Terrain Representation Methods in VR Environment

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Abstract

This paper describes methods for visual 3D representation using VR technology and introduces the terrain representation methods that the authors have developed and some of the application systems using those methods. Furthermore the tangible terrain representation system which has been worked on is shown against the problems of conventional methods. The paper also discusses possibilities of further development of terrain representation systems, positioning 3D terrain representation systems.

Keywords

Terrain representation, Tangible display, Virtual Reality, DEM, VR-CAD

1. INTRODUCTION

Recent advances in the development and dissemination of spatial information have made it possible to obtain and use various types of spatial information easily. It is also becoming possible to obtain and use topographic information on a global scale. Topographic information is in many cases provided in the form of mesh data such as USGS Digital Elevation Models (DEM) . Such information may be provided by, for example, representing different elevations and slopes with different colors, generating contours from mesh data, generating shaded-relief maps automatically or using bird's-eye views prepared by projection transformation for 3D representation. These methods, however, represent terrains in two dimensions on the computer display, instead of as three-dimensional objects as in the real world. These representation methods, therefore, make it difficult to understand topographic relief intuitively. To solve this problem, the authors have been working on the research and development of methods for representing virtual terrain surfaces defined on the computer by applying virtual reality (VR) technology and of systems that can be realized by applying those methods.

This paper describes methods for visual 3D representation using VR technology and introduces the terrain representation methods that the authors have developed and some of the application systems using those methods. The paper also discusses possibilities of further development of terrain representation systems, positioning 3D terrain representation systems.

2. VR-BASED VISUAL 3D REPRESENTATION METHOD

Virtual reality (VR) is a technology to experience a realistic virtual world defined on the computer. The technology uses an interface making effective use of stereoscopic visualization made possible by means of the two human eyes in order to visually enhance the degree of reality.

The mechanism by which a human visually recognizes the three-dimensional configuration of an object involves two types factors: physiological factors and psychological factors. Physiological factors, which are due to the functions of the human eye, include the focus adjustment function of the lens, eye convergence, binocular parallax and monocular motion parallax. Psychological factors, which help reconstruct 3D images from experience, are classified either as geometric or optical. Among these factors, binocular parallax, which is one of the physiological factors, is generally thought to be most important in 3D perception.

The stereoscopic visualization technology used in the field of virtual reality is based mainly on 3D perception caused by binocular parallax. If the locations of the eyes of a human viewer are determined in a virtual space defined on the computer, a pair of perspective images just like images that would be perceived by the two human eyes can be obtained by applying computer graphics (CG) technology. By giving the perspective images thus obtained to the two eyes of a human viewer, the viewer can be made to perceive the images as a 3D object. Devices for giving different images to the left and right human eyes have been developed during the evolution of virtual reality technology. Representative examples of such devices are stereoscopic eyeglasses with liquid crystal shutters, 3D displays, head-mounted displays (HMD) and immersive displays.

1. Stereoscopic eyeglasses with liquid crystal shutters

   A stereoscopic eyeglasses system with crystal liquid shutters provides different images to the left and right eyes by displaying images for the left and right eyes alternately at high speed on a single CRT display and

synchronizing those images with the liquid crystal shutters of the stereoscopic glasses. Because the display area is fixed on the display system, the user is not allowed to move around.

2. 3D display system:

A 3D display makes it possible to have stereoscopic views with the naked eye by using binocular parallax and eye convergence. Like the stereoscopic eye-glasses method, this method does not allow the user to move around. Recent advances in technology, however, have been rapidly making inexpensive systems available on the market.

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4. 3D display system

A representative example of an immersive display system is an IPT (immersive projection technology) device called the "CAVE" (Cave Automatic Virtual Environment) developed by the University of Illinois [Cruz93]. In the CAVE, 3D images can be projected onto about 3m by 3m screens placed at the left and right and at the front of the user and on the floor so that the user can immerse herself or himself into the 3D visualization environment. The CAVE is advantageous because it provides a wider field of view than the HMD and does not require image generation synchronized with movement, so problems such as a delay in image generation do not occur.

In recent years, research and development efforts associated with mixed reality, which aims to integrate virtual space and real space have also been underway. One of these efforts is the research and development of tangible interface. The MIT Media Laboratory, for example, has developed a system called "Illuminated Clay," which projects information onto a terrain surface created with clay [Piper02].

3. TERRAIN REPRESENTATION AND DESIGN SUPPORT SYSTEMS DEVELOPED TO DATE

The authors have been working to develop terrain representation methods making use of VR technology and construct design support systems using these methods. This paper describes (1) a road design support system that uses stereoscopic visualization of aerial photographs and (2) a terrain representation and urban space modeling system that uses an HMD, both of which have been developed by the authors, along with problems of these systems.
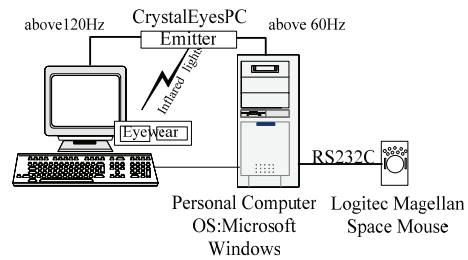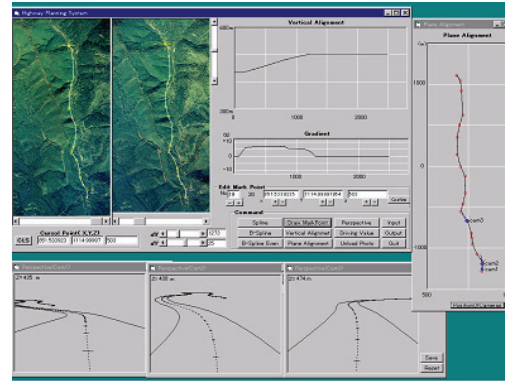

Figure 1 The configuration of HRPS

Figure 2 Interface of HRPS

3.1 Highway Route Planning System Using Stereoscopic Visualization of Aerial Photographs

Makanae[Makanae02] has developed a system (HRPS; Highway Route Planning System) that acquires terrain images through the stereoscopic visualization of aerial photographs and enables road design. Aerial photograph images taken into the computer in the form of digital information are shown on the display of a stereoscopic viewer (CrystalEyes2 manufactured by Stereo Graphics, Inc.) as information that can be visualized stereoscopically (Figure 1). A coordinate system identical to the stereoscopic visualization space obtained by aerial photograph orientation is defined on the computer, and road design is conducted in this 3D virtual space. Parametric curves (B-spline) are used to define road alignments, and control points are located within the space so that their alignments can be defined easily.

Figure 2 shows the interface of the system. A 3D model of each road structure is automatically generated according to the alignment defined on the aerial photograph, and plans, longitudinal profiles and perspectives can be displayed.

An advantage of this system is that it allows an engineer who is good at interpreting topographic characteristics (e.g., landslides) from aerial photographs to directly determine road alignments with the assistance of a road design module that uses parametric curves. This is particularly advantageous in, for example, designing mountain roads under poor topographic conditions. By making direct use of aerial photographs, unnecessary mapping processes can be eliminated. A problem with this system is the applicability of road alignments determined by using parametric curves to the current design standard. Another problem is that the relationship between con-

structed road structures and the terrain surface represented in a virtual 3D visualization space cannot be computed.

3.2 Terrain representation method using HMD: VR-CAD system

In the conventional drawing-based space design method, the designer constructs 3D configurations in his or her mind while preparing drawings. VR technology, however, makes it possible to define any 3D virtual space on the computer. The VR-CAD system developed by Makanae [Makanae03] enables the designer to immerse himself or herself into a virtual space constructed on the computer. In the virtual space, the designer can exist on any scale: the designer can enter the space either as a correctly scaled human figure or as a giant. The system also enables the designer to conduct 3D design without relying on the 2D/3D conversion capability of the designer.

The system consists of a head-mounted display (HMD) and 3D position sensors (Figure 3). By combining the HMD and a position sensor, the position and orientation of the head can be measured and appropriate images can be displayed so that the design has a 360-degree field of view both in the horizontal direction and in the vertical direction.

Since the system is intended for use in constructing large structures such as roads, terrain information is essential. Elevation data (50 m mesh) in Digital National Information are used as 3D terrain models for terrain representation in the virtual space. The modeling input interface of the VR-CAD system has a 3D mouse and keyboard equipped with a position sensor. These devices enable 3D modeling of such features as buildings (rectangular prisms, cylinders), roads and trees by simple operations. Known problems of the design interface of this system include the difficulty in perceiving the position of the 3D cursor and the difficulty in comprehending the relative positions of the terrain surface and the object of interest [Makanae03].

4. DEVELOPMENT OF TANGIBLE TERRAIN REPRESENTATION SYSTEM

Problems of the terrain representation and design support systems include the following:

- Difficulty in comprehending the relative positions of the terrain surface and the object of interest

- Need for a special stereoscopic visualization device

- Limited field of view

- Not usable for group work

Believing that the introduction of a tangible interface helps solve these problems, the authors have been working on the construction of a tangible terrain representation system.

Figure 4 shows the configuration of the terrain representation system. As shown, the system represents a terrain surface by controlling the shape of a stretchable screen used to represent the terrain surface by means of a total
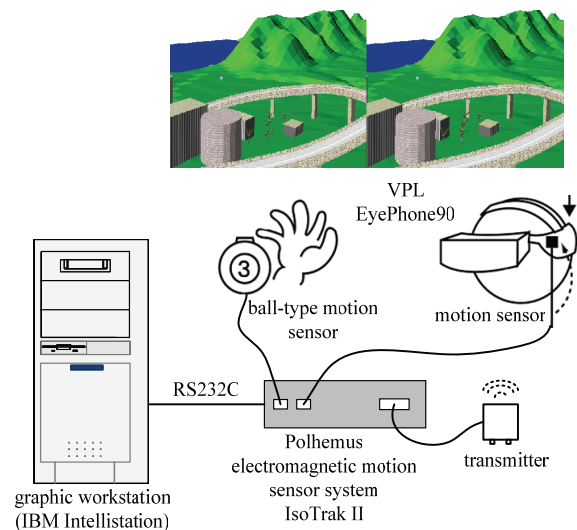

Figure 3   The configuration of VR-CAD

of 64 actuators (8×8) and projecting an aerial photograph onto the screen. Mesh data of Digital National Land Information(Japan) are used as terrain data, and the height of each actuator is determined according to the mesh data values.

Figure 5 shows an example of a terrain represented by using the system. The terrain model onto which an aerial photograph is projected is a touchable terrain model. As the next steps, the authors are thinking of evaluating the validity of the terrain representation system and constructing design support systems for roads and other structures by adapting the existing system.

5. OUTLOOK FOR TERRAIN REPRESENTATION SYSTEMS

The ongoing development and dissemination of spatial information are making it increasingly easier to obtain and use digital terrain information. Obtained terrain information, however, can only be displayed in a limited area of a flat display device. Consequently, it is difficult to give the viewer a sense of three-dimensionality and a sense of scale. The authors have been working on the development of the systems described in Sections 3 and 4. Requirements for a terrain representation system identified in view of the problems encountered in connection with the development of those systems are as follows:

1. Recognition of the three-dimensionality of terrain surfaces is easy.

2.. The user does not need to wear any special device such as stereoscopic glasses or HMDs.

3. Reconstructed terrain surfaces can be matched with digital information.

4. Various types of information can be superimposed.

The first requirement is one of the basic requirements for a terrain representation system, so it is necessary to make a higher degree of three-dimensional recognition possible. The second requirement is listed here because the use of
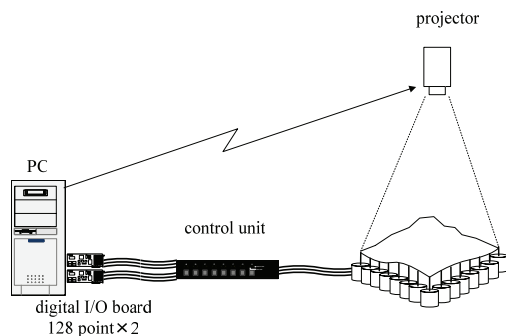
Figure 4   The configuration of the terrain representation system.

Figure 5   An example of a terrain

special equipment may cause fatigue or sickness, making many hours of use difficult. The use of special equipment should be avoided as much as possible. The third requirement is important because in order to develop an application system, it is necessary to extract a particular point on a virtual terrain surface in digital form. The fourth requirement is also important because the terrain representation system can be used effectively by superimposing not only aerial photographs but also other data such as land use data and city plans on the reconstructed terrain surface.

Examination of these requirements indicates that the following systems are thought to be promising in the coming years:

1. Tangible terrain representation system

The tangible terrain representation system that the authors are currently developing can satisfy all of the four requirements listed above. The system, however, is still at the development stage, and it is necessary to further enhance the resolution of terrain representation and develop equipment and devices that can be easily used even by non-expert users. It is also necessary to develop a pointing device for use on a virtual terrain.

2. Terrain representation system using rapid prototyping

Recent advances in CAD/CAM technology has made possible fast advances in rapid prototyping technology to make real 3D models from resin or other materials in accordance with 3D data prepared as CAD data. In recent years, this technology has been increasingly used to make terrain models more easily than by other methods. Problems of terrain representation systems of this type include the difficulty in getting feedback from completed terrain models to electronic information and the necessity of the development of pointing devices as in the case of tangible terrain representation systems described above 1.

3. Terrain representation system with 3D display

A 3D display enables the user to have three-dimensional recognition without using special equipment. A terrain representation system with a 3D display is being developed and used at the authors' laboratory, and the system has proved effective in giving a strong sense of three-dimensionality. The system satisfies the first, second and fourth requirements mentioned above although the degree of strength var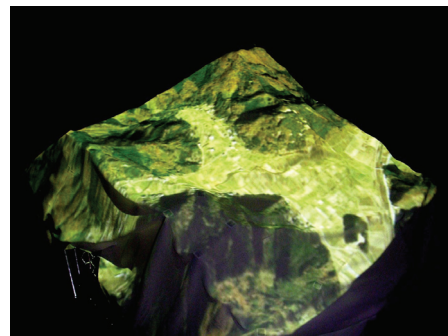ies among individuals. A problem of this system concerns the matching of the virtual terrain surface and digital terrain information (related to the third requirement mentioned above), so it is difficult to indicate a particular point on the terrain surface accurately.

6. CONCLUSION

This paper has introduced a number of methods for reconstructing terrains from digital terrain information that the authors have developed, and application systems using the terrain representation methods. The paper has also identified requirements for a terrain representation system to be used as a GIS tool and has described terrain representation systems that are likely to prove useful in the coming years.

At present, the representation of digital terrain information is restricted by 2D display devices. With further advances in representation and control technology made possible by the progress of VR technology and robotics, however, more realistic and easier 3D terrain representation will become possible. The authors believe that advances in terrain representation technology can contribute to not only research in the fields of technology and science such as geography, geology and civil engineering but also CAD interfacing in the field of construction, and also to a wide range of other applications such as geographic education.

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