AVR Virtual Environment in the New Generation Human Computer Interaction System

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Abstract: - VE (Virtual Environment) provides the three dimensional visual interactive environment for the new generation - the fourth generation natural HCI (Human Computer Interaction) system. Modeling the virtual objects is the key to build VE. The paper focuses on the theory, algorithms and core techniques for AVR (From Actual Reality to Virtual Reality) modeling of virtual environment. Based on the integration of computer vision and computer graphics (CV/CG), the objects in AVR VE are virtualized directly from the shape data (2D images and 3D data) acquired of their counterpart objects in real world by using AVR reconstruction approaches, which provides the AVR VE with a higher-level realism, conciseness and preciseness.

Key-Words: - Virtual reality, Virtual environment modeling, Superquadrics, 3D reconstruction, Human Computer Interaction

1 The new generation - the fourth generation natural HCI system

Human Computer Interaction (HCI) is the communication and interaction between human and computers. With the spread of computers and the rapid development of information technology, the network trends of information storage, the international exchange of information, and the diversity and individuality of individual information lead to an urgent need of natural, harmonious and simple human computer interaction similar to human beings.

In the fourth generation HCI system [1,2], the traditional two dimensional interaction (text, character and image) of visual information develops towards the three dimensional visual interaction in a more realistic and immersed manner. As the key supporting technology, virtual environment (VE) will be the important interactive way in the fourth generation HCI, which provides three dimensional realistic visual interactive environment for HCI.

Combining AVR research and HCI VE reconstruction, the paper focuses on the AVR theory, algorithms and technology in VE reconstruction, including AVR problem definition, application system framework and the key methods and implementation technology.

2 AVR and VE Modeling

2.1 AVR theoretical framework

How to represent and understand the real world by computer is a general problem in many scientific and technological areas, especially in simulation, visualization, machine vision and intelligent information processing. Obviously, this is a type of consistent problem in nature, although in different areas, different attention has been paid to the problem, there is no systemic analysis and description for this problem. It is very necessary to systemically analyze the problem, build special technologic system and further study its theory and applications, Professor Yuan Baozong put forward a novel definition for this problem—AVR (From Actual Reality to Virtual Reality) problem [3,4], i.e. the problem of conversion from real world to virtual reality represented by computer, and the conversion techniques are named as AVR techniques.

For building a common basis of the research on AVR theory and techniques, it is necessary to describe AVR problem in detail.

Definition 1: AVR problem—the problem of conversion from the objects and surroundings in real world to the corresponding objects and surroundings in virtual world, which is described by the following form:

$$AR(O_i, S_i) \xrightarrow{T} VR(O_i', S_i') \qquad (1)$$

where AR is Actual Reality, including O_i (Objects) and S_i (Surroundings) in real world; VR is Virtual Reality of corresponding O_i' and S_i' in virtual world.

Definition 2: AVR techniques— the techniques of conversion from the objects and surroundings in real world to the corresponding objects and surroundings in virtual world with consistent computer representation, which is denoted by T in (1).

2.2 AVR problem in VE modeling

Since virtual environment needs the realistic "reproduction" of real world, VE modeling is a typical AVR problem of visual information, which may be defined as:

$$AR \xrightarrow{T_1} CR \xrightarrow{T_2} VR \qquad (2)$$

AVR problem in VE reconstruction consists of two key stages: first, the computer representation (CR) of real objects is computed from the shape information — actual representation (AR) of objects in the real world; then the virtual representation (VR) of objects is obtained from CR. T_1 is the technology to accomplish the first conversion, which is called AVR reconstruction of real object shape information. T_2 is the technology of the second conversion called as the rendering of VE. In the whole AVR conversion of VE, AVR reconstruction is the core. The decline of AVR technology has been the "bottleneck" of VE development. Therefore, the research on AVR problem in VE reconstruction will focus on AVR modeling, which is named as AVR VE modeling.

3 AVR VE Modeling

VE modeling problem is how to represent 3D objects in computer, i.e. how to convert the real 3D objects into the corresponding computer data structure. The goal of AVR research is to implement the automatic conversion from real world to virtual reality.

3.1 Integration of CV and CG

In AVR VE modeling, computer vision (CV) and computer graphics (CG) are integrated to connect graphics description and image reconstruction, which aims to build the technology system and realize the direct conversion from the shape information of real objects and scenes to the virtual ones.

In the system of integrating CV and GG, the achievements of CV overcome the difficulties of 3D object modeling existing in CG, which enables computer to understand and reconstruct real world as automatic as possible, and accomplish the conversion from real world to virtual reality automatically; on the other hand, the model representation in CG is introduced into CV, which enables computer recognize a large number of real objects even with complex shape and reflect the 3D object recognition process visually by creating the graphic feedback of the recognition results.

3.2 Universal description language: superquadric-based hierarchical description

A superquadric-based hierarchical description [4,5] as the universal parametric description language of the virtual environment objects is implemented, which realizes the universal description of the real objects with different shape complexity and levels of detail deformation characteristics. The hierarchical description includes four levels:

(1) Superquadric-based volumetric primitives;

(2) Boolean operations to volumetric primitives;

(3) Refinement with global Direct Manipulation of Free-Form Deformation (DMFFDs) [5,6];

(4) Refinement with local DMFFDs.

Superquadric-based (SQ-based) hierarchical description is coarse-to-fine description of real objects among different levels of detail. In comparison with other existing models, SQ-based models have much merit for AVR modeling.

(1) SQ-based models are commonly used by both CV and CG, which creates a bridge between computer vision and computer graphics for integrating the two techniques.

(2) SQ-based models describe an extensive variety of real world objects with natural forms and man-made forms in a succinct and natural manner.

(3) Applying the Boolean operations to SQ-based models, more complex objects are created.

(4) SQ-based models are suitable for efficient computation of grasping, avoidance, and collision detecting in virtual environment.

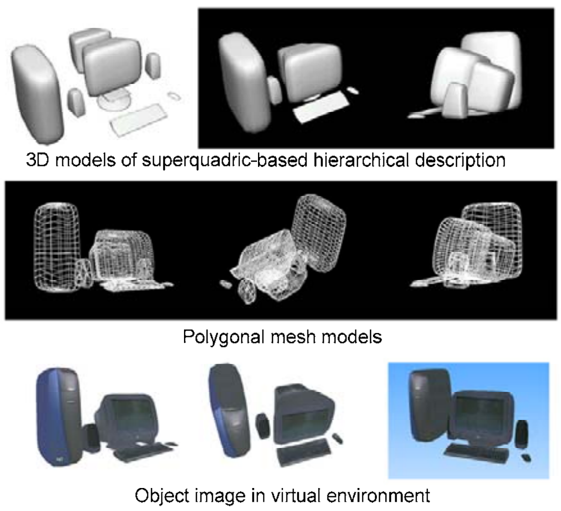


Fig.1 Superquadric-based hierarchical description of 3D object

Fig.1 shows the 3D model of Visual 540NT workstation, where superquadric-based hierarchical description is implemented. The model is represented by nine superquadrics and their CSG operation with only 126 parameters. However, the polygonal mesh model in Fig.1 uses 2328 vertices, 4620 triangle patches and a data table recording the topological connections of all the vertices. Therefore, the SQ-based hierarchical description is more concise and precise than polygonal mesh representation.

3.3 AVR VE modeling framework

As shown in Fig.2, AVR VE modeling framework is decomposed into four functional modules:

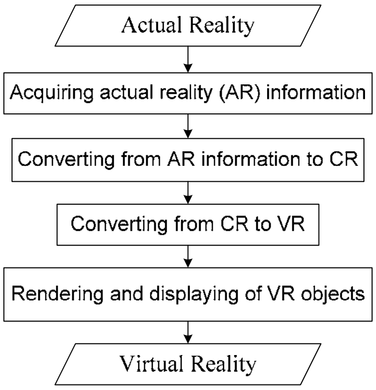


Fig.2 Functional modules of AVR VE modeling framework

(1) Acquiring AR information: The acquired AR information of real objects in VE modeling is mainly the object shape and other appearance information, such as color and texture. AR shape information may be in two dimensional or three dimensional manner, which can be acquired by 2D image acquisition equipment, stereo vision and 3D scanner. In this module, the complete and accurate shape information data of real objects is acquired for computer processing. In addition, this module also deals with the noise and distortion by filtering and smoothing.

(2) Converting from AR information to CR: Since the acquired AR information of real objects, such as 2D image or 3D data, is still the large volume of simple and original data, implementing the high-level visual information processing by computer is very difficult. It is necessary to extract feature data from AR information, and obtain the precise and complete description of real object shape. The conversion from AR information of 3D object shape to feature data based computer model description is accomplished in this module, which is the core of AVR reconstruction.

(3) Converting from CR to VR: VE need not only the precise and realistic object models, but the real-time VR graphics processing system. Generally, considering the precise virtual objects and scenes, and real-time walkthrough in VE, level of detail (LOD) is implemented in VE modeling, which aims to accomplish the real-time rendering of VE. Due to the consistency of superquadric-based hierarchical description with LOD of VE, the computer parametric model description may be converted into LOD data of VE objects. Moreover, the good mathematical properties of superquadrics make the collision detection and geometric interference in VE be computed well. In AVR VE modeling, the acquired colorful texture images from real objects are mapped to the virtual object models, which enhance the realism of virtual objects in VE greatly.

(4) Rendering and displaying of VR objects: The implementation technique of VR object rendering and displaying is determined by graphics processing system of VR, display and output equipments, real-time rendering and interactive operation software of VE. In this paper, software and hardware platforms of VE development system are constructed as the output and display platform of AVR VE.

3.4 Implementation framework for AVR VE modeling application system

In the paper, an implementation framework for AVR VE modeling application system is built as shown in Fig.3. The core of the system is 2D image or 3D data based reconstruction, which converts the shape information of real objects into the VE object models.

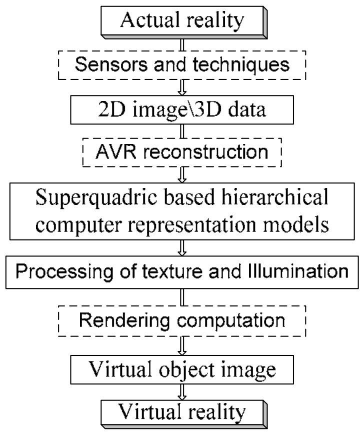
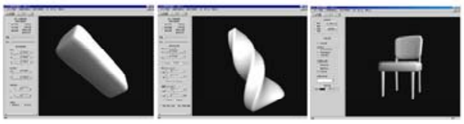


Fig.3 Implementation framework for AVR VE modeling application system

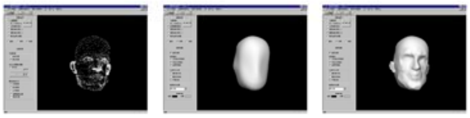
4. AVR VE Experiment System

For constructing virtual environment by AVR VE modeling techniques, the superquadric-based VE modeling software AVRMODEL is developed on SGI Visual 540NT workstation. In AVRMODEL environment, the virtual 3D object models may be created by inputting and adjusting superquadric parameters; the superquadric-based 3D models may be reconstructed by inputting 2D image or 3D data of real objects, which may be displayed in VE and also be implemented in object recognition and scene understanding in computer vision. The created virtual 3D models by AVRMODEL may be edited, rendered and output into the VE development platform on SGI Octane workstation, where the visual, immersed and real-time walkthrough in AVR virtual environment is accomplished. Fig.4 illustrates some running interfaces of AVRMODEL.



(1) Virtual object modeling

(2) AVR reconstruction of 2D images



(3) AVR reconstruction of 3D data

(4) Walkthrough in virtual environment

Fig.4 Running interfaces of AVRMODEL

As the important part of AVR VE technique research, we construct VE development platform on SGI Octane graphics workstation under the help of VR techniques, which is used to study the key techniques and application system of AVR VE.

(1) Real scene of AVR lab

(2) Virtual environment of AVR lab

Fig.5 Real scene and virtual environment of AVR lab

AVR reconstruction technique can accomplish the conversion from real object shape information to the corresponding virtual object models represented by computer, and further creating realistic AVR virtual environment by AVR VE development platform. Fig.5 shows the real lab scene and the corresponding reconstructed virtual environment by AVR VE techniques. The virtual scene is rendered and output on the VE development platform and the walkthrough in virtual environment is accomplished.

5. Conclusion

As the key support technique for the fourth generation HCI system, AVR VE technique provides the three dimensional immersed and visual human computer interactive environment. Based on the discussion on AVR problem, the paper focuses on AVR VE modeling techniques, which may reconstruct the parametric models of virtual objects from 2D or 3D real object shape information data. On the basis of the research work, a superquadric based virtual object modeling software AVRMODEL is developed and a VE development platform is built, which may achieve the display and real-time interactive walkthrough of AVR virtual environment.

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