Thinking in Framework of Digital Earth Integrated Interactive System*

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ABSTRACT The revolution of new technology enables human to obtain mass original data of our society and planet in unprecedented ways. To make these data understandable and usable, a stronger operation mechanism is needed. The vice President of USA, Gore brought forward the concept of "Digital Earth" for the first time in 1998. After some research and discussion, the concept of Digital Earth became clear. And Relative technologies have made a great progress. Whatever the definition of Digital Earth, finally it is concerned about the generation of virtual scene. With setting up a Integrated Interactive System we can do a virtual representation of our planet that enables a person to explore and interact. These paper present the element functions of a Digital Earth Integrated Interactive System based on the characters of Digital Earth. The architecture of Digital Earth can be divided into three parts, data obtaining and refreshing system, data processing and transmitting system, data representing and recognition system. Using technologies of Virtual Reality, Data Warehouse and Geographical Information System as key technologies can build a framework of Digital Earth Integrated Interactive System which implements the basic functions of Digital Earth. Finally, the framework will be a practicable system and it can make huge social and economical profits.

KEY WORDS Digital Earth, Geographical Information System，Virtual Reality, Data Warehouse

1.Introduction

During the last 30 years, the development of information technology increases means of Geography. It is possible for precise earth science research with the rapid development of GIS, RS and GPS, which construct the present technological system of Geography.

The revolution of new technology enables human to obtain vast amount of original natural and cultural data in unprecedented ways. To make these data understandable and usable, a stronger operation mechanism is needed. The vice president of USA, Gore, had a speech "The Digital Earth: Understanding our planet in the 21st Century" in California Science Center, brought forward the concept of "Digital Earth" for the first time in 1998. And he made some attractive description about the prospect about Digital Earth.

Gore's presenting Digital Earth had its own infrastructure background. US government initiated the National Information Infrastructure (NII) in 1993 and National Spatial Information Infrastructure (NSDI) in 1994. Both infrastructures (GII and GSDI) have extended to global scale during the past several years. The presence of Digital Earth is based on these two infrastructures.

As the detail concept and theory of Digital Earth has not completed, most experts have their own understanding of Digital Earth. However, after some research and discussion, many experts agree on that Digital Earth has great significance and extensive functions. The development of geo-science has experienced such a course: qualitative recognition and description, subdivided sciences and semi-quantitative description and analysis, precise research with coordination of different sciences and application of various techniques. Digital Earth represents this trend and will become an important part of geo-science. The implementation of Digital Earth will dramatically improve the technological system of earth science. In addition, it will be one of the infrastructures for the development of science and technology, industrial application, commercial economy and human's living.

2.Definition And Characters Of Digital Earth

There is no exact scientific definition for Digital Earth now. In China, the extensively accepted definition of Digital Earth is that Digital Earth is the

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digital representation and recognition of the planet and its relative phenomena. It includes many spatial data, geo-referenced data, and all the corresponding theories and techniques to transform data to information that can be understood and used conveniently.

Although this definition is general, it points out the essence of Digital Earth. It clearly indicates three kernel questions. The first one is how to obtain the digital spatial data and geo-referenced data or digitize non-digital data. The second one is how to transform original data or non-digital data to information that can be understood and used conveniently. The third one is the data reappear-ance. An environment will help people to understand these data and information coming from the transformed. Meanwhile, people can digitally represent the data regarding what they concern about.

As described above, there are many stimulating des-criptions about the situation when Digital Earth is realized. Then what are the characters of Digital Earth?

Firstly, Digital Earth is a integrated system, an extremely large spatial information system.

Secondly, the operation target of Digital Earth is data. The data comprise all spatial and attribute data which include different formatting data of multi-source, multi-scale, multi-resolution, multi-time phases. Total amount of these data is very striking. Therefore, the data of Digital Earth is numerous in variety and distributed in storage.

Thirdly, Digital Earth is an interactive system. People can get information in different way. The man-machine inter-face of Digital Earth is based on virtual scene, which can support natural communication between man and machine. The nice interactivity can help users understand data and information about Earth. Interactivity is one of the indexes to evaluate the implementation of Digital Earth.

Fourthly, Digital Earth orients the request of user. The services of Digital Earth cover all the social classes. There is an urgent need for most of the users of the world to have the information from Digital Earth. These need are quite different.

Fifthly, Digital Earth should build on open platform and use the technology of component object model to meet users' needs. Digital Earth should use many relative techniques, which have been made by different approaches. Open platform and component object model may provide a good foundation for the integration of these techniques.

The mentioned above are the basic characters of Digital Earth. What distinguish of the Digital Earth could be? As a whole system, it applies and integrates data, developed and developing theories, techniques, abilities together.

3.Digital Earth Application And Integrated Interactive System

Based on three issues in the definition of Digital Earth, it can be divided into three subsystems: data collection and updating system, data processing and transmitting system, data representation and recognition system. The division of these three systems is based on the information processing flow. We may have a clear vision on the different tasks concerning Digital Earth.

Data collection and updating system is the basis of Digital Earth implementation, which is determined by the operation objects of Digital Earth. Data collection and updating system may include obtaining original data, coordinating spatial data, digitizing and preparing other types of data, establishing the framework of data and accumulating historic data. Network-based spatial data infrastructure is the main component of data collection and updating system. However, spatial data infrastructure is far from enough. More efforts are needed to obtain data to realize Digital Earth, which need other techniques such as Remote Sensing, Global Positioning System, Digital Photogrammetry System, multi-media technique, pattern recognition technique, and so on. It is obviously that the main task of data collection and updating system is to produce, prepare abundant original data concerning our society and planet and to meet the request of the other two subsystems.

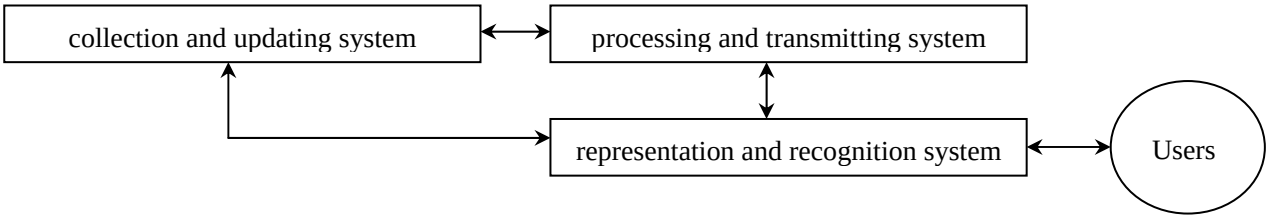

Fig.1 The relationship between three subsystems and users

The main task of data processing and transmitting system is processing of digitized and arranged data and making it easily understand. In the system, Internet is an important infrastructure. Since the data storage of Digital Earth is distributed, a large amount of data that distribute at the different sites need good communication, no matter in the processing or in the transmitting. Compared with the data collection and updating system, based on spatial data infrastructure, many techniques required in this system can not be determined, the treatment of the spatial and attribute data could be very important. The techniques mentioned in the system belong to multiple disciplines. The application of this subsystem determines how far and how wide the data can be understood and used. The construction of the system will directly affect the scientific research of the Digital Earth. The techniques that apply in the system will be the variable factor of the Digital Earth study. The technologies must be achieved progress if the research about the Digital Earth get a new step in following century. This is an important field in the future.

The data representation and recognition system is the section, which directly take action between the Digital Earth and people. People can get what he wants and many results achieved by Digital Earth through it. In summary, this section is the interface of Digital Earth. It can make data representation meet to users' demands and make users deeply understand it, such as the exploring of three-dimensional terrain. And the section should also have some tools to respond users' operation, then it transmit the request to other modules as well as interact with users. Digital Earth depends on this part to interact with users so that data representation and recognition system is an important index to evaluate the implement of Digital Earth.

The relationship between the three subsystems and users can be identified in figure 1. The three subsystems are not separated completely. Instead, it is possible for them to integrate together. In many researches, the integration is necessary. Certainly, the integration does not change the function of the three subsystems, but make them more compacts and respond more wonderfully to the operation. So we called it "Digital Earth integrated interactive system", which is defined carefully to show that it is only a common model of Digital Earth application system, not the system to satisfy the concrete demands.

The interaction system emphasizes interaction among the factors, through which all the operation between Digital Earth and users can be implemented. There are many perspectives of Digital Earth, but there is no doubt that Digital Earth can representation virtual scene. The interaction system is based on this kind of scene. At the same time, it is not only an interaction system. It must also respond to users' operation and demands. Thus, there must be one responding system, which has complete functions to support the interaction. In this perspective, it is an application framework typicalized by completely Digital Earth, and realized the function of Digital Earth according to multiple demands.

There is an example about the vehicle navigation system in the three dimensional environment. The system can receipt information from the GPS system in time, and can process it appropriately, then show them in the system according to the current route, location and direction. In the navigation system, the terrain data comes from spatial data infrastructure, if user is interested in some things, he can get the information from the current database, and can make further analysis of the information through all kinds of tools. This kind of system is a good example of the Digital Earth application system.

4. The Essentialfunctiions And Frame-Work of Digital Earth Integrated Interactive System

(1)The Functions of the System

The system is used for realizing the Digital Earth, as mentioned above, it should face the concrete application. Different application systems may have different models, functions and interaction modes. For example, there are two interaction systems, one uses virtual helm and data glove to interact with user, the other uses mouse and keyboard to finish the interaction, but both of them may belong to one Digital Earth integrated interactive system.There are some essential functions of the system only with which the system can be called Digital Earth integrated interactive system. Now, we will discuss them as following.

- Its data structure is no margin and suture, i.e. it can have multi-scale, multi-resolving power, multi-temporal, multi-format .it can provide to user with the appropriate data of different situations. In the mean while, it has the ability to integrate and demo multi-resources data, along with the reception, process and demo of the data collected timely.
- Digital Earth covers a large amount of information. It is not possible to store the data at the single system, and for the reason of avoiding repeat storage, they should be distributed at different places. So the Digital Earth integrated interactive system must be able to communi-cate the distributed data and can realize distributed system

operation.

• In the integrated interactive system, the browsing perspective should not be limited. Users can select a perspective suitable for him to interact with the machine, and can browse according to his defined path to feel and understand the content. This is different from the animation technique, which relies on changing perspec-tives to generating the image of animation. Because the path of the latter is defined previously, the perspective of animation can not changed by the users.

• The system provides spatial data, attribute data and related materials by the Object-Oriented or Subject-Oriented modes. It can also help people further understand or better use the data by using other techniques such as full text retrieval.

• The system can provide some base measurement and direction operating, including distant, area, volume, center of gravity and other geometry elements' computing and direction determining, through which users can get some simple geometry characters of things.

• The system can do the surface spatial analysis to supply user's requirements what most focus on the surface research of Geo-3D-objects. It includes many polygon analysis methods. For example, Relief profile operation, visualization field generation, slope and aspect analysis, average slope, average aspect and volume analysis.

• Certainly Geo-objects 3D spatial analysis is necessary in the system. Which methods such as 3D statistics, 3D arbitrary profile operation, 3D proximity analysis, 3D conjunction analysis, 3D connection analysis, 3D route analysis, 3D buffer analysis and 3D overlay analysis are mainly used in 3D spatial analysis. The 3D arbitrary profile analysis and 3D conjunction analysis are the most element operation for other 3D spatial analysis or operation.

• The system can add, delete or modify the characters of the object or topography in the three dimensional scene, and can dynamically modeling and testing its results.

• The system is not only the three dimensional system, it can treat data which has temporal dimension, and can build spatial and temporal model. The system can also stimulate all kinds of matters, represent them, and produce the animation.

When a system can realize the mentioned functions above, it can be called a "Digital Earth Integrated Interactive System". Certainly some other modular and tools developing from other techniques can be added with different demands.

(2) Framework of the Digital Earth Integrated Interactive System

We have discussed the essential functions of the system, but what kind of techniques and framework can realize the functions?

The earth information science has been developed very quickly in recent years, so it can strongly support the Digital Earth. And in the past years, many scholars have do many researches in the fields of how to integrate GIS, RS, and GPS. In Digital Earth system, how to receipt and treat spatial data are key problems. GIS, RS, GPS and their related systems, such as the image manipulation system, Digital Photogrammetry System, consist to the essential section of Digital Earth, in which GIS can do data analysis. Because of this, GIS is the center processing modular in the system. Digital Earth needs many other texts, shapes, images and multimedia data besides spatial data, and it will well represent these data to people with better format in Digital Earth Integrated Interactive System. It is fairly difficult to meet the demand of this system with the current architecture of database. First, data storage format is different with the different commerce database software, and the middle access interface as Open Database Connection (ODBC) can not work smoothly. Secondly, the way of data process in database is not as same as the way that Digital Earth process data. In a Digital Earth application system, the data is subject-oriented and object-oriented. On the other hand, many data have spatio-temporal relationship and is distribution in storage. Based on these characters the Data Warehouse that have made huge progress during the past several years can solve the problems that the database software can not do. The essence of data warehouse is that make a processing system between the users and the databases, and it is run when the users need operate database. In addition, data warehouse can help people to practise the data mining and knowledge digging out. Data warehouse is a excellent middle-ware system and it can easy deal with the large amount requirement with cooperating by Meta Database. Data warehouse will be a key technology in the data obtaining and processing.

The core mission of data representation and recognition system is to deal with the data by user demands. The Digital Earth throughly depends on the interaction between the system and users. So the data represent-ation and recognition system is an important index for the implement of Digital Earth. Based on today's knowledge, the Digital Earth can represent the virtual scene. On the other hand, the Digital Earth needs the virtual scene to complete the data representation and recognition. After the thirty years development, at the aspect of

virtual scene' building and representing, Virtual Reality

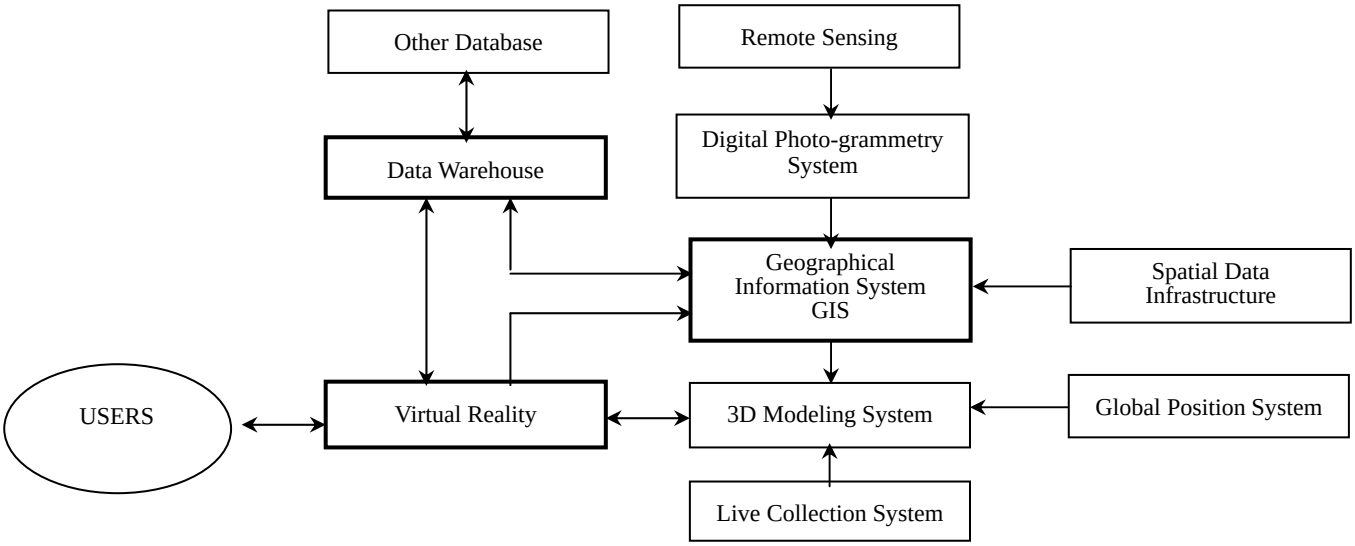

Fig.2 The Framework of Digital Earth Integrated Interactive System

Technology has became mature. Based on Virtual Reality technology, data representation and recognition will be very convenient. But today we can't cosmically apply the Virtual Reality on the 3D terrarin generation. Cooperating with the 3D Terrain Modeling System, geographical information data can be easy to use in the Virtual Reality. Virtual Reality technology will play as an important role in the data representation and recognition system of Digital Earth Integrated Interactive System.

Using these technologies will draw a rough outline of Digital Earth Integrated Interactive System. We can establish a relatively perfect framework of Digital Earth Integrated Interactive System when we integrate other relative technologies into the skeleton. Now we describe the mission and function of various modules in Digital Earth Integrated Interactive System.

*Virtual Reality (VR)***:**
In this framework, the environment which user can explore and get multi-sense experiences is provided by Virtual Reality technology. A application system of Virtual Reality builds a digital model with computer, then the system calculates the current scene with the digital model after viewpoint switched. There are many tools which can help people to understand the virtual scene.

3D Modeling System
Normally, the mission of 3D Modeling System is to build the Model which can be used in Virtual Reality System. It is a subsystem of the Virtual Reality in some definition. It mainly builds the 3D model with the data from GIS, GPS or Live Collection System in this architecture and transmits the processed data to Virtual Reality system. In addition, it will process the request of 3D dynamic modeling and add, delete or modify terrain or objects to accomplish the user's operation in Virtual Reality system.

Data Warehouse
Data Warehouse answers for the data request from other module. Data Warehouse can analysis the data request and operate to database, though the data store in different place in physical. As a middle-ware system Data warehouse doesn't care about the detail database structure or storage format, and on the other hand the operating method of Data Warehouse is most fit the request of Digital Earth Integrated Interactive System.

Geographical Information System (GIS)
Spatial data processing and analysis is the primary job of Geographical Information System. The application of Remote Sensing and Global Position System are based on the Geographical Information System. In a word, GIS is the kernel and soul of the Digital Earth. GIS extract the basic spatial data from Spatial Data Infrastructure, and use the data from Remote Sensing and Global Position System to meet the special demand. It can obtain the needed attribute data by using Data Warehouse. The all

output of GIS should transfer to the Virtual Reality System to process.

Spatial Data Infrastructure

As an infrastructure about Digital Earth, Spatial Data Infrastructure supports the requirement of basic spatial data needed by Digital Earth Integrated Interactive System. The spatial data in Spatial Data Infrastructure is periodically refreshed through Internet.

Remote Sensing (RS) and Digital Photogrammetry System(DPS)

Remote Sensing data are more difficult to use than other data. The data from the Remote Sensing system must be done image manipulation to remedy fault first, then Digital Photogrammetry System generate the Digita Elevation Model of target area. These processed data can easily use by GIS or 3D Modeling System.

Global Position System (GPS)

With the real-time data which is generated from Global Position System, we can do the work that need receive real-time data to control the route selected or others, such as dynamic monitoring or navigation,.

Live Collection System

The Live Collection System gathers the original data about the local scene. We can compare the live collection data with the representation data in Virtual Reality to test the result of simulation system.

We can integrate many relative technologies in this architecture, such as voice recognition, full text retrieval, Expert System and so on. These technologies have matured or developed rapidly. The Digital Earth Integrated Interactive System will be rounded. All of these technologies can combine together to create a application system of Digital Earth. Certainly, more and more theories and methods about the Digital Earth will be discovered and established in the future.

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