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Preliminary realization of immersive EAST system using virtual reality

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ABSTRACT

Aiming at the complex and confined environments of experimental advanced superconducting tokamak (EAST) and the need to improve the ability of resident and visiting scientists to access and understand EAST, the immersive EAST system based on virtual reality is developed. Compared to previous virtual EAST systems, model reality, rendering speed, immersion and interaction functions are greatly increased. In the previous system, models were transformed from CATIA and imported to 3DS Max for subsequent processing. While those models have the advantages of being very precise and easily generated, they come at the price of decreased rendering speed and poor rendering quality because of a large loss of triangle faces. In this regard, EAST models are rebuilt and materials created by photos of EAST device are assigned to models. Moreover, because virtual reality is quite effective at creating experiment scenarios thanks to their ability to provide the feeling of immersive operation and collaborative environments, model libraries are built during this research for future scheme generation and hardware installation training. The immersive EAST system is developed in the Unity3D environment using a Client/Server architecture, the HTC Vive and handheld devices are used to provide the immersive scene, intuitive controls and realistic haptic feedback. Users can roam in the virtual scene and interact with the immersive EAST using the handheld devices and communicate with other users in the system. The establishment of the system provides the framework for a comprehensive and cooperative experiment and training environment for EAST.

1. Introduction

In general, access to any of the international nuclear fusion experiments is nontrivial, but it is especially difficult for those devices with neutron radiation. It is because of this that the research of real device virtual scene simulation and the eventual control of the real scene through the virtual scene has gained serious and widespread attention within the nuclear fusion research community. [1]

The research and development of a “virtual EAST” has been carried out since 2011. The previous virtual EAST system based on VRML/Java3D requires the support of a specific plug-in which causes significant inconvenience for users. [2] Although the improved system based on WebGL provides an integrated and intuitive platform for scientists and engineers to interact with EAST, it lacks the immersive experience. [3] The new tool for autostereoscopic visualization of EAST which gives the 3D effect to users by autostereoscopic technology independent of any auxiliary equipment can greatly improve the convenience and access for the users. However, the 3D effect of autostereoscopic system is not better than the system with wearable devices. [4]

The immersive interactive platform mainly includes the virtual reality system based on a head-mounted display and a projected virtual reality system [5]. The main characteristic of which is to give the user the sense of being in the actual fusion device; able to interact with it via specifically designed interactive devices and handheld devices within the virtual scene.

By analyzing the EAST experiment, two conclusions can be made: (1) As a large superconducting fusion experiment device, EAST is not easy to access. [6] During the period of continuous plasma experiments, the device is in the plasma discharge experimental state and thus nearly impossible to enter. When in the non-experimental period, in order to prevent damage to the internal state of the device, only the relevant scientific researchers may enter the device, and even then only in accordance with a lengthy prescribed procedure. In addition, the device space is small, the internal components are complex, and so only a few people can enter the device at the same time. (2) EAST has a large number of diagnostic components to obtain a variety of experimental parameters. These components require expert design and must be

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carefully installed in the experiment in order for them to work effectively. Having such a large number of diagnostic components all installed in such a limited experimental environment requires the scientists to plan and prepare each component and installation space carefully and completely. The traditional way of determining the installation scheme is to look over the drawings and discuss with other diagnostic personnel several times, and then enter the device and install the parts according to the actual situation. Often, this requires several "trial and error" step to ensure the components are installed in the best possible position to get the best possible results without interfering with other diagnostic components.

In this regard, the immersive EAST system has proven to be a very useful system for scientists to improve their work efficiency. In this paper, we propose the immersive EAST system using a Client/Server architecture to provide the feeling of immersive operation and collaborative environments. Consider future application requirements, the contrasts between traditional system and virtual reality system are given to gain a better understanding of the purpose of the system.

2. System architecture

The global system architecture can be seen in Fig. 1. As the basic configuration, the HTC Vive (Virtual Reality headset) and the graphic workstation (with the minimum configuration of NVIDIA GeForce GTX 1060 and Intel i5-4590 with 4GB RAM) are necessary. The users' information, models, and operation commands are stored in a MySQL database. The users login to the immersive EAST using their standard EAST account on the LDAP logging service. The historical data can be loaded into the system individually. The EAST model is reconstructed in 3ds Max and exported to .fbx format which can then be imported in to Unity3D easily. Interaction and control of the virtual scene are realized using CSharp in Unity3D. In order to realize the cooperative module, socket technology is used to connect to the server in order to access the database to manage the contents.

The immersive EAST system provides the functions of virtual roaming, data visualization and virtual installation. Virtual roaming is the basic application of the virtual reality system; it provides the users a virtual scene to simulate a highly realistic EAST. In order to analyze the experimental results directly, three-dimensional data visualization results are created using computer graphics technology. It is relatively easy and extremely useful to use the virtual reality technology to visualize complex structures. Data visualization in the virtual reality system can help the user to more clearly understand abstract data, the positional relationship of particle trajectories, and the structure of the magnetic fields. The virtual installation module provides an environment in which the diagnostic personnel can coordinate with each other to simulate the installation of various components in the virtual reality system and then generating a well-defined component installation scheme.

3. System realization

3.1. Model establishment

Although EAST has been designed using CATIA with detailed models at various stages of design, it is not possible or suitable to use those models with their high-level details during the visual phase. These models were established at the design stage and so they contain an incredible amount of excessive features; the result being that even loading one complete component onto our virtual scene brings the entire virtual system to a grinding halt. In order to meet the demand of real-time rendering, models are simplified by reducing the number of triangles in the previous system. However, this approach is not applied to the immersive virtual reality system because removing triangles leads to the model being incomplete which reduces the quality of virtual scene.

For the purpose of improving the rendering speed and ensuring the rendering quality, the EAST model is reconstructed (Fig. 2(a)) on the basis of its photographs (Fig. 2(b)) and the actual proportion. As a professional 3D computer graphics software for making 3D models, 3ds Max has been used for many years by game developers, 3D visualization experts and commercial studios. Its powerful modeling capabilities enable us to establish the EAST model conveniently. Its ability to work with surface models which are general in the EAST model and its multiple control of material makes it workable (Fig. 2(c)). Besides, a wide variety of formats can be imported to and exported from 3DS Max for other applications and further work.

3.2. Traditional scheme and improved scheme

In order to control the operation of the fusion experiment, a variety of diagnostic methods are used to measure and analyze the properties of the plasma as well as the engineering parameters and the state of the device [7]. EAST contains dozens of diagnostic components to provide a greater variety and detail of basic parameters. During the process of the experiment, the diagnosis and measurement methods are constantly

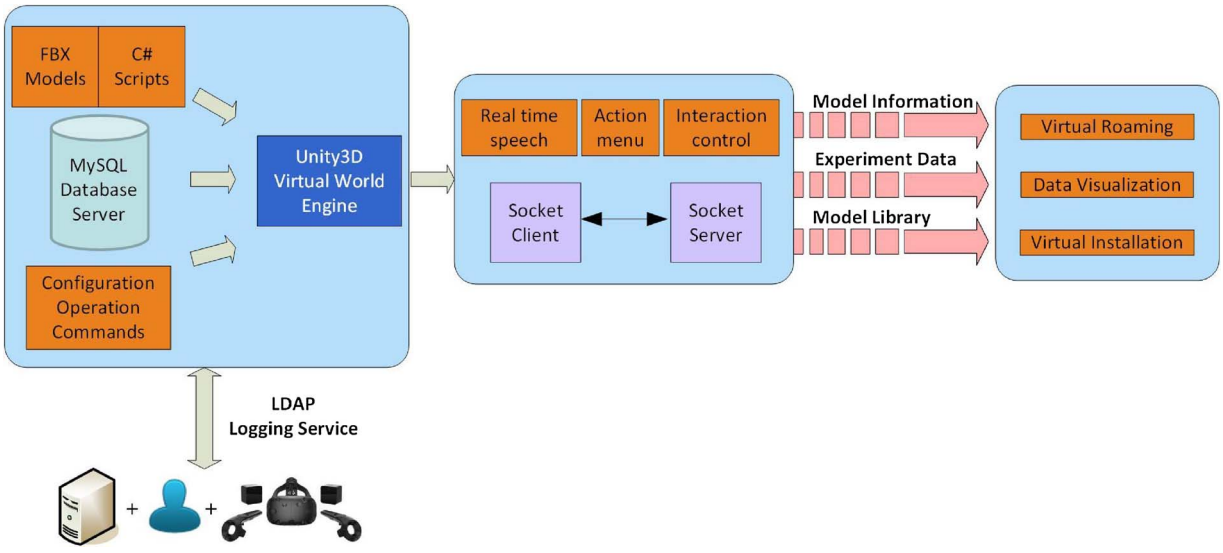

Fig. 1. System architecture.