

The Potential of Virtual Reality Imagery to the Digital Earth Concept

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ABSTRACT In January 1998 US Vice President Al Gore introduced his revolutionary concept of Digital Earth. His vision of a multi-resolution, three-dimensional representation of our planet has stimulated many scientists. This paper discusses this concept showing that it should become an international cooperative programme instead of merely a US initiative. The role of Virtual Reality and remote sensing imagery is vital to the success of this concept and the paper treats several of the relevant issues related to virtual reality. After describing the role of education and training, both as beneficiaries of the Digital Earth Concept and as end users, the paper closes with some conclusions and recommendations related to Digital Earth. A selection of relevant literature and Web-based sources on Digital Earth and Virtual Reality is provided at the end of the paper.

KEY WORDS Digital Earth, Virtual Reality, Remote Sensing, Education

1. Introduction

As Juhani Kuusi, Head of NOKIA's Research Centre in Finland stated recently, the information society builds on the rapid convergence of computers, mass media and telecommunications. Mobility, Internet and their interconnection are the dominant global drivers affecting the development of the future information society services and applications.

The Digital Earth Concept proposed by US Vice President Al Gore fits in well in this information society concept. It is a useful framework for multistage remote sensing imagery, zooming in from the geostationary satellite imagery of the Earth such as provided by Meteosat, through polar-earth observation satellites ranging in resolution of one kilometre (e.g. VEGETATION sensor on board SPOT-4), through 120 metres (RESURS), 80 metres (Landsat MSS), 30, 20, 15, 10, 5 metres (Landsat 5, SPOT XS, Landsat 7, SPOT PAN, IRS-IC), to the 1 metre IKONOS imagery, before seamlessly continuing to zoom in on airborne imagery up to centimetre spatial resolution. However, as for many practical applications we need to study the Earth's surface and the Earth's processes in three dimensions, the technology of Virtual Reality, where we combine imagery, DTM's and other data sources, is becoming an increasingly useful tool, especially in relation to the Digital Earth concept.

This paper will first provide an introduction to the Digital Earth concept, then discuss the benefits of Virtual Reality, before treating the important role of education and training in combining these concepts and bringing them to students, decision-makers,

industry and the general public. The paper concludes with some conclusions and observations on what may be expected in the new Millennium.

2. The Digital Earth Concept

On 31st January last year, the American Vice President Al Gore gave an address at the California Science Centre in Los Angeles, entitled "The Digital Earth: Understanding our planet in the 21st Century". This was a revolutionary concept and has changed the way we look at our planet, as well as being the reason for this conference in China.

In his concept, he envisages Digital Earth as:

- (1) a multi-resolution, three dimensional representation of the planet
- (2) a new framework for integrating a wide variety of geo-referenced data, including natural, cultural and historical components, not limited to 3D space, but also able to deal with time.
- (3) This of course is excellent for modelling processes, be it short term hazards, or long term climate change, geological processes, etc.

His interested audience for Digital Earth is not only remote sensing scientists, but also for the general public. This requires a user interface, which has a more natural immersive environment, facilitated by easy navigation and user interaction. This is where Virtual Reality comes into the foreground as one of the most suitable methodologies to demonstrate the concept of Digital Earth. This is discussed in the following section.

As the Vice President said in his speech, most of the technologies and capabilities that are required

to build a Digital Earth are either existing or under development.

His encouragement to develop a digital map of the world at 1 metre resolution has come a step closer with the successful launch of the IKONOS satellite. In Europe, one of the main organizations involved in this concept and with Virtual Reality and high resolution imagery is the West European Union Satellite Centre in Torrejon, Spain (Prisco, 1999).

In the USA, an Inter-Agency Digital Earth Working Group has been meeting bi-monthly for over a year to plan this USA activity. To date, participants include NASA, USGS, NOAA and many defence agencies (NIMA, DARPA, Army Corps of Engineers). Unfortunately, the participation to date has been limited to US agencies. This is of course totally unacceptable, as there are over 200 sovereign states on this Earth, and no one nation has the sole right to such a concept. Hence this conference, where scientists from many other countries are exchanging information on this concept of Digital Earth is an initiative to be strongly supported. To handle such a concept as Digital Earth, there is probably not a single organization or country that could manage it by itself. Hence, just like with the Internet, we should aim for an internationally distributed network to get the data to the end-users. There are enough technological challenges to be met in order to realize the Digital Earth concept to share such research internationally. In the next section we shall discuss how Virtual Reality and high resolution imagery can make a contribution to this Digital Earth concept.

3. Virtual Reality

When one considers VR systems, there is a tendency to think of head mounted displays. However, this is a narrow view. There are three main types of VR: fully immersion systems, semi-immersion and non-immersion.

- Fully Immersive VR: To achieve this, the user has to employ a head mounted/coupled display. A sense of full immersion is achieved because the display provides a visual image wherever the user is looking, i.e. it provides a 360° field of view. Of course the sense of immersion is a function of the quality of the display, in terms of image resolution, field of view, update rate, image lags, etc.
- Semi-Immersive VR: This is based on a fixed wide angle display system in excess of 60°, provided by either
 - a large screen monitor,
 - a large screen TV projector, or

- multiple television projection systems.

These are the systems well known to the public from the IMAX theatres around the world. As many people can share and be involved in the same virtual environment, it has great value as an educational tool.

- Non-Immersive (Desk Top) VR: This is also popularly known as “fish-tank VR”. The main features of a desk-top VR system are its use of a computer generated virtual environment (e.g. Digital Earth), which is delivered by a hi-res monitor and a PC, with fairly standard interaction devices such as keyboards, mice and joysticks. For true 3D a means of viewing the display stereoscopically is required.

The following Table shows a qualitative performance assessment of these three different VR systems.

Main features	Qualitative Performance		
	Non-immersive VR (Desk-top)	Semi Immersive VR (Projection)	Full Immersive VR (Head-coupled)
Resolution	High resolution	High 1000-3000	Low-medium 300-1000
Scale (perception)	Low	Medium-high	High
Sense of situation awareness (navigation skills)	Low	Medium	High
Field of regard	Low 50° typically	Medium 150°	High 360°
Lag	Low	Low	Medium-high
Immersion	Non-low	Medium-high	Medium-high

Table 1: Qualitative Performance of Different VR Systems

In the broader context, a VR system allows a participant to:

- Become immersed in a completely synthetic computer generated environment such as Digital Earth
- Achieve a sense of presence in the environment
- Become un-inhibited where conventional laws of physics can be controlled in a way that assists greater understanding of our planet.

- Achieve a sense of non-real time; where processes on Earth can be presented in slow or fast time
- Achieve a high degree of interaction that can equal or exceed that achievable in the real world
- Interact in a completely natural and intuitive manner with the synthetic Digital Earth environment
- Repeat the task until the desired level of proficiency or skill has been achieved
- Perform in a safe environment.

Figure 1 depicts a model of a Virtual Environment system such as Digital Earth.

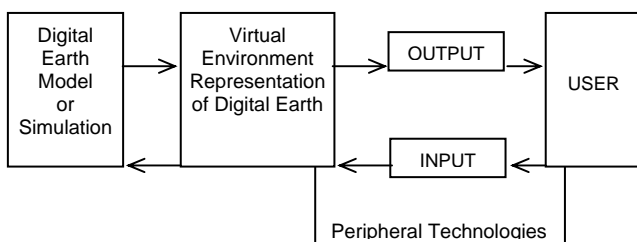


Figure : Model of a Virtual Environment such as Digital Earth.

The Digital Earth Model or simulation is a mathematical representation of the Earth. For example, a mathematical model can be produced that represents the dynamic behaviour of the oceans in relation to the climate change (sea-level rise). The user then has the ability to increase or decrease the sea level, increase or decrease the coastal dykes, or let nature take its course and see what happens. The peripheral technologies represent the input and output devices such as head mounted displays, glove-like devices, etc. The user is of course a very important part of the VR system. Here the continuous feedback role that the user provides in a VR system should be emphasized.

Image-based rendering (IBR) is an emerging technique of relevance to Digital Earth, in that it gets around traditional modelling difficulties. New images for rendering, or view synthesis can be directly generated from existing remote sensing imagery, rather than from a geometric model. Kang (1997) has reviewed these IBR techniques and has shown that they are not only easier than model-based methods, but also increase the speed of rendering. The technique of geometrically valid pixel re-projection has particular potential for remote sensing imagery in the Digital Earth.

Chapman and Deacon (1998) describe another very promising method for making digital image

data more accessible to end-users is "panoramic imaging". A number of viewing packages support such panoramic images and enable users to continuously scroll around a panorama whilst warping the image to simulate realistic perspective distortions as the image is rotated (see for example: <http://www.ge.ucl.ac.uk/vucl>). Such techniques start to put more reality into VR.

The Shuttle Radar Topography Mission (SRTM) will map the world in 3D. Some of the products that will be routinely delivered to NIMA in the US will be:

- Level 2 Terrain Height Data Sets (20 m in X and Y; 16 m in Z)
- Random height error data sets
- Orthorectified image data sets.

Such 3D image data sets will be a major input to many Digital Earth applications. The SIR-C Virtual Classroom gives a preview of what we can expect in the near future, with 3D fly through of imaging radar data.

4. The Role of Education and Training

Education, often described as "the act or process of acquiring knowledge" is universally recognised as a cornerstone of human development. As such, it is becoming one of the most commonly targeted areas of reform in many Developing Countries. For them, as well as their more advanced counterparts, a skilled and knowledgeable human resource base is regarded as an absolute pre-requisite for successful participation in today's rapidly globalizing information society.

Internet technology has a deep impact on education. HTML forms the standard at present for hypertext documents, which may include text and images. 3D images, realised in VRML (Virtual Reality Modelling Language) graphic language files may be added in order to describe interactive simulations of many aspects of "Digital Earth" connected to the www resources through a visualization interface.

If Developing Countries such as China wish to participate in the knowledge-intensive information society of the 21st Century, they must be able to produce large numbers of scientifically and technologically literate, innovation receptive, highly adaptable, and problem solving minded scientists with a predisposition to lifelong learning. Of course it is imperative that they do this in an accelerated timeframe.

Many current educational methodologies are based on the model of rote memorization and do not encourage critical thinking, problem solving and creativity. These are skills essential for a market driven society. The concept of Digital Earth is a useful framework, coupled with remote sensing,

GIS and VR technologies to promote such creative expression.

In ITC's Applied Geomorphological Surveys, image processing laboratories, fast workstations networked together provide desk-top VR, using as a basis ERDAS's Virtual GIS software together with various other image processing software packages (Fig. 2). Of course, these facilities fade into

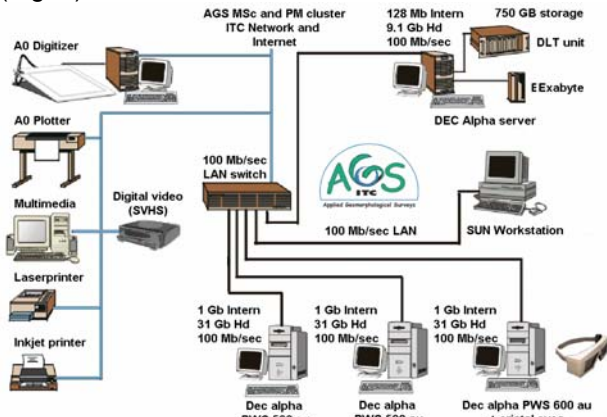


Fig2: Configuration of the AGS new high performance facility.

Potential use	Benefit-compared to traditional methods
Simulation of complex environmental systems	Ability to observe environmental system operation from any number of perspectives, aided by high quality imagery visualization and interaction
Synoptic and detailed visualization	Earth observation of landscape features that would be either too small or too large to be seen on a normal scale system
Fast and slow time simulation	Ability to control time scale of events in the Digital Earth in a dynamic event, such as sea-level rise, natural disasters, etc. This feature operates like a fast forward or rewind preview of a video recorder.
Allow high levels of interactivity	Most people learn faster by "doing" and VR systems provide much greater levels of interactivity than other multi-media based learning systems
Sense of immersion, a powerful characteristic	In some Digital Earth applications the sense of scale is very important. For example in 3D landscape fly-through, or zooming from space to individual object level, a sense of scale is required to visualize the landscape
Inherent flexibility and adaptability	The inherent flexibility of a VR system comes from the underlying software nature of the virtual environment such as Digital Earth. One can easily load different application environments

Table 2: Comparative Benefits of a VR Educational System.

insignificance compared to the CGSC Warlab", which also uses the same software, but use three overhead-mounted Barco projectors onto a 12 metre wrap-around VR screen, (CGSC = the US Army Command and General Staff College, at Fort Leavenworth, Kansas, USA).

Even at secondary and tertiary education level, by far the most prolific country to try VR in education is the USA. Here the concept of "Information superiority" is so deeply rooted, it forms a basic premise of the country's philosophy to new technology. Hence the concept of "Digital Earth", although originally promoted as a political term for the general public, is one that provides a beacon or catch-phrase for further 3D VR study of our planet.

There are of course many areas where VR, RS and GIS could be used to support education in the "Digital Earth" concept. The following table shows the educational benefits or attributes that can be expected.

5. Conclusions

The value of virtual environments in relation to the Digital Earth concept can be enhanced further by:

- Producing case studies
- Providing application-oriented examples
- Reviewing international work
- Reviewing related technologies.
- In a fast changing field such as VR it is important to fully understand the implications of the technology and in particular where and how it can be used in contribution to "Digital Earth". Eventually the technologies will allow Digital Earth to be available on-line through the Internet, once issues such as band width and image rendering speeds are solved.
- The fundamental shift in the new global information society places an increased role on knowledge and information as a critical factor of production. Knowledge and information now ranks as high, if not higher than other major resources – human, financial, natural, etc. as necessary key inputs to a country's development strategy. They are essential in improving a country's productivity, innovation and competitiveness. Furthermore, knowledge and information are unique resources in the sense that they have the power to accelerate and reinforce the development of the other resources. The concept of Digital Earth forms a useful medium to promote development of the integration of RS, GIS and VR.
- The concept of Digital Earth, conceived by the US Vice President in 1998 is an excellent

initiative which will have a profound impact on pushing the frontiers of information technologies such as high resolution 3D imagery, Virtual Reality, multi-sensor image and data fusion, etc. However, it should be broadened to become an international scientific cooperation initiative, as we all live on the same Earth and have to share its resources.

Hence when Gore states that Digital Earth could become a "collaboratory" (i.e. a laboratory without walls) we should expand this concept for all international research scientists seeking to understand the complex interaction between humanity and our environment on planet Earth.

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