DIGITAL EARTH WITH DIGITAL MEASURABLE IMAGES

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ABSTRACT:

Digital Earth is a visionary concept and outlines a charming prospect for the public. This paper starts from the concept and technologies of digital Earth and analyzes the architecture of geo-spatial information services of Digital Earth according to the developing trend of requirement for geo-spatial information services.
As a promising prospect for Digital Earth, the digital measurable images (DMI) from aero-space and land borne geo-referenced image are introduced and their working principles are given in detail. Through analyzing how DMI achieve the four functions of Digital Earth including searchable, visuable, measurable and minable, the conclusion that DMI can satisfy the need of Digital Earth, especially cyber geographic environment, is testified.

1. INTRODUCTION

What is Digital Earth? This is an interesting scientific topic. Digital Earth is a visionary concept, popularized by former US Vice President Al Gore, for the virtual and 3-D representation of the Earth that is spatially referenced and interconnected with digital knowledge archives from around the planet with vast amounts of scientific, natural, and cultural information to describe and understand the Earth, its systems, and human activities.
Digital Earth represents a rich convergence of technological advance, active visionaries and recognition of the paramount need for humans to better understand the Earth. And the industry pioneers who lead the 3D Earth visualization software will present their corporate philosophies and investments for building a true Digital Earth.
Agency leaders from NOAA, NASA, and the United Nations have defined the governance aspects of programs that are helping evolve the Digital Earth Vision.
Digital Earth relates to such supporting technologies as Scientific Calculating, Mass Storage, Remote Sensing, Wide-band Network, Inter-operability and Meta data. Virtual Reality, Geographical Information System (GIS) and Internet are three foundations of Digital Earth. That is to say, in the first place Digital Earth is a virtual reality system that makes people feel to be personally on the scene. In the next place, Digital Earth organizes vast amounts of geo-spatial information through GIS. At the same time a global information network is established to realize resources sharing.
Three layers are necessary for the construction of Digital Earth, as shown in Figure 1. The first layer is Information Infrastructure composed of Space-Based Information Network and Internet. The next layer is Spatial Information Infrastructure. The third layer is thematic data including the files of humanities, geography and economy and corresponding mining tool.

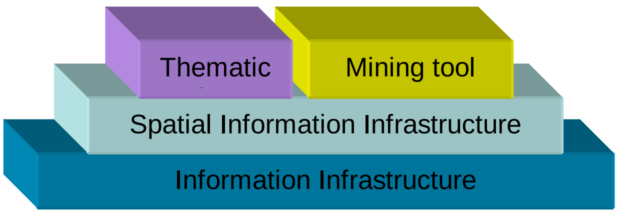

Figure 1. three layers for the construction of Digital Earth

2. THE FOUR FUNCTIONS OF DIGITAL EARTH

What Digital Earth can do for us? Let's see the functions of Internet at first. Internet is something more than information. Internet provides a platform of information sharing, searching and releasing. Currently, almost all mainstream business on Internet is involved with information.
As a media which carries more than 80% of information related to human activities, geo-spatial information plays more and more important roles on Internet services. On the other hand, the quick development of network (the 3rd generation of Internet), 3G （the 3rd Generation of Communication Systems）and Grid technology and the coming out of Google Earth makes geographic information and 3S(GPS,GIS and RS) technologies available, which originally only can be reached by professional users. All internet users can carry out various

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kinds of web services, a majority of which is free, on a uniform web platform. The public geo-spatial services will improve the application and prevalence to a great extent and reduce fund devotion in application process, and therefore promote the explosive increasing of the whole business. Global geo-spatial information sharing plays great role in economic increase macroscopically.

At present, the realization of geo-spatial information services platform mainly rely on 4D product (Digital Elevation Model, Digital Raster Graphic, Digital Orthophoto Map, Digital Line Graphic). With the improving of social informazation, the requirements for geo-spatial information are increasing. The integrality, exactness and up-to-date of geo-spatial data play critical role for the quality and effectiveness of geo-spatial information services. With an eye to the developing trend of requirements for geo-spatial information services, the directions include mass, high-resolution, visuable and minable. With the third Internet Tidal Wave, the concept of Digital Earth and corresponding technologies including Grid and Digital Earth brings new working mechanism for all kinds of business application. According to the concept of Digital Earth, the services provided for users need to satisfy the following six characteristics: Certainty, Experience, Communication, Variation, Creativity and Relation. As regards geo-spatial services, searchable is the basic attribution; visuable is the basis of Experience (e.g. Google Earth and Microsoft Virtual Earth); measurable is the guarantee of Variation and Creativity; minable is the guarantee of Relation. So we make the conclusion that searchable, visuable, measurable, minable are the four functions of Digital Earth.

Service platform based on geo-spatial grid can integrate Web 2.0 technology such as Ajax and provide interactive intercommunion service for users. The architecture of geo-spatial information services of Digital Earth is illustrated through Figure 2.

3. DMI INTEGRATED WITH SEAMLESS STEREO IMAGE CAN SATISFY THE NEED OF DIGITAL EARTH

3.1 The principle of "measurable seamless stereo image"

For a photographic block, many stereo models can be formed by stereo pairs. Figure3 illustrates a block consisting of three strips, with six stereo models in each strip.

In this figure, the overlapping area two adjacent images is called the stereo extent; and a line in the overlapping areas between two adjacent stereo models is called a seam line. The polygon area formed by the seam lines of every stereo model is called valid mosaic polygon of the model.

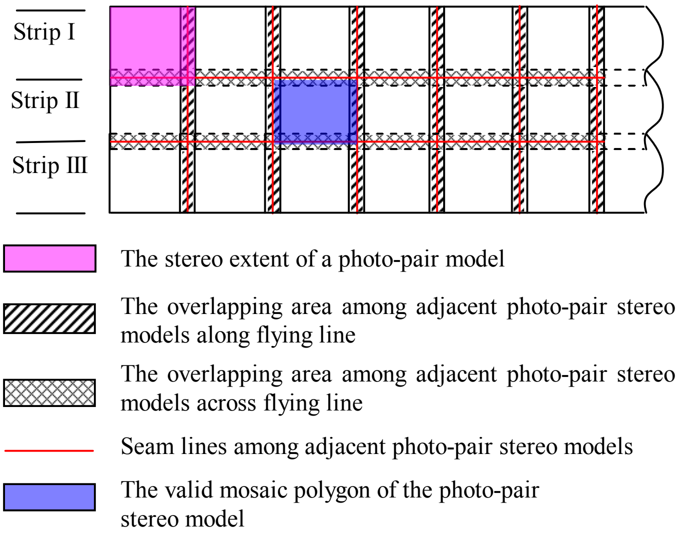

Figure 3. The arrangements of photo-pair models

The mosaic of othoimages of all the valid mosaic polygons in effect covers the whole block seamlessly. Two such seamless could be produced. One is produced from all the left images, leading to a left mosaic, and the other produced from all the right images, leading to the right mosaic.

To produce a stereo view, parallax needs to be introduced to one of the mosaic (e.g. the right mosaic) to form a so-called mosaic stereomate. The value of the parallax for each pixel is a function of the height at its position. Then the left mosaic and the mosaic stereomate form a seamless stereo model.

Such a seamless stereo model is good enough for visualization purpose.To make the accuracy as high measurement, the following strategy is adopted here in this study:

1. The 6 orientation parameters of each image are recorded in a file (i.e. orientation file);
2. The linage of each pixel on both the mosaic orthoimage
3. and mosaic stareomate is recorded. That is, for each point (pixel) on the seamless stereo model, the system knows (a) the (original) left and right images where it is derived; (b) the orientation parameters of both images; and (c) its image coordinates on both images.
4. With such information, when measurement is performed, the ground coordinates of each point on the seamless stereo model is directly computed from original stereo-pair instead of the image coordinates on the mosaic orthoimages and mosaic stereomate.

Such a seamless stereo model is called the measurable seamless stereo model (Figure4).

Geo-spatial information service requirements on Web 2.0

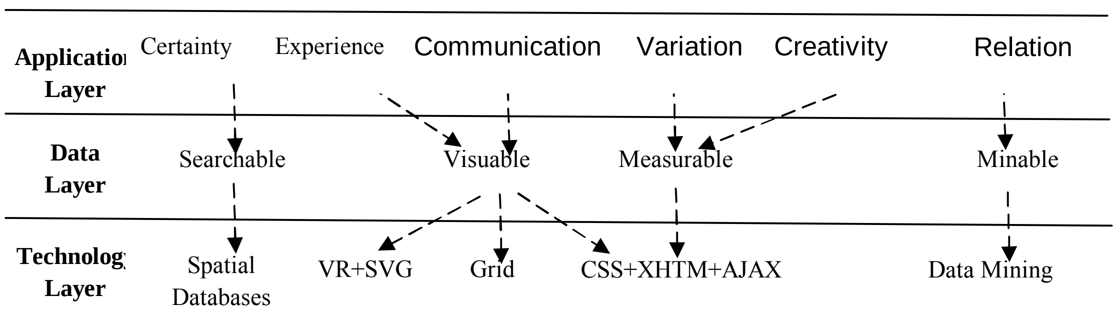

Figure 2. Geo-Spatial Information Service Requirements of Digital Earth on Web 2.0

Figure 4. a 3*9 block of measurable seamless stereo models with three strips

3.2 The integration of DMI and seamless stereo image

Firstly a seamless stereo image database is built and through its navigation function similar to Google Earth and Virtue Earth is realized. When Region of Interest (ROI) is selected, a concept called Visioncruiser^{TM} is put forward, which is related to the integration of Digital Measurable Images (called DMI) and seamless stereo image for the sake of browse, query, measurement and information mining, shown as Fig 5.

Figure 5. The integration of DMI and seamless stereo image

3.3 How to generate Digital Measurable Images?

In this paper a system called Visioncruiser^{TM} is designed and manufactured to generate seamless digital measurable images. The system integrates geodetic quality GPS, inertial navigation system (INS) and multiple digital stereo cameras that are mounted on a land vehicle.

It proves to be the most rapid, convenient, accurate and economic tool of collecting and updating geomatics data. Visioncruiser^{TM} has been used on over 220,000km of right of way in China.

Visioncruiser^{TM} contains spatial semantic information which can not be described by traditional maps. Visioncruiser^{TM} represents the physical situation of the true Earth and catches knowledge based GIS. Thus, the plentiful information of geography, economy and humanities contained in Visioncruiser^{TM} is data source of geo-spatial services. The working principle of Visioncruiser^{TM} is illustrated by Figure 6.

In Figure 6, data is collected from a Visioncruiser^{TM} vehicle traveling at standard road speed. The vehicle captures highly accurate GPS data and best-in class consecutive images while traveling along defined routes.

As a new surveying technology, Visioncruiser^{TM} provides Mobile Mapping System (MMS) which collects Digital Measurable Images (DMI) of roads and sideward objects as the vehicle, which is furnished with such sensors and equipments as GPS, INS/DR and CCDs, runs in high speed. Users can implement measurement-on-demand between various elements, especially the elements besides the road, according to concrete applications based on these referenced DMI.

4. VISIONCRUISER^{TM} CAN PROVIDE THE FOUR FUNCTIONS OF DIGITAL EARTH

4.1 Searchable of Visioncruiser^{TM}

The function of searchable makes convenient, easy, quick query of interesting information become a reality. DMI is integrated with spaceborne/airborne image resources or users' existing data resources seamlessly in Visioncruiser^{TM}, as

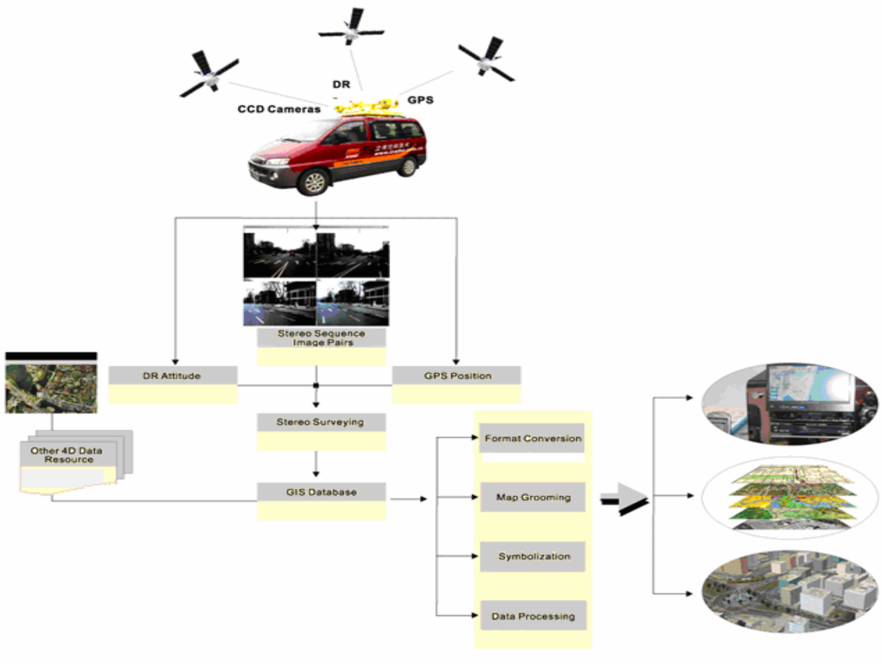

Figure 6. The working principle of VisionCruiserTM

shown in Figure 7, which results in Point-of-Interest (POI) services on Digital Earth as easy as on general electric map. That is to say, when users roam in image space built on the basis of digital images acquired by Mobile Mapping System (MMS), corresponding properties of certain interested object (i.e. bank or shopping mall) can by gotten just by clicking it simply. The operation is as easy as we do it on electric map. The difference is that query by images is more humanistic and more accordant with the requirements of Digital Earth. As illustrated in Figure 8, a query result of the position of POI, here is a Hotel, is returned.

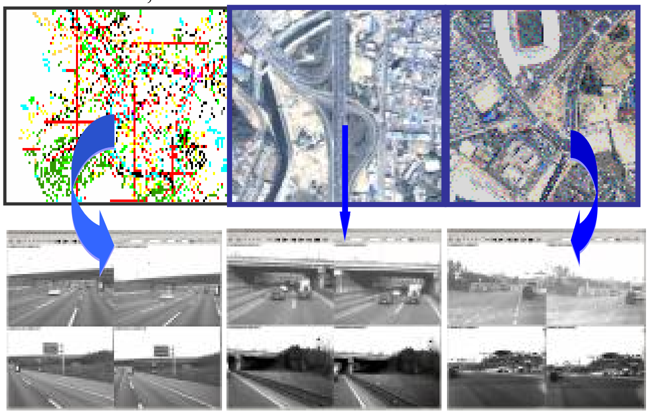

Figure 7. Seamless integration of different data resources

Figure 8. Searching POI images (a Hotel)

Figure 9. The Window of annotation

4.2 Visuable of Visioncruiser™

Here measurable 3D images are contained in the content of visualization other than vector data and raster image data. The goal is to make the representation of objects more vivid and comprehensive. Digital measurable images (DMI) collected by MMS are known as a new products introduced to spatial database. Mass referenced Digital Measurable Images accord with the custom of human activities, which cover information of geography, humanities and economy and have become the preferred product of visuable images series.

Visualization is the most intuitionistic characteristics of Visioncruiser™. A series of video images, which are obtained by double CCD cameras, are matched through image correlation technology. And therefore stereoscopic images are generated to reach the purpose of What You See Is What You Get. Figure 10 shows the visualization result of Qinghai-Tibet Railway, China.

Figure 11 and Figure 12 illustrate two other results of visualization. While the visualization of Figure 11 is the integration result of DMI and aerial image, the visualization of Figure 12 is the associated result of DMI and electric map in vector format. Obviously, the integration results accord with human vision more than single images or vector graphics.

Figure 10. the visualization result of Qinghai-Tibet Railway, China (the total length of Qinghai-Tibet of 2284km, data collection spends 7 days, data processing spends 10 days, resources include 2 operators, 1 MMS vehicle and 1 railcar)

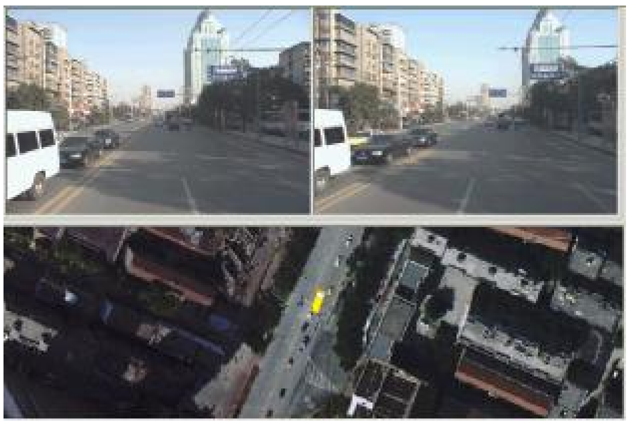

Figure 11. the Integration result of DMI and aerial image

Figure 12. the Integration result of DMI and electric map in vector format

4.3 Measurable of Visioncruiser™

The contents provided by Visioncruiser™ are a general definition of 4D product and Digital Measurable Images (the fifth dimension product other than existed 4 Digital products DEM/DOQ/DLG/DRG). Users can customize concrete services according to their own requirements and implement direct and convenient browse, relative surveying, absolute posing and analytical surveying etc.

DMI gathered by MMS carries such data as External Orientation Elements and Attitude Elements. Cooperated with accurate time parameters, these data constitute the basis of surveying on multiple level and seamless merging of database.

Generally, the height and area information of a building is difficult to measure and the usual method is to get through querying attribute database which save these information by traditional surveying in advance. That is to say, if the information we interested are not stored in database beforehand, they cannot be reached through query operation. However in Visioncruiser™, all information of an object including length, area, perimeter etc can be obtained in real time. Figure 13 shows a result of a real-time measurement by end user on Web. As shown in Figure 14, the distance from appointed site to telecom building is measured.

Figure 13. Measurement of road width and object height by end users on web

4.4 Minable of Visioncruiser™

While the scene exhibited by 4D product is the projection of real world on 2D surface, the scene exhibited by Visioncruiser™ is 3D images. This provides natural and social information which can be mined. Users can achieve attribute information mining through corresponding application software, plug-in and API according to their concrete applications. Visioncruiser™ offers extensive data support for further application including Visibility analysis, transportation ability, business position selecting.

Figure 14. the measured distance from appointed site to telecom building

The information that a great deal of users needs is that relating with professional application and personal lives such as electric equipment of Electric Power Department, Municipal Facilities of Administrative Department, safeguards of police department (fireplug and doorplate et al), traffic information of transportation department and position demand of dining-room etc. All the information can not be covered by traditional 4D product perfectly and effectively, while it can be gained by Visioncruiser™.

For example, certain rule can be discovered from texture images according to content-based retrieval. Figure 15 is the mined result of attribution information through POI retrieval.

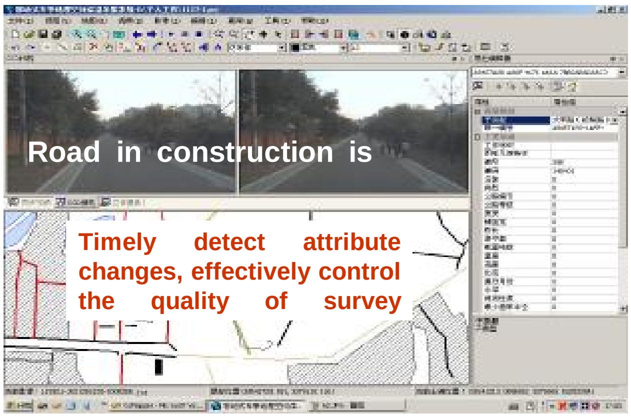

Figure 15. the mined result of attribution information through POI retrieval

5. CONCLUSION

Based on the developing trend of requirements for geo-spatial information services, this paper gives the concept and technologies of Digital Earth, followed by analysis of the architecture. The concept of a measurable seamless stereo model is proposed. The experimental results illustrate that such a measurable seamless stereo model is be achieved.

An integrated system, i.e. Visioncruiser™ integrating a measurable seamless stereo model is introduced to provide a solution to the four functions of Digital Earth. The Digital Measurable Images collected by MMS provide a promising prospect to GIS application and geo-services and it is obviously more advantageous to existed 4D products.

In conclusion, with the ability of meeting the requirements of Measurement-on-Demand geo-spatial Information services for end users, Digital Measurable Images(DMI) is a promising prospect for Digital Earth as well as for VGE.

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