Virtual Geographical Environments: Concept, Design, and Application

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ABSTRACT Virtual Geographical Environments (VGE) are Web- based and graphical worlds in which multi-participants can communicate with each other, and interact with virtual objects that either simulate physical geographic objects or are designed by imagination. VGE can be understood as either evolving and self-organization systems or application systems for dealing with geo-referenced phenomena and process. Virtual geography can be taken as a new dimension of geography that studies that the character of VGE and the relationship between virtual and physical geographical environments. This paper focuses on the system design of VGE. The balanced client/server architecture, web-based and object-based data model, and 2-D and 3-D view based user interface, and 3-D avatars of VGE are discussed in detail. A case study of ShingMun Country Park of Hong Kong is presented and a system prototype, called VirtualPark, is established for managing and disseminating information of ShingMun Country Park, and facilitating public participation in policy-making, protection of ecological systems, and the development of the tourist industry.
KEYWORDS Virtual Environments, Virtual Geography, Immersive, Distributed, Virtual Space, Avatars, Java, VRML

1. Introduction

Rapid development of the Internet and the World Wide Web has been reshaping our world. Geo-referenced information can now be distributed, disseminated, displayed, and interpreted on the Internet (Doyle and Dodge, 1998). The importance of geographical distance and place has gradually decreased in the information society. Geography is a discipline of space and place. Online community and virtual company, however, exist in cyberspace, in a hyper information space at elsewhere (i.e. at nowhere). This means such a reality has just space with no places. As a result, researchers addresses the dead of distance, annihilation of places, shrinking distance and time to zero, and even the dead of Geography in virtual worlds that lead to a deep thinking and wide discussion for geographers in the context of future Geography (Batty, 1997; Kitchin, 1998).

With the virtual reality technology and Web-based VRML (Virtual Reality Modeling Language), 3-D information can be mapped into 3-D graphics that may form 3-D worlds in which we can walk and live (Dykes et. al., 1999; Green, 1997; Plewe, 1997; Strand, 1997). Therefore, it makes possible for us to hold places in cyberspace. Because there are places, there should be a new dimension of Geography in cyberspace. Resulted from VR, virtual environments are now under way of being defined, modeled and developed. By applying virtual environments to geographical issues, this paper presents the concept of virtual geographical environments (VGE). It will be studied from two aspects, namely evolving worlds and application systems.

The structure of this paper is as follows. First, the concepts and characteristics of virtual environments and VGE, as well as virtual geography and VGE systems are addressed in the second section. Next, the system architecture, web-based data models, interface, and avatars of VGE are studied in detail. In the fourth section, a case study is presented. The last section concludes with a discussion of further research directions.

2. Virtual Environments and Virtual Geographical Environments

Immersive virtual reality (VR) and online VR to date are two main aspects of virtual environments (Batty et. al., 1998; MacEachren et. al., 1999). Traditional virtual reality technology makes participants interact and communicate with realistic 3-D objects in an immersive or semi-immersive way. Projected VR systems allow many users to participate in the same virtual world in a semi-immersive way; VR systems with headsets, data-glove, data suit and the like provide capability of making users be present in 3-D worlds and have a realistic feeling as they do in the material world. Based on the Internet and the World Wide Web, online VR, however, enables distributed users to be virtually together, and have an interaction with each other, and with shared virtual 2-D or 3-D worlds. Depending on the above discussed, we argue immersive VR focuses on the relationship between users (in the same place) and virtual 3-D worlds, while online VR on the interaction among users located in different places in a virtual society. Virtual environments (VE) thus can be defined as the integration of major elements of immersive VR and online VR, that allow distributed users to virtually get together and interact with a 3-D graphical world in an immersive or semi-immersive way on the Web.

Naturally, if environments simulate or represent geographical environments in reality or in possibility, i.e., if environments describe geographical phenomena and processes, the virtual environments will specially be the VGE. There are two ways to understand virtual geographical environments. From the perspective of tools, as application systems, VGE enable geographers to compute, display, interpret, and verify geo-referenced data for getting understanding , rules, or laws of geo-referenced phenomena, or for supporting planning and decision-making. From the perspective of system, as evolving and self-organization systems, VGE can provide the humans with space and places to live in social, economic, and political ways. The interaction between virtual geographical environments and real geographical environments and their gradual integration and fusion will greatly remake our humans, and reshape this world.

According to the two levels of understanding VGE concept, this paper introduces virtual geography and VGE systems.

2.1. Virtual Geography

Virtual Geography, cyber Geography, imagined Geography, and Geography in the information society are all the similar terms found in the present volumes that show the impact of modern information technology on Geography.

Batty examines virtual geography in terms of geographical space-place, cspace, cyberspace, and cyberplace, and his ideas of virtual geography focuses on space-place and the relationship and interaction between cyberspace (the Internet and the Web) and the physical (material) world (Batty, 1997). Crang et. al. addresses that focus on what sort of virtual technosocialities one chooses decides the character of virtual geographies. To date, few efforts have been placed on just the new virtual worlds and thus on dealing with the issues of the dead of place in cyberspace.

Based on the above discussion of VGE, we argues virtual geography is to study the characteristics and laws of phenomena and process concerning VGE as well as the interaction and integration between VGE and real geographical environments. Here, the VGE should be understood as evolving and self-organization systems.

2.2. VGE Systems

As application tools , VGE systems can be applied to handling and analyzing geo-referenced data. It is under way to integrate traditional GIS, geographical application models, AutoCAD, and distributed tools such as ActiveX, VRML 2.0, Java, Java3D and the like on the Internet to construct VGE. In the process of building VGE systems, the key issues are system architecture including client/server structure and choice of Internet-based tools, user interface, 3-D avatars, processing of complex and large worlds and shared objects, spatial analysis and data query, model simulation and interpretation, collaborative work, and so on. At present, most VGE are being developed, are rudimental, and just focus on some aspects of VE.

Batty and his group employ ArcView Internet Map Server to design an Internet-GIS to deliver 2-D GIS information and 3-D worlds (using functions of ArcView 3D Analyst), and to provide simple spatial analysis and query, but its performance seems not very well because of every operation required to be sent to the server to be handled, and it has no abilities to carry out collaborative work among distributed users. Therefore they also employ Activeworlds systems and immersive VR to design VGE.

AlphaWorld is a very large virtual world that can be accessed by using the Activeworlds system needed to be installed on the use’s computer first, and provides a good virtual place to allow participants to get together and communicate with each other, but it has no capability of dealing with information analysis, thus just serves for virtual social activities (Activeworlds, 1999).

In terms of applications, VGE can be used for navigation, science(analysis), design, games, etc. (Batty et. al., 1999). In this paper, we design VGE systems to manage and disseminate a variety of multi-dimensional, multi-source, multi-level geo-referenced data, to implement model simulation, computation, and exploratory visualizaion, and to serve for public participation in decision and policy making across the Web.

3. System Sesign of VGE

3.1. System Architecture

There are a variety of ways to develop 3-D graphics based applications on the Web. The main factors to construct a web-based application involve the choice and combination of traditional programming languages such as C and C++, web-based programming tools such as Java, Java3D, and ActiveX, 3-D scene modeling languages like

VRML97, as well as different schemes of thick/thin client and heavy/light server (Lin et. al., 1998; Rohre and Swing, 1997; Verbree et. al., 1999). In this paper, we employs a balanced client/server structure, Java, Java EAI and VRML97 to design the VGE architecture.

A balanced client/server structure signifies that some tasks are handled on the server side while others on the client side (Fig. 1). The working mechanism is as follows. When a user on the client side sends requests such as a change of VRML world, spatial query and the like on the VE interface to the server computer, Java server applications or a 3-D object database server will be fired to deal with the requests on the server side. As tasks are accomplished, the results will be transferred to the client computer to be handled by the VRML viewer or Java applets.

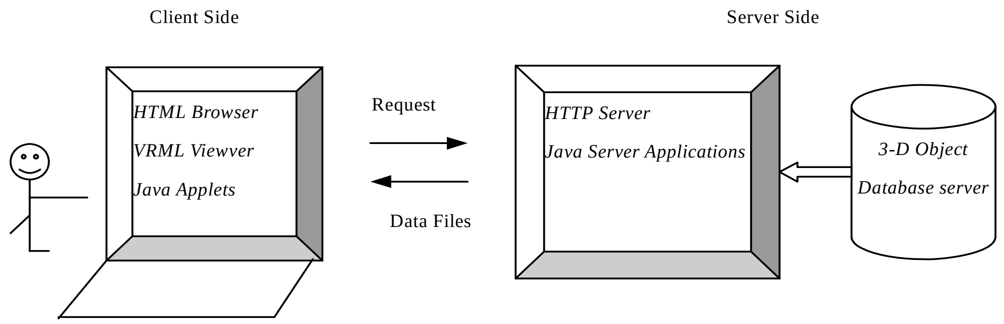

Figure 1. Balanced client/server architecture of virtual environments

On the client side, the communication and interaction between Java applets and VRML world can be carried out by way of either JavaScript, or the Java External Authoring Interface (EAI) classes. JavaScript can be used as the scripting language for a Script node in a VRML world. It receives/sends events from/to other nodes of the world through a Java Script Authoring Interface (JSAI). The EAI approach, not utilizing an event coming into a Script node, allows a currently running Java applet to control a VRML world. This paper employs the EAI classes to design VE. The EAI classes are included in the vrml.external.* packages (npcosmop211.jar) that come with the Cosmo Player plug-in. These packages contain all the classes and methods needed to access the VRML world, send events to it, and register notification methods when an event is generated in the world.

3.2. 3-D Object Based Data Model

As a natural way of observing and constructing worlds, the object-oriented (OO) methodology is now preferred to be used to deal with data modeling or system design and development In terms of OO methodology, generalization, inheritance, aggregation, and grouping (or association) are main means to form objects (classes) that have both attributes and methods (operations). In this paper, we just adopt the OO idea to design our data model.

Each geo-referenced entity is taken as an object, that has metadata, internal attributes, perceptual attributes, and relational attributes. Metadata refers to data about data, that describes data format, object constructing date, object owners, scale, data accuracy, etc. Internal attributes are defined as spatial location (coordinates) and topology, time and temporal topology, geographical attributes including physical, chemical, and biological elements, geographical knowledge, and so on. Perceptual attributes demonstrate the relationship between objects and observers that includes visual, audio, tactile, and smelling attributes. Relational attributes represent relationship among objects in dimensions of space, time, material, energy and information.

In view of this research, there are two typical classes: field based objects and entity based objects. Field based objects include DEM, aspect model, slope model, soil distributed model, and land use model. Entity based objects are individual entities such as trees, buildings, roads, telephone booths, and the like. In terms of VGE, real-time navigation and interaction, and realistic 3-D graphics are key factors to let users feel immersive and present. However, geo-referenced data are always large and complicated. Special ways thus should be taken into consideration to model geo-objects. This paper focuses on topographical landscape models and 3-D entity models.

3.2.1. Topographica Landscape Models

Topographical landscape models can be defined as the integration of geometric and non-spatial attribute distribution models such as DEM, slope, aspect, landuse, soil type and the like. Because of the large data volume of DEM and its geometric and thematic complex, as foundational 3D spatial frameworks, topographical landscape models are key to a realistic, real-time handling of 3-D scenes. This paper addresses multi-block and multi-level schemes to model complicated topographical landscape models. In general, when a handled region is too large to carry out data transferring across the Internet and geo-computing and graphics rendering in real-time , we then need to divide the large region into several blocks. In Fig. 2, we design R×C blocks to represent a region. With regards to every block, there possibly exist many levels describing different geometric and attribute details. Fig. 2 demonstrates that the block S_{22} is represented by T1, T2,..., Ti,..., Tn in terms of geometric resolutions, and by A1, A2,...,Ai,...,Am in terms of thematic resolutions. Meanwhile, supp-ose resolutions turn higher with a increase of i.

In practice, the number (R×C) of blocks is determined by real-time handling capacity of client computers and the highest geometric (Tn) and thematic attribute (Am) resolutions that depend upon the data sources. The maximum observing range of users decides the lowest geometric (T1) and thematic attribute (A1) resolutions. When application systems are executed, users can choose the proper geometric and attribute levels depending on their own requirements as well as the Internet capability and computer performance. In fact, given a specific computer environment, the number of real-time handling triangles should be certain, and it is supposed to be NR. Then, as a region, named R, needed viewing is selected, users should choose some spatial level so as to allow the number of triangles within the region R to be equal or similar to NR. Thus, it is possible for users to implement real-time visualization and analysis.

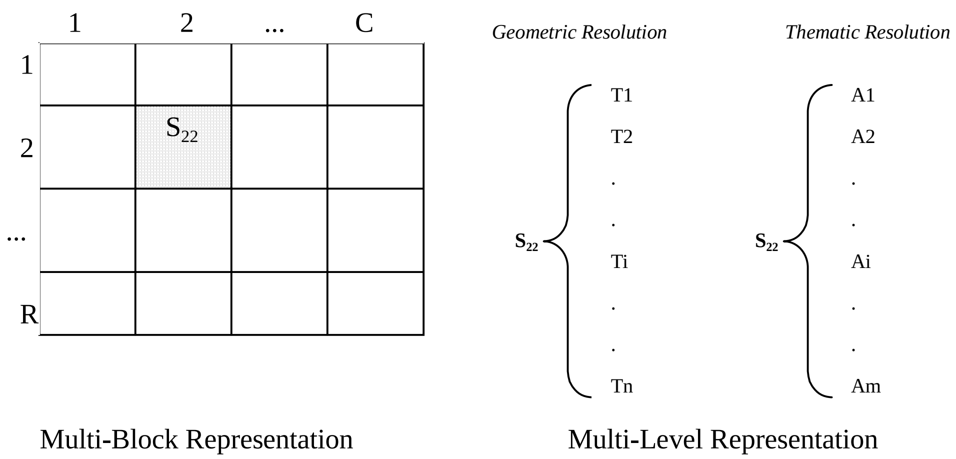

Figure 2. Multi-block and multi-level representation of spatial and thematic attributes

3.2.2. 3-D GEO-ENTITY Models

In traditional 2-D GISs, geo-referenced entities such as buildings, trees, phone halls, etc. are usually represented by using color or 2-D graphical symbols. This approach needs a conversion from abstract, 2-D symbols to 3-D geo-entities, and places a heavy load on information cognition and processing.

In this paper, we design a 3-D graphical object base to simulate 3-D geo-entities so that users can directly identify geo-entities, and feel immersive into the virtual environment. AutoCAD systems are firstly employed to create 3-D geometric objects. Together with the geographical coordinates, size, and orientation of entities obtained from the ground surveying, the 3-D geometric objects can be further processed into 3-D objects for constructing VGE. Fig. 3 demonstrates the 3-D graphical representation of six entities, namely flower, telephone pole, telephone booth, toilet, swing, and kiosk. These objects are described in VRML.

Figure 3. 3-D graphical representation of 3-D entities

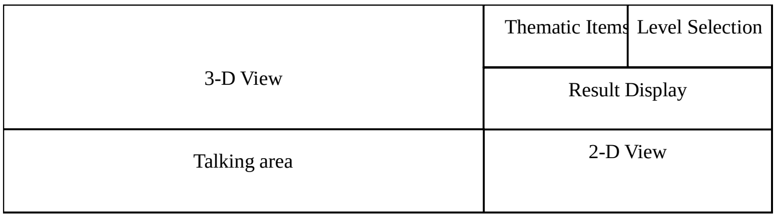

Figure 4. The structure of the interface of virtual environments

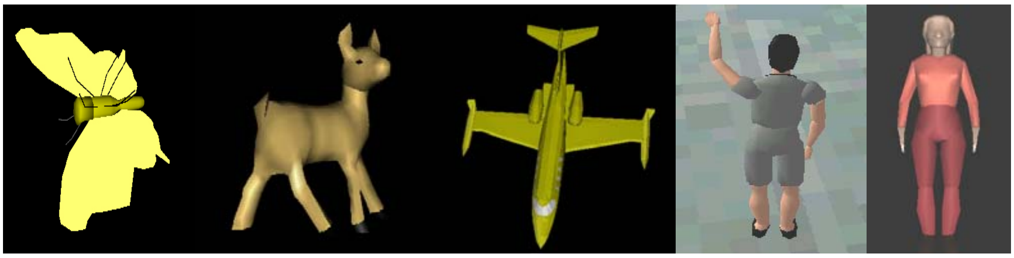

Figure 5. 3-D avatars

3.3. Interface Design

Explaining the functions of VE, the interface should be friendly and flexible. Fig. 4 describes its structure. In Fig. 4, the different areas are functioned as follows. *3-D view* is the major part displaying a 3-D VRML world. *Thematic Items* allows users to select one thematic attribute to be displayed and analyzed. *Level Selection* permits users to setup some spatial or thematic resolution so as to have a real time operation or good quality of 3-D images but a slow processing. *Result Display* shows the results of spatial query and analysis. *2-D View* displays the 2-D map of a 3-D VRML world. *Talking area* allows distributed users to carry out communication and collaborative work.

3.4. Avatars

As 2-D/3-D graphics representing human bodies and body behavior, avatars are interfaces to enable communication and interaction among users. The locations and orientations of avatars change depending on viewpoint positions and view directions. Communication among avatars can be carried out through text based or voice based dialogue, or body behaviors such as smile, dance, waving and the like. Fig. 5 demonstrates some avatars that are butterfly, deer, airplane, waving man, and woman. VRML is used to model each avatar. Users can freely select his avatars, and different avatars lead to different users' sensation, cognition, and social behaviors .

4. Case Study

There are 23 country parks in Hong Kong whose area is 41,582 hectares, and occupies 40 percent of the total land area of Hong Kong (Wang, 1998). The ShingMun Country Park is located in New Territories of Hong Kong, with a range of 4.5 km in East-West and 4.68 km in North-South, and an area of 14.04 km squares. We use it as an example for the study of virtual country parks.

A system prototype virtual ShingMun Country Park, called VirtualPark, is developed with Web-based languages of Java and VRML for managing and disseminating information of ShingMun Country Park, and facilitating public participation in policy-making, protection of ecological systems, and the development of the tourist industry.

Fig. 6 is the interface of VirtualPark. In this paper, the free browser Cosmo Player (Version 2.1) is adopted to view VRML world. Users can choose areas of interest on the 2-D map, and setup appropriate spatial and thematic levels according to the Internet transferring data speed and performance of client computers.

In Fig. 6, the 3-D map describes the terrain of ShingMun Country Park with the spatial and thematic level set at 1. In the 3-D scene, users can use mouse to measure the coordinate of any point. The top-right window shows the coordinates (x,y,z) of selected points.

In the virtual environment, avatars, in the form of 3-D graphics, represent users. When VirtualPark is started, every user needs to choose her/is own avatar. Distributed users interact and communicate through avatars and text-based dialogue. The bottom-left window shows the talking dialogue and the present online users. The remote collaborative work can therefore be carried out.

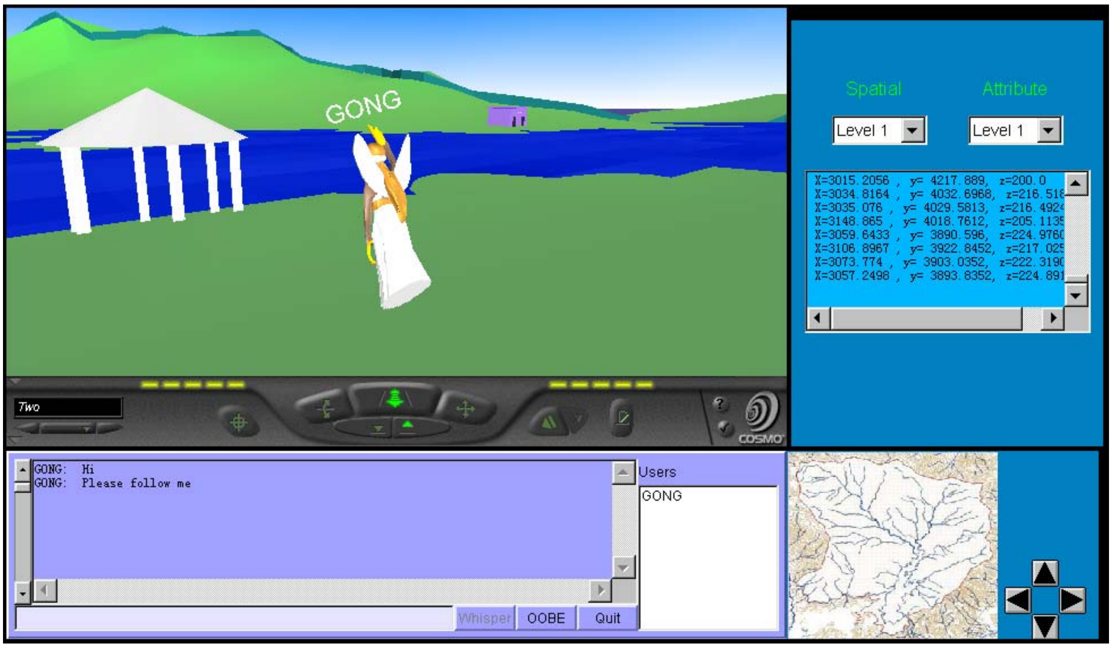

Figure 6. Virtual Country Park

5. Conclusion

Everything of this material world is being virtual. But we have no enough and clear knowledge of virtuality. The character of virtual geography have therefore been debated by focusing on either virtual worlds or material worlds or the interaction between virtual and material worlds. In terms of space and places, this paper argues VGE and the relationship between VGE and real geographical environments are the key study issues for virtual geography. In this paper, however, research focuses are placed on the design of VGE-systems. A case study is presented and a system prototype, VirtualPark, is created. In the future, for practical application systems of VGE, we need to build a 3-D individual geo-object database with more entities, design models and approaches to implementing smooth movement of large worlds, and add more functions such as agent-based servers, spatial analysis, object based query, intelligent data mining, as well as management, simulation and interpretation of application models on the Internet and the Web.

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