

## On the Application of Multi-scope Digital Earth Models in Virtual Earth

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**Abstract** *Digital Earth Model* includes three kinds of models such as digital framework models, digital elevation models and digital unit models. The scientific problems of establishing *Virtual Earth* exit two aspects: one is setting up rigorous digital earth models and the other one is to effectively develop and use the information of models. The paper discusses the five characters of *Virtual Earth* and key technologies. In the establishments, developments and researches of Digital Earth, the requirements of economic construction of China act as jumping-off places. The five major aspects of economic developments of China should be tackled. The paper also discusses the five engineering's and fields.

**Key words** digital earth model, virtual earth, and information

From industrial economy to intellective economy and from industrial society to informational society, the information technologies have been playing more and more roles. The recommendation and application of internet is a greater change than previous. Take the electric's business as an example, the exchanges of commodities are becoming more and more. According to the authorized prediction, the amount deals of exchanges will extend 1000 billion U.S. dollars.

Recently, accompany with development of the Internet technologies in China, the discussions on *Digital Earth* have been hold more widely and ardently than previous stage when the remote sensing was in the first instance and setting up planning. Since February of 1993 when U.S. President Bill Clinton brought about accept of *Information Highway*, the Internet has been sweeping the whole world as a newness guise. The informational industry in United States has gained a great development and achieved plentiful and substantial profits. These lead the U.S. economy to sustaining growth,

reducing the rate of idleness and are welcomed by U.S. people. The Chinese government has been extremely attaching importance to the developments of computer internet. In order to catch up with the paces of information technology developments, China constituted and actualized "Three Golden Engineering's"(Golden Bridges, Golden Cards and Golden Networks). Under the great prosperous and rapid development circumstances of Internet, the U.S. Vice-president Gore brought about *Digital Earth* again in January 31 of 1998. This further extended the fields of information technology. The *Information Highway* pioneers a wide road for global information and the Digital Earth provides magnanimity sources for it. Combining the flow and source will force the

information technology to a new step.

### 1. From 2-dimension Pottery Maps to Multi-dimension Virtual Earth

The Earth is the home for mankind living. For 20 million years, mankind has been recognizing it in order to create favor living spaces and improve the living standards of both substance and culture. In accompany with the development of science and technology and deeply understanding of the Earth, the process of the understanding extends form a part to wide space, recording the understandings on different carries. From the investigation of the Earth by field to setting up Virtual Earth, we can divided four stages in the rough as follows:

Stage 1: Observing the Earth from Field. This stage went through 20 million years. From the naissance of the mankind to A.D. 1600, due to the under-developed science and technology, the mankind observed the Earth only by field. The ken of mankind was limited seriously because of the observed objects sheltered from trees and mountains. The scope of observation only extended few kilometers. The real aspects of the Earth could not be recognized and the exiting relations among the spheres. In history, mankind recorded the observations on different carries. The earliest maps were urban maps which were carved in pottery slices using glyph by ancient Saumur in 21<sup>st</sup> century B.C. During the progresses of development, many sorts of maps such as husbandry, agriculture, water resources, navigation, military affairs and so on. This stage, however, was very long.

Stage 2: Observing the Earth from Low Altitude. This stage lasted more than 200 years. In order to widen the ken of observing the Earth, many people tried to fly to the space like a bird. Through many failures, a fire balloon blasted off in France in 1783.

This exploited a new history of watching the Earth from space. The first aerial photograph was shoot from a camera attached to a fire balloon by French in 1858. This initiated a new stage of mapping by aerial surveying. This kind of surveying raised the field and flat surveying to an aerial photographic solid surveying. Aerial photographic solid surveying transferred all field information to indoors, raising the precision of obtained global information, shortening the period, actualizing the first forward leap of studying the Earth from space. After the World War II, aerial photography was abroad applied to obtain up-to-the-minute field information. This absolutely changed the system of obtaining, processing, transferring, reappearing, storing of mapping information, providing many kinds of mapping products for using, meeting the needs of mankind living and economic development and driving the development of economic construction ulteriorly.

Stage 3: Observing the Earth from Outer Space—Naissance of Remote Sensing. At the forcing of rocket, outer space and information technologies, the first artificial satellite was launched by former U.S.S.R. The launching created a new era of observing the Earth from outer space. In August of 1958, the satellite of Explorer 6 of United State successfully made a first photo for the Earth, unveiling a new era of space remote sensing (RS), global positioning system (GPS) and geographic information system (GIS). Because the satellite remote sensing can obtain images of more macroscopical, more abundant and dynamic characters, it has been developing very fast for half of century. It has been making a lot of achievements which applied in all aspects of economy that have relations with the fields of geo-science. For recent 50 years, more than 2000 artificial satellites have been launched all over the world and more than 200 satellites are used for remote sensing. The spectrum resolving rate of some images can reach millimicrons. Especially, the utilization of radar remote sensing can observing the Earth at all-weather. The commercial images can reach the field resolving rate for meters. These provide abundant information sources for observing the Earth.

Stage 4: Observing the Virtual Earth by Computer and Internet. The accept of the *Digital Earth* put forwards by U.S. Vice-president Gore is that "a sort of the earth expression can embedded abundant data, have multi-resolving rate and 3-dimension structure ". He definitely pointed out the *Digital Earth* consanguineously relate high technologies such as remote sensing, geographic information system, computer technologies,

internet technologies, technologies of multi-dimension virtual practical world with social requirements such as sustainable developing decision-making, agriculture, disasters, resources, global changes, education, military affairs and so on. According the agenda provided by Gore, the *Digital Earth* will realized primarily till the year 2020 and can be realized basically around the year 2005. The researches and applications of integrative development of the *Digital Earth* combining space technologies, information technologies, computer technologies and geo-science will drive the world economy rapid development.

## 2. The Characteristics of the Virtual Earth

The Earth is huge system. There exit reciprocity and interdependent among its spheres such as lithosphere, atmosphere, hydrosphere and biosphere. In a multiphase coupling condition of the solar and earth energies, the system obtains energy dynamic balance. This extremely complex acting process have been exploited. The process may develop from points to area, from primary to high-level, from microscopic to macroscopic, from part to whole earth and from quantitative to qualitative changes. The energies exchanging dynamic balance may be lengthy. If a high quality *Virtual Earth* can be established during the process of understanding the Earth, it can play important roles in further exploring the rules of energy exchanges among the earth's spheres, protecting the earth's environment, studying economic trends and shaping goals for mankind's sustainable development. The Virtual Earth may have the following main characteristics:

1)Multi-scope earth digital information. According to different requirements, the information includes three kinds of earth information: micro-information, medium-information and macro-information. In the supporting of electrical navigating technologies, the information can be zoomed randomly and provide user information services of omnidirection and efficiency.

2)The digital earth information includes information of physical science, social science and economic science. It is a syntheses of simplex and special information. It can be analyzed not only by single factor but by bi-phase or multiphase according the selection of different quantitative special information. It also can be studied not only partially but macro-studies for wide areas. It has widely agility.

3)Integration of 5-dimension earth space information. The five dimensions are flat position of the earth ellipsoid, altitude, attribute and temporal variables. The integrative description of

5-dimension information may show the differences of information among physical factors and social economy. It can be analyzed for different factors by position, quality, quantity, timing and for different altitudes. In the condition of efficiency of space-time data, the disciplinary of space-time historic variables can be analyzed, in order to provide scientific basis for exploiting the whole process of changes from quantity to quality for substances.

4)The oneness and difference of space data infrastructure. In order to actualizing the construction of *the Virtual Earth*, it is necessary for organizing obtaining, processing and machining for the earth space information which must have plans and steps. It is also need to accomplish depositing, updating, maintaining, managing and contributing of information, in order to form a high efficient mechanism for the utilization of the earth information. For boosting the benefits of application of the earth space information and realizing its efficient using and sharing, it is an essential to harmonize organically the construction of the earth space infrastructure and reduce randomness. Firstly, each country should draw its plans, constitute standards of data and technologies according to high consolidation, in order to plan, design, produce and gather the earth information of multi-scope, multi-type and different resolving rates. On the basis of actualizing the infrastructure of state space technology, the infrastructure of regional and global space data should be instructed rapidly. However, because of differences of cultural basis, historical backgrounds, regional ranges and management systems among countries and regions, the infrastructure of earth space data for different countries exists different ways. In order to realize the exchanges of information, the technical supporting system must be designed.

5)The standardization of earth space information is a scientific problem and a key technology. The author used to cooperate with U.S. Geological Survey and U.S Land Management Bureau on study of geographic information system, knowing that coordination system used by U.S.G.S was grid system of longitude and latitude and the disparting system of maps used standard of international 1:1 000 000. The U.S.L.M, however, used local coordinating system which set a state as original coordinating point to expand around when surveying cadastry maps. The cadastry maps have been used for 200 years. In order to actualize the oneness and standardizing of the earth framework information, the United State throw a lot of manpower and material resources into information exchanges, transforming local coordinating system

to international system. Since the middle of 1980s, China has set up mapping databases of scale of 1:1 million and 1: 250,000, digital elevation models and toponym databases. All of the databases are made according to international departing system. They formed bases for exchanges of information among regions and global areas, insetting of physical and social-economic information, analysis of multi-factors, multi-scopes and multi-space-time, sharing of multi-dimension information.

### 3. Digital Earth Models

1) The Digital Earth models and their Constitution. The Earth system is a space multi-dimension system. It is a huge system consisting of atmosphere, lithosphere, hydrosphere and biosphere. There are two scientific problems when setting up digital earth models, One problem is to establish a accurate digital model and another is exploiting and using the information of the digital earth model. A digital earth model consists of three parts of the earth framework model, digital elevation model and digital unit model. The key point is to setting up a unified standard of earth framework. On the basis of the framework, the multi-dimension digital elevation model and unit model may be constructed. The framework model comprise information obtaining and updating system, data processing and data standards systems, data framework and data storage systems, data handling system, database system and managing system of all subsystem of the earth system. In order to using and exploiting the information of digital earth models, it is necessary to set up and expand information transmitting system, set up efficient network system, information service and management system, applicative models and software system.

2) Digital Elevation System and Its Construction. The digital elevation model is a solid digital model to express altitude of the surface of the earth by regular positive and negative dots. Multi-dimension digital elevation model can be divided three types according to their scales, altitude precision and dot density. First type is large-scale model of 1:500 to 1:50 000 and its altitude precision is 20 centimeters to 10 meters. Second type is medium-scale model of 1:100 000 to 1:500 000 and its altitude precision is 10-100meters. Third type is small-scale model of less than 1:1 million and its altitude precision is 100-1000meters.

There are three methods of setting up digital elevation models. One method is all field survey, using high accurate levelers, theodolites, all station equipment or GPS. According to plan, the plane ordinates and altitude are surveyed in the field by

kilometer grids or longitude and latitude networks. High accurate digital elevation can be obtained by this method. The precision of plane and altitude may reach above centimeter level. The second method is to using multi-scope aerial and space images and accurate stereo-photogrammeter to make a automatic relation among image points or dialog relation between man and computer to obtain the attribute data for altitude. Then the data are transited to grid data. This method can get high velocity and benefits. The precision of DEM depends on the scale of images of remote sensing and the accuracy of accurate measurement equipment. The third method is to obtain the data from newest topographic maps. For example, the handy digitizer can be used to digitize the contour lines, or contour map can be scanned to get altitude data automatically and then the data transited to grid data through software, or the grid altitude may be read on the contour map directly and than the data are input in computer to creat digital elevation model. In 1980's, when I studied to set up national basic information system of 1:1 million, I used new measured topographic map of 1:50 000 and 1:100 000 for more than 20 000 sheets, reading the grid altitude points to set up China first digital elevation model. The model widely used in economic construction and got benefits apparently. For example, the Ministry of Broadcasting and Films used the model to design national television networks which saved more than 90% amount of working.

3) Digital Unit Model. The purpose of establishing digital earth model is to use it. The benefits are good or not, not only depending on the qualities of digital earth framework model and digital elevation model but also on the scientific contents of digital unit model. Firstly, the digital unit model should make organization and classification for different factors of sub-systems within the earth system. The unit information is the information of basic unit which is consisted by different qualitative matters of the earth surface and its utter space. Actually, the unit information includes all information of hydrosphere, lithosphere, atmosphere and biosphere. On the basis of the information of earth framework model and digital elevation model, the information of the quaternary geology, soil, climate, sunshine, temperature, rainfall, wind, land use, land cover, plants and animals, and the information of socio-economy is built in. The organization and classification of setting up digital unit model and digital unit information is a key point of limiting the efficient utilization of digital earth. The impacts of it are two aspects. One is to excavate the space information

resources of the earth system, organize and harmony the strict classification of the space constitution of the earth system and its sub-systems, undertake the standardizing and unit of the system in order to identify, visit and use it by users. Another aspect is to analyze all the classified factors qualitatively, positional and quantitatively and to transfer the information, in order to deepen the understanding of the rules of the earth existence and its behaving.

#### **4. Application Analysis of Digital Elevation Model (DEM)**

DEM is used very widely in economy construction. It has conceded the following constext during its study;

1) The Surface Area of China. China has its total surface area of 9.6 million square kilomers. This authorized datum has been used for 50 years in government's reports and planning forms. The datum was declared at The First Session of The People's Consultation Conference of China in 21 September ,1949 by Chairman Mao Zedong and it was measured by three people organized by Cheng Pu of Department of Campaign of General Staff of Chinese People's Liberation Army. The datum was measured actually by Mr. Zeng Siying who organized the measurement in 1932, according to a national map of scale of 1:7.5 million. The area was projective area of the earth on plane instead of surface eerea. When Prof. Hua Luogeng, a famous Mathematician, studied integral calculus, he tried to detect a formula measuring mountain surface using mathematics, he failed due to the complex of China's mountain. At the beginning of 1980's, when I studied establishing the digital elevation model of 1:1 million, I put forwards a scenario of measuring the country's surface area using DEM. For this, I visit Prof. Hua Luogeng. The scenario was cognized and supported by Prof. Hua. Prof. Hua figured out that using DEM and combining it with mathematic method may accurately calculate the surface area of mountains. He also hoped that he might supervise to calculating surface area after finishing the national DEM of scale 1:1 million. The surface area measurement is actually to integrate the sphere triangle of each mountain. The constitution of the sphere triangle are ridge lines, valley lines and other topographic lines. China is a mountainous country. The mountain areas have widely prospect of utilization and development. In order to use the resources of mountain areas efficiently and scien-tifically, it is very important to calculate the surface area for making layouts for plantation and husbandry, calculating the amount of grass

production and supporting animals, planning receding cultivated lands to forest lands and grasslands, combating soil and water losing and for the small water basin transforming and using.

2) Accurate Calculation of Precipitation and Runoff of Upper Reaches of Rivers. Each basin is a unit of independence and obturation. The dispersive runoffs are collected to form streamlets, then reaches to anabranches and finally are gathered to main river. Rainstorms can form a wide scope of dispersive runoffs. When the dispersive runoff become too large the flood can come into being. How large is the flux of the flood? Does it create disaster for middle and lower reaches? We can calculate accurately the water amount of each anabranch, flood amount of main river, the forming location, the forming time, and velocity of that flood according to the precipitation, runoff of catchment basin, and slopes, length, shapes and constitution of watercourse. Then according to the distribution of topography and ground objects, the flood of middle and lower reaches can be forecasted at the support of digital elevation model and digital unit model.

4) Disaster Reducing and Curing Emulation and Appraisal of Disaster Situation. The middle and lower reaches of seven major catchments of China are the area with economic developed, populous and more flooding. To set up high accurate digital elevation model and digital unit model, especially to set up 20 centimeter level of digital elevation model with newest data of social economy and population, and to set up emulational model for all kinds of disaster, are solid basis for disaster reducing, foreseeing and appraisal of disaster situation.

5) Scientific Planning and Designing for Global Communication Rebroadcasting Stations. For near 5 years, China's global communication system has developed vary fast in company with the fast economic development. Now the global communication system is centered by cities, expanding around. Because the obstacles of ground objects and buildings, the effects of receiving of global communication are not good on the outside areas of cities, the areas between cities or even some areas within a city due to the location, distribution and amount of rebroadcasting stations. At present, the so-called *Global Linking* or *Linking Global* is just a partly linked and the communication in many areas is seized up. In order to meet the needs of the designs of global rebroadcasting stations, it is necessary to plan and design the best options of them, in the supporting of accurate digital model built-in the information of land use, land cover to pledge the realization of global

linking.

6).The.Engineering.Design.of ommu-nication Networks and Selecting Lines for the Transferring South Water to Northern Areas. For expediting the market-orient economy, it is necessary to construct railway and highway networks. For solving the drought problem in north areas, the water transferring from south to north is urgently need. Whether the abound of water resources in south areas can be transferred to North China and the Yellow River, is concerned by the people all over the world. It is not to meet the needs if the traditional method of selecting lines. On the basis of setting up high accurate digital elevation model and digital unit model, according to the requirements of line selecting and at the support of special software's and electric navigating techniques, multi-options of line-selecting can be compared and optimized in order to select a optimal plan.

7) Providing a Virtual Earth Environment for the Study of Geo-science. Along with the progress of using and changing the earth environments, the understanding of constitution of the earth system and interworking among the sphere has been deepening. The constitution and interworking, however, are very complex. There are many major difficulties need us to understand and exploring, for example, the movements of continental plate, the raising of Qing-Tibet Plateau, the cause of formation of global dissertation, the mechanism of hazard climate and the cause of formation of earthquakes. In order to study the major problems of geo-science, on the basis of setting up digital elevation model and digital unit model all kinds of information needed by scientists may be built-in to establish a virtual earth environment to make researches of multi-topics and multi-variables. These can play important roles in boosting research's qualities and speeding up research's steps. The road of era of information is wide and glory. The opportunity is God-given. In the construction and researching of digital earth, we must nearly go from the requirements of our country's economic construction, grasp and tackle the major problems such as en-vironment pollution, decreasing of cultivated land, occurring of natural disasters and the unbalances between eastern and western parts of China, which restrict country's economic development. We must turn our hands to the mission, catch up with the adv-antage of world's information technologies, make achievements with high lever and bo-ost sustainable development of the country's economy to bring into playing important roles.

