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Virtual reality (VR) technology, coupled with GIS technology and functions, has created a geo-virtual environment (GeoVE) and attracted human awareness of geo-cognition. GeoVE can help understand geo-environment and phenomena, and innovates the ways of spatial concept formation. Recently, many applications have appeared to suggest its substantial potential for simulating environment and exploring human cognitive aspects. However, the validation of environment simulation and enhancement of human geo-cognition, in terms of their degree of realism and reliability, has so far lagged behind.

Environment simulation and subject evaluation CHEN Xiaogang (Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China) Abstract: Virtual reality (VR) technology, coupled with GIS technology and functions, has created a geo-virtual environment (GeoVE) and attracted human awareness of geo-cognition. GeoVE can help understand geo-environment and phenomena, and innovates the ways of spatial concept formation. Recently, many applications have appeared to suggest its substantial potential for simulating environment and exploring human cognitive aspects. However, the validation of environment simulation and enhancement of human geo-cognition, in terms of their degree of realism and reliability, has so far lagged behind. Key words: virtual reality; GIS; environment simulation; subject evaluation CLC number: P283.7; P208 Funded by Land and Water Australia, the project, Community Exploration of Changing Landscape Values, recently commenced. It is aimed at: a) creating a landscape-simulated environment, allowing people to walk/drive through or fly over the realistic renderings of the changing landscape; b) conducting survey of human response to landscape simulation and subject evaluation; and c) demonstrating the effectiveness of techniques and approaches while applied in a case study area. This paper introduces a preliminary stage of this development: the building of the 3D models from GIS data sets, construction of different simulated environments, and a survey of the acceptability of simulated environments. As the project develops, various levels of visual and modeling sophistication for exploration of changing landscape values will be available, with particular focus on detailed and effective visualization to allow local people of any background to be actively involved in reviewing landscape options. Human subject evaluation and effectiveness tests for the new technology are being used to determine the acceptability of different presentation options. 1 Introduction 1.1 Geo-virtual environment The use of virtual reality (VR) technology in geo-sciences, either immersive or non-immersive, to create geo-virtual environment (GeoVE) fundamentally changes the traditional way of acquiring spatial knowledge, and extends the geo-cognitive capabilities of human beings (MacEachren et al., 1999; Neves et al., 1999; Slocum et al., 2000; Hedley, 2001). GeoVE offers an intuitive way of manipulating data and enhance our interaction with geo-data through innovate ways of interactive exploration and spatial knowledge construction (Buziek and Dollner, 1999). Many applications suggest the substantial potential of GeoVE for exploration of both natural and built-up environment (Bishop and Karadaglis, 1997; Verbree et al., 1999; Bishop and Dave, 2001). However, the validation of environment simulation and enhancement of human geo-cognition, in terms of their degree of realism and reliability, has so far lagged behind. In the following, we will address issues, arising from our on-going research, on linking GIS and GeoVE for environment simulation and visual exploration, and subject evaluation at different levels. 1.2 Origin and objectives of the research Recently, there has been a growing recognition that the landscape provides multiple benefits ?C water, bio-diversity, recreation, aesthetics ?C and these shape people ' s landscape values. The project, Community Exploration of Changing Landscape Values, intends to create a simulated environment for landscape evaluation, helps people learn about their local landscape, and support informed decisions about lan d use. Particularly, it aims at: a) developing a computer system linking GIS and virtual environment technology for the input of land use change options; b) producing a virtual simulated environment, and conducting survey of human response and subject evaluation to explore the consequences of environmental change; and c) applying the tools and demonstrating their effectiveness while conducting system evaluation with the local community in the case study area. 2 System development Development of GeoVE from GIS data is being increasingly automated (Perrin et al., 2001). Our development is a mix of system-based and manual procedures. It involves the following major phases: 1) creation of geo-database and texture library, 2) data processing, 3) 3D modeling, simulating and rendering, 4) interactive visualization, and 5) effective testing. In the PC environment, ArcView 3.2 (and more recently ArcGIS 8) with multi-extensions is used for data format conversion, feature generation, two dimensional mapping and three-dimensional visual analysis. Smart Image and ERDAS Orthobase have been used for aerial photo processing, registration and mosaicing, and Photoshop 6.0 for texture creation and image format conversion. The real-time 3D system has been developed using Performer (Rolf and Helman, 1994) and OpenGL libraries under IRIX (Silicon Graphics) and Linux (PC) operating systems. Immersion is provided by the use of three-screens and three projectors to give a 135 degree field of view. Real-time computer performance in such an environment is commonly based on a single very high performance computer (e.g. SGI Infinite Reality). Because of budget restrictions and the need for easy portability, three low cost computers will be used ?C one for each projector. This however has required some special software development. We have used both Poetic Dimension (PD from Immersion Studios, Toronto) and our own development (PA ?C object Animation with Performer) to link the 3 rendering computers (Bishop and Dave, 2001). A fourth ' master ' computer can be used to control operations and this is network linked with computers supplying the base information. A change in the modeled virtual environment will, for example, be triggerable from ArcGIS on a workstation or purpose-developed decision support software on multiple pocket-PCs used by the stakeholders. 3 Geo-data processing and 3D modeling 3.1 GIS data manipulation The original GIS data cover topographic, thematic and image data, which provide information on location, features, types and distribution of geographic objects. The following steps were taken in development of these into a 3D landscape modeling and visual geo-analysis. · Topographic data included contours for generating DTM, rivers, streams, boundaries and roads. These linear features were provided in Intergraph .dgn format. · Thematic data include the existence, class and density of vegetation, provided in vector format. Vegetation data are geo-processed using Arc View to generate new codes as vegetation type-density classes. All grid-based data manipulation was based on a 10 m cell size. · Aerial photos are rectified based on topographic data, such as roads, rivers and then mosaiced into the entire aerial photo for the first focus area. · All topographic data, thematic data and aerial photos are then clipped into a test area of 8 x 9 sq. km and a sub area of 1 x 1 sq. km, under unified geo-reference. 3.2 Generation of 3D data and simulation of environments Terrain ArcView 3D Analyst extension built the DTM (at 10 m, 50 m and 500 m grid sizes) from the original 10 m contours. The different DTMs were exported as ASCII raster files (.asc). A program was especially written to convert these to Alias-Wavefront (.obj) format files. Vegetation Treed areas: The vegetation type-density classes were also exported from ArcView as .asc files. When processed in conjunction with a DTM, different DTM cells were allocated to different groups on the basic of their type-density class. Another user-written program generated .obj files with trees covering the corresponding portion of the DTM. Different tree models/textures can be applied for each defined group. Individual trees: individual trees (coordinates) were identified and positioned from the rectified and mosaiced aerial photos in ArcView. In ArcView 3.2, development of a file with the x, y and z positions of each tree involved a series of step including gridding the location file, multiplying by the DTM and merging of attribute tables. This process is much simplified in ArcGIS 8 with x, y and z values for the point exported as a text file. Buildings This were positioned and modeled in much the same way as the individual trees but with a somewhat more complex structure applied to each building. Houses were distinguished from farm sheds and a variety of simple generic structures defined (Figures 1a and 1b). Figure 1 Local view of buildings and farm shed (a) and Buildings in simulated environment: house on the right and farm shed on the left (b) Fences The option of assigning z values (from the DTM) to a line and exporting as .dxf was used here. Vertices are assigned at each DTM grid cell (i.e 10 m spaces in this case). The dxf file was processed by another in-house program to extrude the boundary lines by 1 m in Z. This created a series of panels 10 m long and 1 m high. A fence texture was created using Photoshop, converted to .rgba format (for transparency) and applied to these panels. Roads Road center lines were exported as a .dxf in the same manner as the fence lines. These were converted to .obj files and then processed again to produce a corridor of specified width. 4 Interactive visualization Interactive visualization shows the distribution and pattern of environmental elements and their interrelation. It links maps and database as well as providing access to the tools for describing, measuring and manipulating relevant data. A good visualization also allows for retrieval of information and analytical outcomes, and for explora tion of hidden regularity with spatial and temporal references (Kraak, 1999). While these attributes are more commonly applied to more abstract scientific visualization they ideally also apply when a component of the system is a virtual environment. Such is the objective of interactively linking the GIS with the GeoVE and with simple devices for individual or group input. Using existing GIS based maps of ecological condition of the vegetation (density, diversity of vegetation species and their distribution over space) and stochastic models of decline it is possible to reveal in mapped form the human impact on the remnants over time. What if..? games can be played to change patterns of pasture or weed management which may affect the native trees. At the same time, weed spread can be modeled under different control scenarios. But, we assume, this becomes much more effective for local residents when the interaction and immersion provide a level of presence in the VE. GeoVE offers an intuitive way of manipulating data and enhances the interaction with the geo-data to create new ways of interactive exploration, spatial concept formation and spatial knowledge construction. Real-time tracking with six degrees of freedom is available for interactively manipulating triggered features, such as trees, water bodies, roads, buildings and fences. The availability of vivid and detailed visualization provides realistic views of the study area from any ground or aerial viewpoint, allowing walk or drive through and fly over the modeled environment, thus creating a platform for local people to be directly and personally involved in changing landscape values. 5 Subject evaluation Clearly a trade-off still exists between level-of-detail in computer graphics and refresh rate. In order to provide real-time performance and autonomous exploration of the GeoVE, some simplification is necessary in the 3D model in order to keep polygon numbers manageable. Figures 2a and 2b show a pair of real and computer generated views from the same location within the data set. It is easy to see which is the VE view and it is also apparent that the VE view is inadequate in terms of foreground detail. There are roles for which the simulation is not appropriate ?C but is it acceptable for the role anticipated in this project? Figure 2 Real view (a) and Simulated view (b) To address the issue, we have undertaken an “acceptability of landscape simulation” survey. Subjects with various background (local and non-local, experts and non-experts) were included at different stages of survey. Presently, 63 undergraduate and graduate students majoring in Landscape Architecture and Geomatic Engineering had responded. They were exposed to pairs of static computer-simulated images and real digital photographs. These showed different combinations of fore, middle and background vegetation, buildings and fences. The major tasks were inclusive of collecting sufficient data on the understanding of simulation, the perception of scenic beauty and the degree of realism. A series of questions about the identification of features and cognitive understanding and level of ease of interpretation of images were asked. Then, they will respond differently to the pairs of 2D and 3D landscape, static and dynamic simulated environment. The difference of cognitive aspects will be identified and explained. Later on, local people will be asked further questions about recognition of the location, recollection of features and interpretation of changes to examine the suitability of GeoVE used in this project. Finally, dynamic, interactive, semi-immersive simulated environment in fly or drive mode will be provided with different settings of parameters to test the effectiveness and acceptability of construction of virtual landscapes. This aspect of the research should answer questions such as: a) the number and growth of different tree types required to be represented; b) whether all trees need to be present or only a sub-set; c) how is foreground best portrayed; and d) how is time best represented. The quality of representation will also improve as more objects and additional vegetation types are added to the library. 6 Conclusions Instead of modeling virtual environment manually, we have just begun to explore the potential of coupling GIS and VR technology for applications. It is apparent that GIS provides precise positioning for VR modeling and exploration, which in turn provides visually interactive spatial and 3D analysis for environmental knowledge construction. The availability of vivid and detailed visualization provides semi-realistic views of the study area from any ground or aerial viewpoint. Preliminary environmental modeling and visual exploration through realism and abstraction, and effectiveness testing from students with design and IT backgrounds have been conducted. In order to achieve higher degree of realism, more and detailed digital geo-data and texture information would be necessary. The paper was written on the project, Community Exploration of Changing Landscape Values, funded by Land and Water Australia and chiefly investigated by Associate Professor, Dr. Ian Bishop, Center for GIS and Modeling, University of Melbourne, Australia. Post-Graduate student, Abdul Rahim Abdul Hamid, Faculty of Architecture, Building & Planning, was responsible for the first-stage survey of acceptability. I greatly appreciate their contribution. References Bishop I D, Karadaglis C, 1997. Linking modeling and visualization for natural resources management. Environment and Planning B: Planning and Design, 24: 345-358 Bishop I D, Dave B, 2001. Beyond the moving camera: system development for interactive immersive exploration of urban environments. In: Proceedings for Computer in Urban Planning and Urban Management, Honolulu, July, 2001. Buziek G, Dollner J, 1999. Concept and implementation of an interactive, cartographic virtual reality system. 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