MAP SPATIAL COGNITION THEORY
——THE INTERFACE OF CARTOGRAPHY AND COGNITIVE SCIENCE

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Abstract

A map is not only a result of human spatial environment cognition, but also a tool of human spatial cognition. For many centuries, as a kind of graphic communication tool of spatial information, a map has been playing an important role in human spatial cognition.

Spatial cognition is the process of spatial information processing. Spatial cognition is an important research area of cognitive science, also an emphasis issue studied by psychology, cartography, geography, computer science and Artificial Intelligence. Map spatial cognition is the process of realizing spatial cognition by using a map.

As the popularization of digital mapping and Internet，one has been having more demand for and the interest in maps. An electronic map is a kind of electronic tool of map spatial cognition. GIS extends the means of human spatial cognition. Multimedia electronic map and virtual terrain environment are much more correspond with human spatial cognition, because they overcome the inherence deficiency of conventional maps. A webmap is a kind of electronic map based on Internet, and they will make more people have interest in maps. Therefore, a map as a kind of spatial cognition tool will play an important role in the condition of digital mapping.

The author believes that the exploration of map as a tool of human spatial cognition and the reconsideration of relationship between human beings and maps in the condition of new technology are the heart of theoretical cartography in the 21th century. Map spatial cognition theory is a new cartographic theory in digital mapping. Using an information processing viewpoint, map spatial cognition theory study systematically how a map user gets spatial information he needs from maps, how spatial information are stored in his mind and extract from his memory when he needs. Therefore, map spatial cognition theory is the theory that is developed for combining cartography with cognitive science.

The core content of map spatial cognition theory is the study of relationship between human beings and maps in digital mapping. Cognitive mapping and mental maps are the basic concepts of the map spatial cognition theory. The starting points, theoretical background, the research aims and

contents of map spatial cognition theory are discussed in this paper. In author's opinion, map spatial cognition theory is to better guide cartographic practice and prompts the development of human-computer systems in the area of cartography.

1 Introduction

The core content of map spatial cognition theory is the study of the relationship between the human beings and the maps in the digital mapping, and the starting points for a study of map spatial cognition theory are the research on the cognitive process of human in making and using maps and the exploration of role and function of map as a tool of spatial cognition.

Firstly, as a kind of tool and result of human spatial cognition, maps have been making a great contribution to the development of human civilization. A map is an important and effective tool of spatial cognition, but we don't know how a map user gets spatial information by reading maps, that is to say, we don't know how the spatial information on a map cognized by a map user. In the traditional mapping, this question doesn't stand out. We can make and use maps without knowing the mode of spatial information stream and how it flows between a map user and a map, because our work is providing a map for map users, whose contents as detail as possible. Map users are passive receivers of map information, and they couldn't decide the content and the appearance of maps. Now in the condition of digital mapping, using GIS or CIS software, map users may make maps that meet their needs and represent the results of their spatial cognition on map in real time. In most cases, cartographers provide map users no longer with a finished map product, but a map visualization environment. An important factor on a visualization environment is human-machine interface. If we don't know the cognitive characterizes of map users in using maps, and if we don't know how to promote the exploration for spatial problems through the interaction between a map user and a map visualization environment, we should have a lot of problems in providing map users with a map visualization environment they need.

Secondly, along with a wide application of computer technology and graphics technology to cartography, naturally, we want to replace traditional handwork with computer to design and make maps. Therefore, for many years we have developed many cartographic expert systems, such as map design expert system, map projection expert system, etc. When developing cartographic expert system, we need to summary cartographer's knowledge, then, we find we cannot say the knowledge and the mental process of mapmaking with clarity. In traditional mapping, cartographer can successfully design and make excellent maps, though they cannot explain their mental process of

designing and making a map clearly. But in the digital mapping, human cartographers must "tell" computer what to do and how to do, thus, he must know exactly the mental process of his making a map, and divide the process into several steps and encode them, then, assign the task of mapping to a computer, ultimately realize cartographic production automation. The realization of cartographic production automation should need a long time, now a basic method is human-machine collaboration, that is, a computer accomplishes one part of work, and human beings fulfill another part. Thereby, we should compare a computer with human mind, probe into how human mind processes spatial information, and analyze respective advantages in processing spatial information between a computer and human mind. Cognitive science is in cartographers' good graces, no other than it is to study thinking in accurate form, and that is theoretical basis of resolving above-mentioned problems.

2 The theoretical and technological background of map spatial cognition theory

Owing to the application of new technology to cartography, many cartographic new terms appear in cartographic area. In digital mapping the ways of map-making and map using differ greatly from the ways in traditional mapping. Cartographers are confronted with many new questions. Some cartographic theories anciently cannot be adaptable in digital mapping, and then, we need a new cartographic theory. Map spatial cognition theory is a new cartographic theory in digital mapping. Cognitive viewpoint in cartographic research is the theoretical background of map spatial cognition theory.

2.1 The cognitive viewpoint in cartographic research

Beginning in the 1950s, cartographic research had been being influenced by psychological thoughts. Most of cartographic researches incorporated the research methods of psychophysics and examined the stimulus-response relationship of individual symbols. In the late 1960s and earlier 1970s the emphasis on psychophysical studies began to be widely criticized (Petchenik, 1975). Most psychophysical studies made use of highly simplified maps with little base information or merely symbols within a frame. By the earlier 1970s, although psychophysical studies continued, many cartographers slowly changed the direction of their research. In the late 1970s, cartographic research developed in the direction of cognitive psychology and became concerned with how maps were mentally processed and memorized.

Since the 1970s there had been a growing volume of research which can be called cognitive cartography. Many cognitive studies in cartography have focus on human learning and memory by using maps. Olson suggested that the study of "mental constructs" which emerges through the interaction of cognitive processes and the map. Petchenik pointed out the necessity of going beyond psychophysical experimentation in cartography and exploring the cognitive processes that are involves in reading a map. Guelke noted the importance of cognitive aspects of map reading influenced by differences in people's experience and cultural background.

Up to now, there have been a lot of researches on cognitive cartography, but there has never been a complete theoretical system. The author believes that it is necessary to present a new cartographic theory, map spatial cognition theory, in order to study better cognitive issues in cartography in digital mapping. Using the viewpoint of information processing, map spatial cognition theory studies systematically the problems such as how a map user gets spatial information from a map, how these information are restored in a map user's mind and how these information are extracted from memory when he needs. Map spatial cognition theory is continue of the study of cognitive cartography in digital mapping, and cognitive cartography is theoretical background of map spatial cognition theory.

2.2 The demand of new technology on map spatial cognition research

The application of computer, graphics, GIS and VR to cartography has a great effect on cartography. The way of map-making is transferred from traditionally by hand to digital mapping. Cartographic products are extended from static maps to interactive maps and three-dimensional maps. Therefore, many problems which had never been took into account appear in cartography, and bring the demand on map spatial cognition research, which can be concluded as follows:

1.Map making and map production is not the patent of educated cartographers any more. As the popularization of the application of CIS and GIS software increasingly will result in ultimately anyone who has a computer can make his own maps.

CIS and GIS mapping software supply more people with the possibility of making maps. But there are some problems, because the chance of making map by one who has no cartographic education increases, these maps designed and made by non-specialist has no guarantee in the quality of map design and the precision of map content. Therefore, there is a great need for providing GIS users with learning system and map design expert system so as to help them master basic methods of designing and making maps as quickly as possible. A GIS end-user may be a novice who has never made maps or has no knowledge about map design, may be a cartographer or a geographer. Then, whether there is different mental strategy between a specialist and a novice in making electronic map with GIS and CIS? How the previous knowledge and education background of users influenced them in using GIS?

Knowing about the mental process in using electronic maps for spatial cognition between a specialist and a novice will be helpful to design human-machine interface and develop a learning system in GIS.

2.The application of new technology changes the way of map using.

In conventional mapping, we follow the paradigm of cartographic communication and think that there is a "best" map and the task of cartographer is making a best map. In this case, map users passively receive information on map, which reflected by cartographer according to his understanding of reality. But in digital mapping, a map user is no longer a passive receiver of cartographic information, but an active gainer of cartographic information, and he can make a map interactively by using cartographic software and extracting data from database according to his own needs. That is to say, the way of map using has been transformed from visual communication to visual thinking, from public to private, from low interaction to high interaction with maps, the task map user accomplished is data exploration.

The changes of way of map using also arise the changes of way of user thinking using map to spatial cognition. Then, how the mental processes of map using took in map visualization environment? Whether the ability and limitation of user spatial cognition impact on electronic map using or not? It is hopeful to solve these questions through map spatial cognition research.

3. The development of new technology in cartography also presents that now cartographer can use multimedia technology to join map with animation, text, image, graph, video and sound, then make a multimedia even hypermedia electronic atlas.

For a long time, the maps we have made and used are static paper maps in single media, so cognitive research into map using was only visual cognition research. Now in digital mapping, how to bring into play the spatial cognition role of multimedia electronic atlas is a question. Such as, what affects the hearing cognition and touch cognition on map spatial cognition? How to use them? What does the mental process of dynamic visual cognition? All these are the research contents of map spatial cognition.

4. With the popularization of Internet and its application in cartography, people may acquire map and correlated information through Internet.

From the viewpoint of cartography, Internet may become the resource of spatial data, attribute data, electronic atlas, electronic mapping software and GIS. Cartographers are faced with map function never before, but it is necessary also for us to know the public how to interact with webmaps and their different demands on webmaps.

Map spatial cognition theory research will provide experimentation and practical method for the designing of webmap more easily to use.

5.Virtual Terrain Environment (VE) simulation technology constructs a three-dimensional map environment, and extends the means of map spatial cognition which more accord with the

characteristics of human spatial cognition. But map users has been used to use general maps for a long time, there is a great difference between using virtual terrain environment and general maps, especially with different viewpoint. Then, whether it is valid anytime for virtual terrain environment? How to design VE can take full advantage of VE? Map spatial cognition theory has a great hope to resolve these questions.

3.The research aims of map spatial cognition theory

Cartographic theory is the result of combining cartographic research object with cartographic methodology. An object of study of map spatial cognition theory is map as human spatial cognition tool, and its methodology is the method of cognitive science.

Although researching into cognitive issues in cartography had formed a research area of cartography and made considerable achievements in scientific research, cognitive cartography is advanced in traditional mapping, which research into cognitive issues in cartography by countering paper printed maps using and pay less attention the mental process of map making. Now, it becomes very important to account the mental process of mapmaking in digital mapping, especially for the development of cartographic expert system.

 "A map is a result of human spatial cognition, also is a tool of human spatial cognition". That is the premise of map spatial cognition theory research. The core content of map spatial cognition theory is the study of relationship between human beings and maps in digital mapping. The aims are to study the role of map in human spatial cognition by introducing the view of point of information processing, to study how to design a map from cognitive characteristics of user, and to increase the value of map spatial cognition and enhance the efficiency of map as spatial cognition tool.

The relationship and the differences between map spatial cognition theory and cognitive cartography:

1.The study of cognitive cartography was by piecemeal and in isolation, which had no complete theoretical system; but map spatial cognition theory introduces the theoretical framework, and organizes the research of map spatial cognition into a system, which will be helpful to study cognitive issues in cartography deeply. Therefore, map spatial cognition theory has own theoretical system.

2.Aiming at printed paper map, cognitive cartography studied static visual cognition only, but the focal point of map spatial cognition theory is the study of electronic map as map spatial cognition tool, so besides static cognition, its main contents are dynamic visual cognition, hearing cognition

and touch cognition. The research contents of map spatial cognition theory are many arrangements and many orientations, and its research result can supply theoretical law for the design and production of electronic map.

3. Cognitive cartography researched the cognitive process of map using basically, and the mental process of mapmaking was carried out rarely. But the stand of map spatial cognition theory research is taking map as a human spatial cognition tool, therefore the mental process of mapmaking is also its main research content. Map spatial cognition theory regards map making and map using as indiscerptible two parts of system, and integrates map making and map using at a new high degree so as to adapt to the demand of map visualization environment.

Although there are above differences, there are countless ties between map spatial cognition theory and cognitive cartography. Cognitive cartography supply theoretical preparative for map spatial cognition theory research and map spatial cognition theory is the deepening and development of cognitive cartography in the condition of digital mapping.

4. Research contents of map spatial cognition theory

Using viewpoint of information and theory of information processing, map spatial cognition theory studies how human beings pay attention to and select spatial information, how cognize and memorize spatial information and how make a decision and guide spatial behavior using spatial information, etc., so map spatial cognition theory is a product of combining cartography with cognitive science. Taking the relationship between human beings and maps as its start point mainly, map spatial cognition theory studies the characteristics of map as a kind of spatial cognition tool, the processes and the laws of spatial cognition human beings use map. Spatial cognition, map spatial cognition, mental map, cognitive mapping, the spatial cognition model of map making and map using are basic concepts of map spatial cognition theory.

The main research contents of map spatial cognition theory as follows:
1.Studying the characterizes of map, especially electronic map, as a spatial cognition tool, employing the results in designing and making of electronic maps, in order to the validity of electronic maps as spatial cognition tool.

2.Studying spatial cognition model of map making and map using and the role of thinking in image in map making and map using, its aim is providing theoretical support for the development of cartographic expert system.

3.Studying mental process of map learning, simulating it by computer, and supplying theoretical gist for cartographic pattern recognition and the development of learning system in GIS.

4.Studying the role of map symbols as visual language in the process of map spatial cognition, especially the characteristics of spatial cognition and the role of three-dimensional map symbols in virtual terrain environment and three-dimensional geographic information system. And supplying theoretical background for virtual terrain environment simulation and the build of 3D GIS.

5.Studying different roles among the feeling channels of vision, hearing and touch in map spatial cognition, and supplying ergonomics knowledge for the development of multimedia electronic atlas and virtual terrain environment simulation.

6.Studying spatial cognitive factors in the design of human-machine interface of CIS, GIS and VE from the point of view of cognitive science, in order to supply theoretical law for design of human-machine interface with human cognitive characteristics.

7.Studying different characteristics in spatial cognition by comparing real reality with map, virtual terrain environment with map, and static maps and dynamic maps as spatial cognition tool, supplying different users with map spatial cognition tool which meet their cognitive needs.

8.Studying meaning of map spatial cognition in culture, spreading map and cartographic knowledge among the people, and increasing spatial cognition ability and education level of the people.

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