HYPERMAP TECHNIQUES IN FUZZY DATA EXPLORATION

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ABSTRACT This paper intends to incorporate hypertext and intelligent multimedia presentation techniques into the process of fuzzy data exploration, and to provide a conceptual framework for such a coupling. Basically, there are two types of information to be considered, one is the so-called graphical information and the other one is text-based. Different from the previous hypertext models out of the GIS field, which are mainly oriented to pure-text documents, this discussion concentrates particularly on the graphical context. As a fundamental concept, hypermap -- a map-centred hypermedia is discussed first, then the paper focuses on the way hypermap benefits fuzzy data exploration including some key components which could construct the nodes of hypermap, a set of exploratory acts, and hyperstructure.

1. INTRODUCTION

For years, fuzzy information processing including fuzzy information representation (Wang et al. 1990); fuzzy query (Wang 1994) and fuzzy overlay analysis (Jiang et al. 1995b) have obtained increasing attention in GIS. In contrast to the precise side of reality, fuzzy data is relatively difficult to handle even with probability theory and fuzzy set theory. On the other hand, fuzzy data can be visualizied using cartographic principles, (e.g. Van der Wel et al. 1994). However, visualization approaches could not be always efficiently perceived, this is due to the fact that not every individual could equally obtain the same information from a map represenation. That is, some people may be much familar with color saturation in uncertainty presentation, while some may not.

To enable efficient communication about uncertainty visualization, cross-referencings can offer instructions in understanding what the visualization elucidated. Different from the situation in the pre-computer-age, advanced visualization techniques including direct manipulation, multiple perspective treatment, real-time operation modes and flexible online help provide a wide spectrum of applications in data exploration (Jiang et al. 1995a). Multimedia originally derived from hypertext facilitate fuzzy data exploration because of the following two reasons: provision of multiple perspectives on a dataset, and because hypermedia act as a mechanism for directly cross-referencing.

In this paper, the authors develop a hypermap concept based on existing treatments on hypermap by previous researchers with emphasis on its internal structure. There are two basic principles to guide fuzzy data exploration with hypermap. The first is that hypermap is not dumb or passive, thus a set of exploratory acts are defined for exploration visualization. The second is based on the assumption that perceptibility is different from person to person.

2. FROM HYPERTEXT TO HYPERMAP

Hypertext can be dated to the 1940's, the two important components of hypertext being nodes and links. Different from linear text, hypertext techniques offer the readers a mechanism for cross-referencing through which the reader can immediately seek the relevant text segment. The extension of hypertext into multimedia like graphics, sound, animation and video is what we refer to as hypermedia.

Apart from text segments, node types could also be multimedia in the framework of hypermedia. Compared to linear-arranged documents, hypermedia do provide a flexible access to various media information presentations in a variety of fields. A growing research area has been addressed through the application of knowledge-based techniques for creating intelligent multimedia presentation systems (Roth et al. 1993).

There is enough evidence to accept the integration of maps into documents, which is referred to as hypermap (Laurini et al. 1992). Two forms of integration of map into hypermap are discussed: document-to-map, and map-to-map. Thus maps can either be connected to documents or associated to other map is a node which is unfoldable. However, a map has its own internal structure. Ormeling (1993) provides insight into the structure of multimedia atlases, he mentions the layering tool which allows one to construct a specific cartographic image layer by layer, in the specific sequence one wants. Szego (1987) discussed the visual planes including setting, actor, and play behind the paper map. So in addition to the two relationships, internal hierarchical structure and relationships should be added hypermap.

Hypermap at least has a threefold meaning. One is that of multiple perspectives. For a dataset, a hypermap structure should have a variety of symbolizations which offer multiple viewing, in order to allow for differences in individual perception, i.e. different persons have different preferences to certain symbol. Multiple symbolization would offer the users different choices. With the advent of multimedia, sound and animation may provide efficient cartographic visualization methods, particularly so as multimedia is beneficial in explaining visualization strategies or principle. To effectuate this, a hyperstructure behind hypermap has to be constructed. It is the hyperstructure that provides the cross-referencing access to the different information items (Fig. 1).

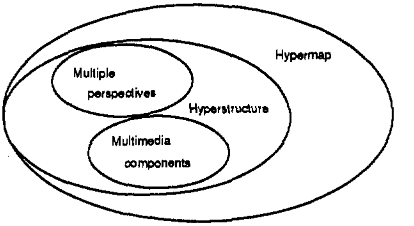

Fig. 1 The components of hypermap

If the traditional cartographic representations offer multiple perspectives, then multimedia components provide more efficient communication to best exploit multiple human sensory systems or modes of communication including vision, hearing and feeling. Shepherd (1994) has made detailed investigations of multi-sensory GIS with particular focus on data representation. Animation shows great potential in geographic visualization (e.g. Peterson 1994; Fisher 1994). Sound variables (Krygier 1994) have been investigated for sound map. Much distinct from paper maps, hypermap is actually a type of coordinated multimedia presentation.

Hyperstructures serve the task to connect various nodes containing information through direct links in much the same way as information is associated within the human mind. They are thus beyond the sequential style of composition and are akin to the neural structure of a thesaurus (Laurini et al. 1992).

3. FUZZY DATA EXPLORATION WITH HYPERMAP

Fuzzy data need to be explored using hypermap techniques mentioned above in which a number of exploratory tools are connected into a hierarchical structure. Fuzzy data exploration integrates all alternative semiology, media, and interpretations, which will be illustrated below.

3.1 Nodes in Fuzzy Data Exploration

In the following discussion, fuzzy data exploration is viewed as a hypermap in which all the exploratory tools or components serve nodes.

Sublayers: A sublayer is an uncertainty map which is derived from a layer in fuzzy spatial analysis. It provides more intuitive visualization about primary linguistic notions. Through consulting with sublayers and operations on sublayers, mental structures about them can be generated in the users' mind, which benefits decision-making.

Membergrams: Fuzzy set theory starts with membership function which could be represented as a number of membergrams. They also construct one of the important components of fuzzy data exploration. Membergrams could be shown in various forms. But, whatever forms of membergrams are used, two kinds of components are necessary for each kind of membergram. One is the standard point which represents the standard object; and another is the graduation between uncertainty 0 and 1. Changing any one of the two components may obtain a new fuzzy distribution.

Visualization Schemes: McGranaham's (1993) two visualization strategies for data quality which have same instructions on linguistic uncertainty are explicit and implicit symbologies. The former mainly follows traditional cartographic principles, explicitly encoding uncertainty information, and the latter is implicit, using metaphorical presentation of uncertainty which seems to have more intuitive effect than the first one.

The effectiveness of information communication in a display depends on the way how closely the structure inherent in the information is mapped onto the modes by which the visual system processes the image (Haber et al. 1982). There exist a set of metaphors for uncertainty which need to be explored further to benefit uncertainty visualization. Fog is a commonly accepted metaphor for uncertainty (Beard et al. 1991), which can be conducted using visual variable focus (MacEachren 1992). In the minds of average persons, probability and uncertainty share the same meaning although they can be distinguished from each other in the strict sense. The random dot can be viewed as another metaphor for uncertainty (Fisher 1992). As the third one, noise might be an alternative metaphor for uncertainty. According to dictionaries, noise is an unwanted or unpleasant sound, so it seems more suitable for referring to data quality or error. The last metaphor for uncertainty we consider, is blink. Blinking gives us an unsteady feeling. In terms of its frequency, lower frequencies give a steadier feeling than higher frequencies, and zero frequency means absolutely steady. Corresponding to those metaphors, a group of sensorial variables for uncertainty are extracted (Jiang in preparation).

Pop-up Explanations: Fuzzy exploration should not only present but also interpret the presentation. To enable effective exploration, some necessary explorations or instructions are helpful in understanding some points in the course of exploration. For instance, what are linguistic notions? How are they visualized? What is the meaning behind a certain visualization approach? All answers to these questions together construct the main content of explanation which is attached in the form of a text segment. They are invisible and pop up only in case one wants to consult them.

As the main body of explanations, knowledge about visual display (Tufte 1983; Bertin 1983; Tufte 1990) provides understanding about visual presentation. Graphical perception is much different from text. A document consists of such different semantic units as words, sentences and paragraphs. A graph or a map consists of points, lines and polygons. What distinguishes a graph from a document is that the basic graph component is not always the basic unit of meaning. The users should be instructed to understand a full-meaning unit, for instance, in a sublayer consisting of random dots, as individual dots would not make sense. Another example is that in a choropleth map a single field block of color is meaningless, while a set of associated blocks of color illustrates a pattern.

3.2 Exploratory Acts

One of the two basic principles to guide fuzzy data exploration with hypermap is that hypermap is not dumb or passive; in this way a set of exploratory acts can be defined for exploration visualization. In this connection, there is a need to mention the following exploratory acts which explicit human (physical and cognition) capacities such as memory and attention in exploration process.

Blink Blink refers to the act of blinking in a certain frequency. It play the role of attracting attention when it is applied to some object on the screen. In fuzzy data exploration, the areas with certainties over 50% we are likely to be interested in, could blink to attract attention. Since not all parts of a screen display could be given equal attention (Hearshaw 1993), blink is useful in attracting attention to parts which might be neglected.

Highlight Highlighting is an act of keeping some areas or object categories of a picture or photograph lighter. It is another method to attract attention similar to blink. In the same fashion, fade is the opposite to highlight.

Zoom in/out Zoom-in/out are acts of changing the size of an object, zoom-in is magnification while zoom out is to shrink. Zoom-in is beneficial to find / recognize more detailed internal structure, while zoom-out is to get deep insight about overall patterns.

Pan left / up/ down / right Pan is an act of changing the position of image through the scroll bars attached to windows. It has four basic directions: left, right, up, and down.

Drag Dragging means picking up a intended object and putting it in another position for further exploration. For instance, putting object groups into two juxtaposed sublayers would be beneficial for comparisons in order to assess their co-occurrence or correlation, which is one task of fuzzy overlay analysis. Another typical example is that, through the dragging act, the similarity in shape of the African and South American coastlines could be easily noted, which is a key step in Wegener's development of the theory of continental drift (MacEachren et al. 1990).

Click Click is a basic cursor act including single-click and double-click. Some other exploratory acts often starts with the primary click act. In addition, some node information behind certain hotspot could be pop-upped after clicking.

Just as the visual variables' (Bertin 1983) role in paper-map serves static graphic presentation, exploratory acts could be viewed as exploratory variables in animated cartographic environment to do exploration. That is to say, different from the visual variables, the functions of exploratory acts lie in animated exploration instead of static representation.

3.3 Hyperstructures

All components of exploration could be constructed into an architecture through hyperstructures. This way the users can be instructed in understanding all aspects about fuzzy data and learn by themselves how to do fuzzy data exploration which is helpful for visual thinking.

All the nodes discussed above have to be connected in order to construct a rational structure to facilitate exploration. Currently, almost all online help authoring functions have a HyperCard structure, That is, all nodes are pre-defined, which is not so suitable to the task of exploration. They can be used in implementing some tutorials for exploration, for instance, as suggested by Beard et al. (1991); users need to be instructed in understanding visualization methods with examples. All the examples can be constructed into tutorials with a hypermap architecture in which flexible cross-referencing is provided for referencing.

Pre-defined hyperstructure cannot offer the interpretation of the results of currently-going on exploration. The principle of "live information" introduced by Cornell et al (1993) provides the possibility to implement what we refer to as dynamic hyperstructure. That is, all the exploratory tools and visualization methods are connected dynamically into a hyperstructure. It is actually an object-oriented approach.

4. SUMMARY

The discussion of this paper can be viewed as an extension of online help which is implemented in our prototype system FOAT:W. Under the framework presented here, more multimedia presentations could integrated together for the purpose of exploration.

Instead of seeking optimal cartographic representation, hypermap not only integrates all as many as possible alternatives, but also provides interpretations about visualizations. As hypermap integrated all potential visualization schemes, the gap between map-maker and map-reader (Kolacny 1969) in conveying information could be reduced, and the effectiveness of communication may thereby increase greatly.

Although the conceptual framework exploratory acts are discussed primarily with a view to fuzzy data exploration, its approach could be equally applied to other explorations e.g. to statistical data exploration. Hypermap techniques promise to enable systems and users to explore and understand fuzzy data to their best knowledge in two ways. First, it increases the raw bit rate of information between user and system through using a variety of media for information exchange. Second, it can facilitate user interpretation of information through pop-up explanations.

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