Adaptive geovisualization: an approach towards the design of intelligent geovisualization systems

WANG Yingjie, LIU Yue, CHEN Xiaogang, CHEN Yufen
(Inst. of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China)
LIqiu Meng
(Inst. of Photogrammetry and Cartography, Technical University of Munich, Germany)

Abstract: Adaptive geovisualization has been marked as a research front that addresses design issues of a user-centered geovisualization system. By constantly keeping trace of user actions, a highly adaptive geovisualization system is able to predict the behavior of its end user and accordingly provide him with the visualization that suits best his personal taste and need. An adaptive geovisualization system does not either hide its own behaviors from its end users. Such a mutual transparency is made possible by the mechanism of self-description and self-evaluation coupled with the capability of self-organization and self-navigation based on user models. This paper clarifies some major concepts and techniques of adaptive geovisualization, pinpoints the existing bottlenecks, analyses the main components of an adaptive geovisualization system, and put forward some research directions. Among others, the authors have discussed topics such as adaptive GUI design, dynamic structuring and re-structuring of databases, adaptive design of geo-query functions (intelligent geo-database navigation), adaptive symbolization etc.

Key words: adaptability; graphic user interface; usability; geovisualization; designer model; user model

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1 Background and existing problems

With the geoinformation being overwhelmingly acquired in digital forms, an increasing number of maps have accordingly found their residence in CD-ROM as well as local or global networks, and are distributed as final products on display screens of varying sizes and resolutions. Cartographic visualization on screens has a number of advantages over the paper maps such as fast retrieval through query or browsing, seamless coverage of the earth surface, large storage capacity, easy connection with semantic attributes, efficient maintenance and management, interactive communication, etc. Unlike paper maps that primarily serve as information source and communication tool, a screen map together with its functions and database connection can very well be treated as an information system. Recent years, countless digital cartographic products have emerged across a wide range of disciplines, thus made significant contribution to the development of geovisualization systems. No doubt, digital maps as one of the favorite and efficient presentation forms of spatial information will continue to serve a variety of keen users and flourish in the 21st century. However, the survival instinct of keeping pace with the technological evolutions leaves the professional cartographers less and less time to extend cartographic theories, vocabulary and standards. Due to insufficient understanding of user demands and user behaviors, many existing geovisualization systems are far from satisfactory. User interfaces of these systems are equipped with poorly structured and unnecessarily intricate operations that can only be mastered by expert users. The overcrowded graphic contents on the screen are obviously resulted by the paper thinking. These problems have sometimes made
the map reading on screens a passive and uncomfortable experience. Often many short-lived screen maps have never reached their intended users because of the troublesome interface and/or the visual overload. Thus screen maps have so far not been proved the most favorite way for the communication between data providers and users. As a matter of fact, some elaborated theories and methodologies developed for paper map production could not be simply transplanted into the design process of screen products. In order to prevent new techniques from misleading map users and to create an adaptive environment for information representation, analysis and exploration, there is an urgent need to extend cartographic conventions and theories, narrow the gaps between map designers and end users, and finally enhance the usability of geovisualization systems.

2 The concepts of adaptive geoinformation visualization

There are many subject fields where the term “adaptive” has already been explored. “Adaptive programming”, “adaptive software”, “adaptive system”, “adaptive hypertext and hypermedia” are just some examples. Although “adaptive” is coupled with various domain-specific contexts, the major feature of user orientation embedded in the concept of adaptability remains the same.

By “adaptive geovisualization” we mean the design approach towards a user-centered geovisualization system. An adaptive geovisualization system should have the functionality of self-description, self-evaluation, self-organization and self-navigation. Depending on different user models, an adaptive geovisualization system should be able to play different roles (e.g. as tutor, guide, assistant or agent) in helping users get the expected geoinformation and perform special tasks.

The technical evolution in cartography from hardcopy to e-media including the Internet has made it indispensable for designers of geovisualization systems to consider the changed requirements, tasks, skills, prior knowledge and experiences, preferences, habits, working environment of end users. In adaptive systems, map contents and their interactive functions could be logically queried and re-structured, map symbols and user interface could be dynamically adjusted, and navigation agent could change its orientation strategy based on the actual user behaviors. In order to construct such a system, there is a need to fully integrate the research findings from cognitive and instructional psychology, computational and psycholinguistics, artificial intelligence, electronic engineering, remote-sensing technology, cartosemiotics and geographic information system.

Based on above statements, the development of an adaptive geovisualization system will include following fundamental tasks: modeling cognitive aspects of map designer and end user; classifying users based on user tasks and requirements; design of adaptive GUI; dynamic structuring/re-structuring of geographic database; design of adaptive geographic queries and intelligent navigation through the geographic database; adaptive symbolization; and construction of other adaptive system modules. Some of these tasks will be discussed in detail in subsequent sections.

3 Contents of adaptive geovisualization

3.1 Cognitive theories and methods

Adaptive geovisualization strives for the effective, efficient and comfortable communication and exploration of geographic information. An adaptive geovisualization system should work in a similar way to a human-human dialog where both participants are active and ready for compromise. The process of its design and use requires considerable mental efforts. Although many software developers have noticed the importance of cross-platform or platform-independent solutions, most commercialised geovisualization tools are not even adaptable because they can only provide default solutions for an assumed typical user instead of various stereotypes of users who really work with the tools. In order to improve the usability of a geovisualization system, there is a need to apply cognitive theories and methods in the following two