CHINESE GEOGRAPHICAL SCIENCE
Volume 13, Number 1, pp. 84 – 90, 2003
Science Press, Beijing, China

BRINGING FORWARD OF THE CONCEPT OF COGIS AND ITS ARCHITECTURE RESEARCH

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ABSTRACT: Based on the analysis of the development of GIS technology and application, this paper brought forward the concept of CoGIS, namely Cooperative GIS. CoGIS is GIS facing group-users and supporting human-human interaction, which makes it differ from the former GISs. Then, the characteristics of general Computer Support Cooperative Work (CSCW) applications and the complexity of Geographic Information Science were analyzed, and the conclusion that CoGIS was not a simple GIS layer on CSCW was reached. Further, this paper gave the hierarchical architecture of CoGIS, and analyzed the cooperative platform in detail from the following: 1) basic elements; 2) collaboration patterns; 3) cooperation control mechanism; 4) synchronization mechanism; 5) security and 6) group communication and so on. With those, the problems about GIS applications are discussed, such as 1) distributed multi-source GIS information and knowledge sharing platform; 2) the fusion and visualization of GIS information; 3) virtual reality cooperative modeling; 4) dynamic simulation; 5) expert system and 6) decision-making. Finally, this paper analyzed CoGIS application mode in brief.
KEY WORDS: CoGIS; group; human-human interaction; complexity; sharing

CLC number: P208　　Document code: A　　Article ID: 1002-0063(2003)01-0084-07

Because of the complexity of the geographic information and the continuous development of computer software technique, GIS has been applied more widely and deeply. There are two obvious trends about the further development of GIS: 1) be socialized, and merged into other information services, for example, Location Based Service (LBS) (VRETANOS, 2001) or Position Based Service (PBS), Mobile GIS and Social GIS, whose aims are to supply seamless geographic information service whenever and wherever to any one; 2) further join with correlative fields, and emphasize particularly on the development of the geographic information model (MA, 1996b) of those fields. The emphasis of the former lies on the construction of service platform and extension of service mode, while the latter pursues for the theoretic breakthrough. But, in reality, most work is accomplished by a group of members under some particular group environment, and essentially, mankind's life style and production style are social and cooperative. Particularly, with the development of network, what man wants is not simple human-computer interaction, but human-human information communication by computers. How does GIS reply?

1 BRINGING FORWARD OF CONCEPT OF COGIS

To face group-users, we should research cooperative work among group members involving geographic information, that is, how they work cooperatively and set up collaborative friendship based on geographic information, particularly, how computer environment supports and helps group's GIS work, finally design and develop a software system supporting cooperative GIS work. That system provides a platform to support virtual groups' cooperative work depending on geographic information, which may access various shared information, including virtual scene, and on which groups may simulate, consult and make decisions. This is completely a new Geographic Information System, which we call Cooperative Geographic Information System (CoGIS). We define CoGIS as a Geographic Information System with a network platform to support group users' accomplish-

Received date: 2002-09-29
Foundation item: Under the auspices of National High Technology 863 Project of China (No. 2001AA136060).
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ment of a common task cooperatively and effectively. A group of users with a common task and sharing environment is the key that makes CoGIS differ from the former GISs. CoGIS is a new interdisciplinary research field, which not only researches Geographic Information Science and computer science, but also involves sociology, psychology, organization theory, human engineering and cognitive science etc.

Technically, to some extent only with many technology bases which have developed such as network infrastructure, data infrastructure(especially spatial data infrastructure), application service infrastructure and spatial decision-making model etc. , can CoGIS be brought forward and implemented. CoGIS is the very result of the integration of distributed data, computing resources and applications. CoGIS requires rapid and real time multi-cast communication network, multi-source heterogeneous spatial information sharing platform and scalable cooperative work platform, interoperable GIS.

Compared with the former GISs, CoGIS will be a kind of GIS facing group-customers, needing support of group communication, and will change GIS from human-computer interaction to human-human interaction. Compared with general Computer Support Cooperative Work(CSCW) study, CoGIS is much more complex in the data and application, which dissimilates itself from general CSCW application.

1.1 GIS Facing Group-users and Supporting Human-human Interaction

Seen from the relationship of GIS and man, GIS can be divided into two types: 1) GIS facing non-group-users, supporting human-computer interaction and 2) GIS facing group-users, supporting human-human interaction. Human-computer interaction GISs facing non-group-users include all of the former GISs: 1) GIS under concentric environment, including GIS modules, integrated GIS, modularized GIS, kernel GIS; 2) GIS under network environment, including COMGIS, Agent GIS (LUO *et al.*, 2001), WEBGIS and CyberGIS. Among them, COMGIS concerns the decomposition and distribution of computing. Agent GIS pay more attention to automation and intelligentization of software component. WEBGIS, CyberGIS and CoGIS we brought forward all can be implemented with component technique, and Agent technique. WEBGIS and CyberGIS pay more attention to the distribution of data, computing and application, and their distribution of computing is just a principal and subordinate mode(C/S, B/S mode), their focus is the strategy by which computing between client and server is demarcated, and the technique which is used to implement it. Although there are many users at the same time, every user just interacts with the server. However, in reality what man wants more is interpersonal interaction and cooperation, so CoGIS is a better application for man, which will improve interpersonal information communication, especially geographic information communication, reduce, even remove interpersonal spatio-temporal compartmentalization, and improve the quality and efficiency of group work involving geographic information. Previously someone researched GIS based on events(JIANG and CHEN, 2000), and introduced some CSCW mechanism into GIS, but they had no systematic research and did not bring forward CoGIS. On the foundation of general GISs, CoGIS should still study group communication of geographic information, geographic information cooperative mechanism (group cooperative mode, cooperative control mechanism, safety control mechanism, synchronous mechanism etc.), and expand general GISs to meet the requirements of group cooperative work involving geographic information. So CoGIS is a completely new phase of GIS.

1.2 Being Different from General CSCW Applications

CoGIS is not to add simply one geographic information application layer to general CSCW. Compared with general CSCW research and applications, CoGIS faces with much more complex data and applications, which are brought by the complexity of geographic information science itself.

General CSCW researches a certain affair, and primary CSCWs include Workflow Management System (WfMS), Multimedia Conferencing, Cooperative Authoring and Computer supported Cooperative Design (CSCD) and so on. 1) For WfMS, workflow means a series of operation steps used in the multi-person participating office affairs, and the steps can be ordinal or parallel. WfMS manages the workflow by offering assistant support, and automatically completes related information exchange to improve efficiency. For example, IBM FlowMark is a typical WfMS. 2) Multimedia Conferencing can deliver distributed circumstances of attending members, meeting contents and all kinds of data and information to everyone who is attending the conference in time. It needs to deal with audio stream, video stream, cooperation operation data etc., and realizes real-time multimedia information interaction, and processes real time discussion and corporative design.

For example, Cu-SeeMe of the United States Cornell University is a typical Multimedia Conference system. 3) Cooperative Authoring and CSCD provide users with tools that can finish multimedia document compiling and product designing in cooperative work model at any time, at any place, for example DIstEdit of American Michigan University is a typical Cooperative Authoring (SHI and YANG, 1999). For WfMS, Cooperative Authoring and CSCD, Multimedia Conference, the type of involved data, quantity of data and operation series are relatively fixed and limited.

CoGIS researches objects that include Geography phenomena, geography cognition, geographic data, GIS operation, geographic information model (geography law), geographic information transmission, geographic information cooperative operation mechanism (including cooperative mode, cooperative control mechanism, synchronous mechanism etc.). Geography phenomenon is a kind of complex phenomena, and Geographic Information Science, which researches geographic information mechanism, is a kind of complex science. Geography phenomenon possesses the features of non-linearity, complexity, comparability(MA, 1996a) etc., which lead to the complexity of geography data, GIS operation, Geographical Expert System, Management Information System, Aided Decision-making System(MA, 1998).

In regard to geographic data, it is now difficult to find a uniform data model to express simultaneously the spatial characteristic, the attribute characteristic and the time characteristic of geography phenomenon. Existing geographic data models(CHEN, 2000) include vector model, grid model, Digital Elevation Model, Object Oriented model, vector and grid integration model and so on. The category of geographic data is numerous, and quantitative geographic data, especially the Remote Sensing data, is great, therefore researching geographic data seems to be particularly important, especially to such open system as CoGIS which deals with geographic data metadata, geographic data organization and management, storage, query, transmission, compression, visualization, transformation, fusion, safety and so on.

In regard to GIS operation, general analyses(CHEN, 2000) include geometry analysis of spatial characteristics, DEM analysis, network analysis, digital image analysis and multi-analysis of geographic variable, and will become continuously increasing with the development of applications. Also there are specific geographic information model in different application fields, and different GISs interoperate each other, therefore, to do so complex analysis operation and decision-making by so complicate data and to make it synchronization, the complexity can't be compared with general CSCW.

In regard to CoGIS application mode, a group of distributed users can discuss the same problem in different ways based on the same data or different data. For example, an ecologist, an aerologist, an agriculturist, an economist evaluate a region's soil erosion, and apply different models such as environment model, ecology model, agrology model, economy model etc. to process related data. This process substantially is a cooperative work about some problem across fields and disciplines, not just cooperative work of some affairs.

2 COGIS ARCHITECTURE

The architecture(Fig. 1) that we bring up combines the strategy of layered logic with concentrated control structure. Layered logic means constructing a user-oriented application platform between application and network services, through which users get access to network resources. The concentrated control structure means using a few public servers to harmonize groups' cooperative work. The strategy of layered logic and concentrated control structure, on one hand guarantees the transplant ability and interoper ability of CoGIS application, on the other hand guarantees the consistency of shared data and system integration.

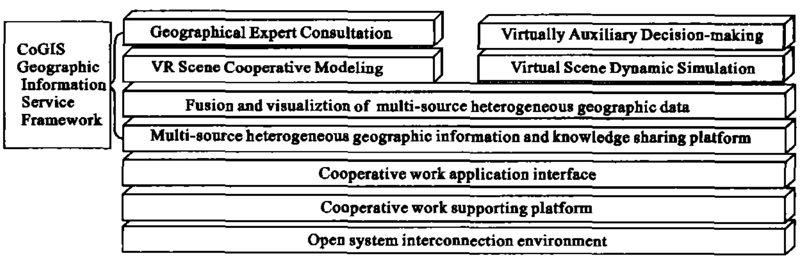

Fig. 1 CoGIS architecture reference model

2.1 Open System Interconnection Environment

CoGIS is designed to harmonize a group of members' operations through computer networks, which delivers geographical data and multimedia information to distributed users, which requests network bandwidth and delay with higher quality.

2.2 Cooperative Work Supporting Platform

This part mainly provides the main mechanism and tools (SHI and XIANG, 1997) to support cooperative work, including group cooperation mode, cooperative control mechanism, synchronicity mechanism, information safety control, group member management, shared object management and so on; and it also provides real time service of various functions and interaction services, such as white board sharing.

The fundamental elements of CoGIS include four parts: member role (role), shared objects, cooperative activity and cooperative event. The member role describes the functions of group members in cooperative work. Because of the complexity of Geographic Information Science itself, the roles in CoGIS are more complex than general CSCW, and a group may include members from different fields and disciplines, thus the member role dividing is greatly different according to different requirements. All kinds of shared data objects, mainly including distributed multi-source heterogeneous geographical data, are objects of cooperative operations by every member or of visualization in the cooperative process. Cooperative activity describes the process of group members' cooperative work, which is divided according to different roles of members, and consists of GIS operation series that operate on complex shared objects. Cooperative events are the indications of cooperative work headway and status changes, to harmonize members' operations.

2.2.1 Variety of CoGIS group cooperative mode

(1) Because of uncertain relationship among members of CoGIS, group cooperative mode may be concentrated control cooperation and peer cooperation. For example, in a geography-experts' cooperation that a government leader calls in to handle urgent incidents, the concentrated control mode is needed to harmonize other members' work. While to cooperate a group of scientists who study the same area, each member is equal, and they need not only cooperation, but also independence.

(2) Because member information exchanges request different time limitation, CoGIS can be synchronous cooperation and asynchronous cooperation. The synchronous cooperation requires real time information exchange between members, such as multi-army cooperative action in modern battles. The asynchronous cooperation has no strong time restriction of information exchanges between members, such as city planers' cooperation.

Because of the complexity of CoGIS group cooperative mode, we must understand deeply the members' cooperation mode aiming at concrete requirement, and exactly abstract the characteristics of group cooperation to select appropriate cooperative technology and ways, the key of which is to assort the cooperation mode abstraction with corresponding supporting technique.

2.2.2 Cooperative control mechanism

The cooperative control mechanism is the embodiment of rules that people follow in a cooperative process in CoGIS. It discusses logical relation of all kinds of events produced in the cooperation process. And concrete cooperative control requirements include action order assignment, consistency check, concurrence control and confliction settlement and so on. The emphasis of abstracting cooperation rules and implementing cooperation rules in CoGIS lies in cooperation data model and concurrence control model (SHI and XIANG, 1997).

(1) Cooperation data model. CoGIS involves various data. Geographic data itself is various. Considering text, video, audio and other data media, the data model describing all data should have powerful descriptive ability. Now research about this aspect is not enough and will be an emphasis.

(2) Concurrence control. It is very necessary to realize data integrity and consistency in CoGIS research how to use corresponding concurrency control strategy for different cooperative data. 1) Group interface consistency. In CoGIS, human-computer interface is multi-user interface, that is, group interface. Group interface is the same or the samilar to all users in a group. The key problem is to support special activities of multi-user system and complex management brought by synchronous activities, and the substance is shared objects' (map or image etc.) consistency. "What you see is what I see" is the principle of multi-user interface designing (SHI and XIANG, 1997). The operations changing shared objects by group members and their results should be expressed on the interface, through which a member can know others activities. To facilitate members, CoGIS multi-user interface should support different views, such as thumbnail and local map. Except operations of changing shared information and cooperative control operations of CoGIS, other operations should be processed as local operation and have no in-

fluence on other members. 2) Broad area feature. The system wants to realize cooperative work through Internet, however, the speed of Internet is much slower than that of Intranet, and the communication is not reliable. Because the geographic data, especially the remote sensing image data, are large, data management and distributed control strategy in CoGIS are good problem needing researching. 3) Data consistency. Reasons in network information system that trigger shared data inconsistency include two: one is data concurrent access; the other is invalid site which loses touch with outside, leading to its information out of date. To balance servers' load, copies of shared data can be placed in each site. Thus, to guarantee data consistency, three problems need to be settled: ① Exactness of shared objects operated concurrently. Now GIS vector data is layered: element→elements→layer→group→project, and the problem on which layer to handle concurrence control arrives, that is to say, the problem of choosing concurrence control granularity. ② There exists correlation among data, which will cause consistent problem among data objects. Because of the existing layered management model of GIS vector data, operations on a certain layer may influence upper layer, such as deleting certain element may influence its layer; because of the correlation of GIS data itself, operations on certain element may influence other elements in the same layer, or other data adhering to that element, such as its attribute data. ③ There exists consistency among multi-copies of shared data objects and version control.

2. 2. 3 Synchronicity mechanism

Synchronicity mechanism maintains consistent work environment for each member(SHI and XIANG, 1997). There should be only an operation on a specific shared object at certain time, and all kinds of events should follow some time relationship. Time consistency is realized by synchronicity mechanism, and its difficulty lies in describing synchronicity relation and providing real time services. Nowadays we lack valid ways to describe synchronicity relation, and existing operation systems can hardly provide real time services. The synchronization of CoGIS is divided into real time event synchronization and continuous media synchronization. Real time event synchronization describes the occurrence of one or a series of related events and the time order relation among the events, such as real time influence of one member's operation on a shared object on other members. This demands to study the events and event model of GIS, and various complex GIS operation, operation flow on various complex GIS data and their time order.

2. 2. 4 CoGIS safety control

There are three problems associated with CoGIS security control: identity verification, authority control, encryption and decryption. Because of the hierarchy of GIS data, authority has granularity. Key research question of data encryption and decryption in CoGIS is how to improve transfer efficiency of large GIS data while guaranteeing safety of GIS data in a group communication environment. Because of layered management mode and local characteristic of GIS information, CoGIS security control has to face the problem of secrecy of certain geography objects or areas.

2. 2. 5 GIS and group communication standard

Considering group cooperative mode, cooperation control mechanism, synchronicity mechanism and safety control, and GIS data model, data structure, semanteme and GIS operation semanteme, we need research group communication standard fitting for GIS including user-manager and user-user parts.

2. 3 CoGIS Application

In CoGIS, cooperation services based on geographic information are constructed on cooperative work supporting platform. First, distributed multi-source heterogeneous geographic information and knowledge sharing platform enables group members to share all kinds of data and services through Web, including GIS data, model, knowledge and GIS services; on cooperation work supporting platform and sharing platform, multi-source heterogeneous GIS data needs fusion, visualization, and real time interaction, cooperation; with the support of virtual reality scene cooperative modeling, CoGIS can support fieldwork meeting and virtual scene dynamic simulation; with the support of shared knowledge library and logic library, with CoGIS we can carry through specialist consultation; with the support of decision-making model, virtually auxiliary decision-making can be processed on CoGIS.

2. 3. 1 Distributed multi-source heterogeneous GIS information and knowledge sharing platform

Group work demands shared information, including GIS map, image, attribute, GIS knowledge, model and other data, and a mass of new shared information will be produced, therefore, there should be a tool to manage, search, access and update shared information for cooperative group members. It is Distributed Multi-source Heterogeneous GIS Information Sharing Platform(Fig. 2).

2. 3. 2 Fusion and visualization of multi-source heterogeneous GIS data

Through open GIS information and knowledge sharing

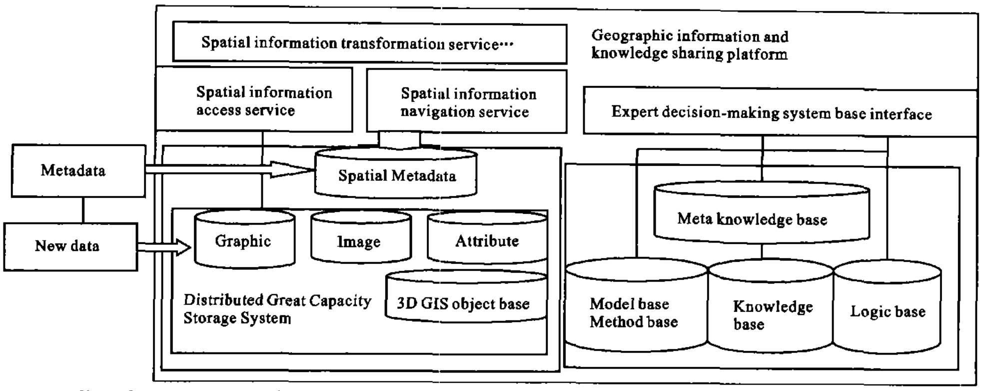

Fig. 2 Multi-source heterogeneous geographic information and knowledge sharing platform

platform, distributed members obtain all kinds of distributed heterogeneous GIS information, do some operations, integrate and visualize them. Members' operations are synchronous through cooperative work supporting platform, to maintain consistency of shared object and achieve the aim of interaction and cooperation. Nowadays there are mainly geometry fusion and information fusion concerning multi-source heterogeneous GIS data fusion research to be developed still in future.

2. 3. 3 Virtual reality scene cooperative modeling

There exist two basic directions about virtual environment development, one is technique development based on virtual reality(VR), the other is 3D graphical environment development based on Internet and World Wide Web(GONG and LIN, 2000). CoGIS virtual environment is the second, and the modeling tool normally is Virtual Reality Modeling Language (VRML)(WU and CHEN, 2001) based on World Wide Web. In CoGIS, 3D graphical world and all kinds of 3D objects are distributed and shared. When a member adds, deletes, or changes some 3D object in his 3D world, other members will immediately see the change of the 3D object in their virtual environment. Its data flow includes three parts: 3D source data→3D geographic objects→VRML world.

3D source data may be obtained from field collecting or digital photogrammetry etc. First establish 3D geographic object model based on object-oriented method; process data to get 2D, 3D vector data and grid data, then transform them to 3D geographic object library; according to users' parameters, transform 3D geographic object model into VRML world. To be shared, the 3D geographic objects and VRML world should be produced at server sides.

When receiving members' requests, 3D geographic object server processes data modeling of geographic object according to such parameters as the display range, required spatial resolution rate, attribute resolution rate, geographic objects in display range etc. VRML world creating server dynamically transforms corresponding geographic objects into VRML world model for members to browse and interact. The server manages members' information and communication data delivered between them. At some specific time, only one member has authority to process a specific shared object, and the server guarantee synchronicity. The operations and their changes are reflected to server which will then deliver them to other members.

2. 3. 4 Virtual scene dynamic simulation

In the process of group simulation training(ZHAO, 2000) and virtual process simulation, geography environment changes always. Besides dynamic simulation objects' state changes continuously, 3D terrain environment changes continuously because of the interaction between dynamic objects and environment and changes of the environment itself.

Therefore, on the basis of virtual reality scene cooperative modeling, it is still required to create dynamic objects, such as planes, tanks and so on. Dynamic objects have geometry model, physical attribute set and action attribute set. Dynamic object model is created according to the simulation objects' size, action and state requirements in the simulation process, and objects' physical modeling methods and action modeling methods are research emphases. When a dynamic object, which is controlled by members, moves, view point control, terrain matching, scene attemperment and collision check should be done according to changes of the scene. If collision occurs, collision response should be done according to environment, physical characteristics and activity feature of the dynamic object. To maintain the consistency of dynamic environment, when environment changes, other members should be given notice. All changes can be divided into creating, deleting and modifying of the dynamic object, and Environment Changing Message (ECM) contains some dynamic object's ID, type, characteristics parameter and so on. Other members simulate changes to implement interaction and cooperation according to ECM.

2.3.5 Expert consultation based on geographical knowledge

The expert consultation in CoGIS needs support of spatial and non-spatial database, model base, methods base, knowledge base and reasoning machine. These resources may be obtained through open geographic information and knowledge sharing platform. Members obtain all kinds of distributed heterogeneous GIS data, fuse and visualize them. Further, choose shared objects and analyze them with the model and method from open geographic information and knowledge sharing platform, and reason with the knowledge and logic from it, visualize results and deliver results to other members. Other members evaluate the results and do their own analyses and reasoning. In the whole process, cooperative work supporting platform maintains the consistency of shared objects. Finally the aim of consultation is reached(MA, 1998).

2.3.6 Virtually auxiliary decision-making

In CoGIS, each decision-maker obtains data of target area through open geographic information and knowledge sharing platform, including geographic data and attribute data etc. After finishing the cooperative operations such as modification, query, spatial analysis of geographic objects or scene data, each member can make deeper understanding of fundamental conditions, characteristics, and problems of that area about resources, environment, society and economic; then do model simulation, predication, scene analysis, planning and designing etc. with quantitative models, methods and knowledge combined to get schemes to be chosen; finally, get the final scheme through dialogue, discussion and vote among members. In the whole process, through cooperative work supporting platform, all shared objects and the operations on them, and the results, scheme, and interaction among members are visible and consistent to all members, thus cooperative decision-making is realized(MA, 1998).

In addition, in the development and construction of CoGIS, it still involves research and application of the following techniques: 1) research of geographic data metadata standard; 2) GIS interoperability; 3) data management model of multi-source, multi-resolution, multi-scale data and large GIS data storage system; 4) highly efficient spatial index mechanism; 5) remote sensing image query based on content; 6) highly efficient compression method appropriate to network transfer; 7) multilevel buffer memory and buffer management mechanism; 8) large GIS data parallel processing and fast display technique; 9) related filter mechanism (including data and control data etc.) etc.

Because geographic information is fundamental, all-around and distributed, CoGIS has a very broad development future. In military direction, fighting a flood and handling disaster, handling traffic accident, fire fighting etc., and tourism, business negotiation, distance learning, remote medical treatment, virtual enterprise etc., CoGIS will have broad market. CoGIS is a new interdisciplinary research field that is contacted with but differs from traditional GISs. Now theoretical research of CoGIS just starts, and there are still many problems to be researched in technology and application.

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