by stratified expansion R-tree and Quad-tree hierarchy; and multimedia information data were organized and managed by hypermedia model based on an electronic map. Considering electronic map features, the paper also proposes a method for spatial data organization, which integrates Digital Landscape Model and Digital Cartographic Model, and a hybrid model between vector and raster spatial data. Then, the paper studies information visualization mechanism of multimedia electronic map. Finally, the paper certifies the results via a case of multimedia electronic map authoring tools software—Atlas2005.

Keywords  electronic map; information organization; hypermedia model; visualization

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Introduction

With the development of computer technology and digital mapping technology, the traditional map is gradually being replaced by virtual maps based on new media. Koop considered the change in information transmission media as the third technology innovation of cartography. Once digital technology was used not only for map production and design, but also for publishing and using, digital map data will be extended to multimedia products based on cartography, called Electronic Map or Interactive Map. It changed the role of map users. The end users can not only be a map producer, but also join in the map design process according to their desire and get more information through interactive operation.

From this point of view, maps are more appropriate as part of the users’ individual visual thinking than as tools of public information transmission.

Electronic map (Atlas) as a new product played a more important role in the information age. Apart from language and music shared by human beings, map was called the third language of information communication[1]. Map has been serving us for a long time. It is not only a way of spatial information transmission, but also serves as spatial information storage medium. However, the introduction of spatial database and flexible date output system separated spatial information display and storage. It also makes use of spatial data not just for map production. Many spatial analysis and applications such as spatial-related decision-making are possible[2].

Multimedia technology has not only widened the
channel of users for getting information to visualize and study data through many different intuitive ways, but has also made the interface of users visit information in the process of map information communication. Miller also pointed out that multimedia was a potential and powerful tool for expressing geographic information which can enhance the capability to communicate spatial information by fully using many kinds of media. Thus, users can study, operate and transfer spatial information in a dynamic, interactive environment. They can also use various media to design map products, and more and more relative products have occurred. These make map makers pay more attention to multimedia in map design.

The development of scientific visualization technology, multimedia technology, virtual reality technology and data analysis technology proposed higher demand for mapping expression. Currently, map and visualization environment caused the Kolacny Model to change, from which emerged information communication model based on interactive and visualization; whereas the factors causing this change include digital map production technology, database technology and knowledge technology. Multimedia electronic map includes both the static map symbols, such as static images, and dynamic map symbols, such as animation, video images, as well as language symbols, such as text, voice, music. These multimedia data, which will play important roles in decision-making in the near future, were usually ignored by some GIS software. In this sense, multimedia technology extends the tools of modern map expression and spatial information communication—the concept and study scope of map linguistics.

Different from most of the GIS software which only have some limited mapping function, GIS extends mapping function with its strong data management capability. But electronic map or mapping system is gradually developing into cartographic information system with strong analysis function (cartographic information system is referred to CIS). As to electronic map or electronic mapping system, it will be involved in the organization, management and visualization problems of multi-resource and multi-scale data including spatial data and multimedia data. Having flexible, non-linear information organization and expression characteristics, hypermedia has a network structure through the nodes which express information and chain with a navigation function. Therefore, hypermedia has the ability to produce data of large volumes, complex and rich link, as well as cross-visit data. Many scholars once proposed the thought of managing spatial data through hypermedia technology. On the basis of the analysis above, this paper studied the information organization method for multimedia electronic map and the visualization mechanism of electronic map. What's more, it took the software Atlas2005, authoring tool software by which multimedia electronic maps can be designed and published, as an example to certify the experimental results.

1 Information organization method for electronic map

1.1 spatial data organization method

1.1.1 Multi-resource data organization

Various data formats are the bottleneck of multi-resource spatial data integration, and the rapid development and wide application of GIS led to the emergence of spatial data multi-resource. Its emergence and performance can mainly be summed up into four levels: multi-semantics, multi-spatial-time and multi-scale, multi-resource and multi-storage-format.

According to multi-resource data's function in electronic map, the data can be divided into two categories: one is used for background display, while the other is used for spatial analysis and multimedia information query (thematic data or hotspot data, sometimes called point of interest, POI). The former focuses on visualization results of spatial data. The latter is usually hidden and focuses on spatial location and spatial relationship information, mainly used for providing location and relationship information for spatial analysis and inquiry. Therefore, it is necessary to consider the multimedia spatial data integration of electronic map in the next two levels. First, background data needs to maintain the multi-resource
data’s representation style and effects. If the visualization effect of data used for background in the resource format is poor, the data need to be considered by the mapping software and transferred to the electronic map system. Second, some multi-resource data which could be used to support spatial analysis or inquiry can be directly transferred to the system. According to the above-mentioned, the authors designed an electronic map data integration model (Fig.1).

Fig.1 Data integration pattern of electronic map

1.1.2 Vector and raster data integration

In electronic map, vector and raster data are always integrated. This scheme takes full advantage of the vector and raster data in display. If vector feature level is overlaid on raster image level, or contour element level is overlapped on DEM level, these will bring real three-dimensional effects. Sometimes this representation method can give some additional information. For example, if DEM data which is raster format is overlapped with vector features like residence, road, river, the third high-dimensional information of DEM is attributed to vector features (needing some algorithm support), then we will get the altitude of features such as residence, roads, river, etc.

Having fixed the resolution, the display accuracy of raster data will be reduced while the resolution increases, that’s the so-called “mosaic” phenomenon. However, the vector data can retain continuous changes while the display proportion changes. Under the support of certain algorithms (such as smooth curve, anti-aliased font), the representation method of the vector will enhance the representation accuracy of the vector data. Therefore, if the vector data is overlapped on the raster data, its representation accuracy will be different with different zoom proportions (This inherent accuracy difference of vector and raster data resource will not be discussed in this paper). In order to reduce this difference, the classification organization strategy of vector and raster data will be used. It means that these two types of data need to be classified separately, and that the display rank will be automatically controlled according to display scope to realize the effect of automatic zoom. In the electronic map, the integration schemas are as follows:

1. Themetic data in vector format is overlapped on raster map
   In this way, the raster map exists as geo-referenced background, while the thematic vector data is set for thematic query and analysis, which is also a creative organization method in this paper.

2. Vector data is overlapped on DEM
   DEM data will be generated from contour data in the same region, then the vector data is overlapped on DEM data in this region (it can also include contour data). This overlap method enhances the three-dimensional effect of two-dimensional features. Meanwhile, some additional information is added, such as the third dimension value (height). If we overlap vector data on DEM, we can get more realistic three-dimensional effects.

3. Vector data is overlapped on digital orthophoto map
   Overlapping images and vector data will receive more authentic visual representation effect. The vector data is used for supporting query and analysis function.

1.1.3 Integration of geographic model and cartographic model

Digital Landscape Model (DLM) and Digital Cartographic Model (DCM) are two important concepts in GIS and cartography. DLM describes geographic database, while DCM describes cartographic database. The data stored in the geographic database exists as entities which describe accurate location, shape, attributes and relationship between entities (such as topology). But cartographic database represents the above content in the form of symbols at some scale,
so we can say cartographic database symbolizes the geographic database[9]. DCM is different from DLM. DCM emphasizes on visualization, while DLM emphasizes on spatial analysis.

This paper proposes a data organization method for geographical model and cartographical model integration, which strengthens the visualization effect of spatial data, and improves the spatial analysis ability of electronic map (Fig.2).

![Fig.2 DLM and DCM integration](image)

Limited by computer hardware (such as monitor display resolution and screen size, etc.), the expression effect of map elements and readability have been affected, such as the aliased phenomena of fonts and features. The capacity of information loading of electronic map will inevitably be limited by the expression condition as conventional to ensure map’s readability; all the scales of maps which are replaced by resolution are no longer fit for digital environment. That is to say, at different resolutions, information volume expressed by the map (especially the visualization results) is limited. There are many methods for overcoming such restrictions. For the contradiction between information volume and readability of map, the authors adopted a method of integrating background information and thematic hotspot object. The background information provides certain spatial reference information, and thematic hotspot objects are partly represented on the map, most of its information is hidden in the database associated with it. This information will be shown by various multimedia forms when users need it. Because the information of hotspot can be hidden (stored in database), the maps with different resolution can have information with the same details, which is difficult to realize in a conventional map. In fact, this “background + hotspot” representation method is actually one of integrating digital geographical model and digital cartographic model.

1.1.4 The organization method of multi-scale spatial data

The organization content of electronic map seamless spatial data is reflected in two levels: vertical seamless means the multi-scale spatial data organization; horizontal seamless means the spatial data organization of horizontal adjacent map at the same scale. As the electronic map spatial data organization researched in this paper is on organization method of integrating DLM and DCM, the organization of its seamless spatial data is reflected in two aspects: the organization of many electronic maps (at different scales or the same scale); the organization of spatial object at different scales or the spatial object crossing the adjacent maps at the same scale (mainly referring to the spatial object used for spatial analysis and information query in electronic map, called hotspot). Therefore, the strategies provided in this paper are object-oriented data model organization, and the objects can be defined workspace, maps, features, geometric objects, etc. Hierarchical extended R-tree is used to organize maps and build a map index mechanism. Moreover, the spatial objects are organized and establish spatial object index by hierarchical linear Quad-tree.

Hierarchical extended R-tree, whose idea originated from the concepts of R-tree and alternative reactive tree, is used to build map levels according to scale. Each level has its own R-tree and increases the dimension which puts map or feature layer display scale as its weight to two-dimensional map. The weight is mainly used to control display scale scope $S_M$ of different scales, display scale scope $S_L$ of different feature layers at the same scale. Obviously, the display scope of feature layers is within that of the map, matching the condition: $S_L \subseteq S_M$. Suppose logic (actual) scale of current view (screen) is $(X', Y')$ and MBR (Minimum Bounded Rectangle) of all the maps at every scale is $(X_0, Y_0)$, weight is: $S_M' = \text{Min}$
(X^i / X_0, Y^i / Y_0), the calculation method of \( S^i \) is the same as that of \( S^\mu \).

Fig.3  Map data organization based on hierarchical extended R-tree

The structure of hierarchical extended R-tree is shown in Fig.3 in which only maps are shown (while maps feature layers haven’t been shown), and X-axis and Y-axis indicate map spaces in the two-dimensional plane, and Z-axis indicates extended weight dimension (recorded as map’s display scale); in it, 3D MBB is composed of 2D MBB and weight at Z-axis. The width of every MBR recorded as \( p \) (display scale scope) can be different in weight. That is to say, data of different scales can have different display scale scopes. When the map’s weight is \( K \), the projection at Z-axis of its MBB is \((k, k+p)\).

1.2  Hypermedia model organization method

Hypermedia Model Based on Electronic Map (called HMBEM for short) is a complex information network composed of the interrelations of the information nodes, the geographic entities linked to multimedia information including maps, and links, the relations among geographic entities, which were created with hypermedia technology on the basis of electronic map\(^{[10]}\).

All kinds of nodes are defined in HMBEM, which include not only those adopted in common hypermedia system but also several other types that can be used to represent the geographic information such as catalog node, map group node, main map node, map node and table node.

And four basic links are defined as: link between contents and atlas, link between main maps and sub-maps, link between sub-maps and sub-maps, link between main maps or sub-map and media.

There is also a three-level structure for HMBEM, and after structural analysis of HMBEM with the Graph theory, the end user can find a more reasonable data organization method and simplify the network structure so as to improve the navigability of electric map hypermedia to the most extent as well as retain its high freedom.

2  Visualization mechanism of electronic map

2.1  Integration visualization of multi-source

1) Multi-source data visualization

Multi-source data visualization means the visualization representation of the data such as basic geographic data, statistic data, geographic names data, thematic data, and multimedia data, etc. The visualization representation of multi-source data is realized by various methods mainly through topographic map or thematic map design and adopting certain multimedia representation means.

2) Classified visualization of vector and raster data

Raster data of different resolution adopts the classified organization and representation method of pyramid, but vector data having different detailed degrees uses the method of classified representation control.

3) Visualization of integration geographical data and cartographic data

Cartographic data as background emphasize on spatial geo-information’s communication and representation, while geographic data as foreground (hot-spot) emphasize on GIS’s analysis function. Cartographic data adopt the style of design and representation of electronic map for visualization. Geographic data, which can be displayed or hidden, makes full use of hypermedia to be expressed.

2.2  Multi-scale data visualization

Considering data organization method of multimedia electronic map, the logical expression to realize seamless data visualization mechanism is as follows:

The map set matches the condition that is shown in the current display window (the actual coordinate, indicated by \( W^i \)) is:
In Eq.(1), \( M' \) is the map set matching current display scale, Intersect is a function to judge whether the two rectangles intersect, MBR is a function to calculate the minimum bounded rectangle of maps.

\[
M' = \forall m \in M \land \text{Intersect}(\text{MBR}(m), W_i) \quad (1)
\]

In Eq.(1), \( M_i \) is the map set matching current display scale, Intersect is a function to judge whether the two rectangles intersect, MBR is a function to calculate the minimum bounded rectangle of maps.

In Eq.(2), \( L_i \) is the set of all element layers in \( M_i \), \( \text{Show}(l) \) judges whether the element layer is displayed (usually controlled by users).

The background feature (object) set \( O_i \) which matches display conditions within \( L_i \) is:

\[
O_i = \forall o \in O \land \text{Intersect}(\text{MBR}(o), W_i) \quad (2)
\]

In Eq.3, \( O_i \) are all the objects which satisfy condition layer. According to the condition, whether the smallest outside rectangle of an object and the current display scope intersect, or whether to display background features, can be judged. This is a rough judgment, so we can use intersection relationship between actual coordinates of an object and windows to judge conditions accurately. According to the search order Eq.(1)→Eq.(2)→Eq.(3), we can get background objects displayed, the display methods for hotspot objects and background objects.

The concrete steps to realize seamless data visualization mechanism are described as follows (Fig.4):

1. Judging map levels are shown, calculating the display scale in terms of current display range \( W_i \), that is, determining the scale of map which will be shown;

2. On the basis of display scale, getting map \( M_i \) of matching feature layer conditions in map metadata table;

3. Intersecting with MBR of every map within the results of Eq.(2) and current display range one by one, and getting map set \( M_i' \) to be shown last;

4. On the basis of display setting (users’ interactive control), determining the displayed background feature layer \( (l_i') \) to being is shown;

5. Determining feature object \( O_i' \) to be shown in background layer according to the current display range;

6. As to hotspot object to be shown, needing to search rapidly through hierarchical quad-tree index, combining accurate calculation to determine the object to be shown, and displaying them according to the organization levels of hotspot object one by one.

3 Case study

On the basis of the study above, a multimedia electronic map (Atlas) authoring software Atlas2005 was developed (Fig.5). Atlas2005 multimedia electronic
Geo-spatial Information Science 11(4): 262-268

The map system is mainly composed of two modules: authoring tool and demonstration tool. Authoring tool design and integration of electronic map, is a simple, convenient and applicable authoring platform provided for users, so as to integrate multimedia information organically. Its main function includes the conversion of vector and raster background map data, the import and editing of thematic data, attribute data’s connection, multimedia data’s connection and establishing various hyperlink relation. Demonstration tool directly aimed at product and end-users is a multimedia integration platform, which has many powerful functions including map browsing, thematic information searching, visualization and spatial analysis.

The main functions of authoring software are: (1) the definition of various nodes (hotspots), such as point, line, polygon, text, as well as the flexible links between multimedia information and map; (2) powerful data conversion interfaces; (3) multi-manner information querying; (4) the spatial seamless organization and display strategies of multi-scale map data; (5) zooming, pan and other view operation functions; (6) GIS analysis and querying function based on map; (7) graphic user interfaces of windows and the function of interface user-defined.

![Fig.5 ‘Electronic map of Wuhan’ designed by the software Atlas2005](image-url)