Interactive System based on Augmented Reality and Anomalous Screens and Implementation

Yimin Chen, Ming Chen, Yunhua Zhang, Qiming Li, Sheng Xu, Chen Huang
School of Computer Engineering and Science,
Shanghai University, Shanghai 200072, China
ymchen@shu.edu.cn, cmyes@shu.edu.cn
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Abstract

This paper proposes and implements a novel multi-users real time Human-Computer Interaction (HCI) platform and system based on augmented reality (AR). The platform uses AR and multi-anomalous screens for exhibition. We focus on research and applications of multi-user real time HCI technique. Platform of AR rendering, HCI and network communications are designed and implemented. The system has been used at the EXPO 2010.

Keywords: *Augmented Reality, Real-time Human-computer Interaction (HCI), Anomalous Screen*

1. Introduction

Augmented reality (AR) has emerged as a result of the rapid development of virtual reality (VR). It connects the real world information to the virtual world information seamlessly [1].

VR can create a computer-simulated imaginary world. Users can get an immersed and interactive feeling of the pseudo-environment by watching, hearing and touching. An AR system can check the VR in real environment.

Technology development trend indicates that the virtual experience mode connecting the real environment is an important technology in VR [2]. One of the programs in the computer application section of the 11th five-year Plan of China is the construction of human interface environment [3], which is VR technology, in fact.

USA, Japan and some Europe countries have made much progress in some key techniques in AR [4]. They also get many satisfactory results by designing and making key equipments [5]. For instance, the AR system which is used in metropolitan program is developed by the Fraunhofer Institute in Germany. This enables architecture designers to get a preview of their designs. At EXPO 2005, Hitachi Enterprise Pavilion in Japan showed the close relationship between human and nature through an AR system. The recreational show method brought huge benefit to Japanese enterprises. The AR technology is still underway in our country. Shanghai University started the research on AR system based on PC platform in the first half year of 2002. It designed the structure of AR system based on PC, realized the calibration method which is easy, automatic, highly accurate, robust and fit for AR system, and gained some achievement in real-time HCI [6].

The special shaped screen technique projects several scenes onto the nonplanar abnormality screen. Thus a multi-viewpoint and multi-screen environment is created by combining modules and scenes with special image processing technique. The research on special shaped screen and relevant application have been registered as intellectual property [7] [8] interiorly. Patent [9] virtualizes the common display set connecting computer to the network projecting set. Therefore, it is convenient to simultaneously display the projecting content coming from multi-projection source through network, and to change display between the projections. However, just taking button pressing as the Human-Computer Interaction approach makes users hardly feel immersion rather than utilizing the advantages of the multi-projection system well. Patent [10] brings forward a multi-projection big screen splicing method based on turntable. This method can do geometric correction and alignment and locate the overlap in order to get ready to unify brightness. But it neglects the problem caused by communicating with image contents of multi-projection.

There isn't any application of multi-projection system in grand theater both at home and abroad, to say nothing of the application combining AR technology with special shaped screen technology, which supports multi-projection virtual network system. We propose and realize a multi-user real-time interaction platform based on AR and multi-special shaped screen technology for exhibition and display. Related rendering platform is also designed and realized in AR interaction system.

2. The design of system structure

For some key equipments are special, the AR system is complex. The structure of AR system is shown in Fig.1. The data, which comes from the video cameras and magnetic tracker, are corrected and fused. Coordinating with the script control timing of the network control platform, the refined data registers the virtual physical model. The real-time optical see-through Helmet mounted display (HMD) augmented display system consists of two sets of OLED, a video camera with telescope and a process PC. The real-time multi-special shaped screen interaction system is a PC LAN transmitting system. Each projection is controlled by rendering PC. Another PC charges the control of timing and script.

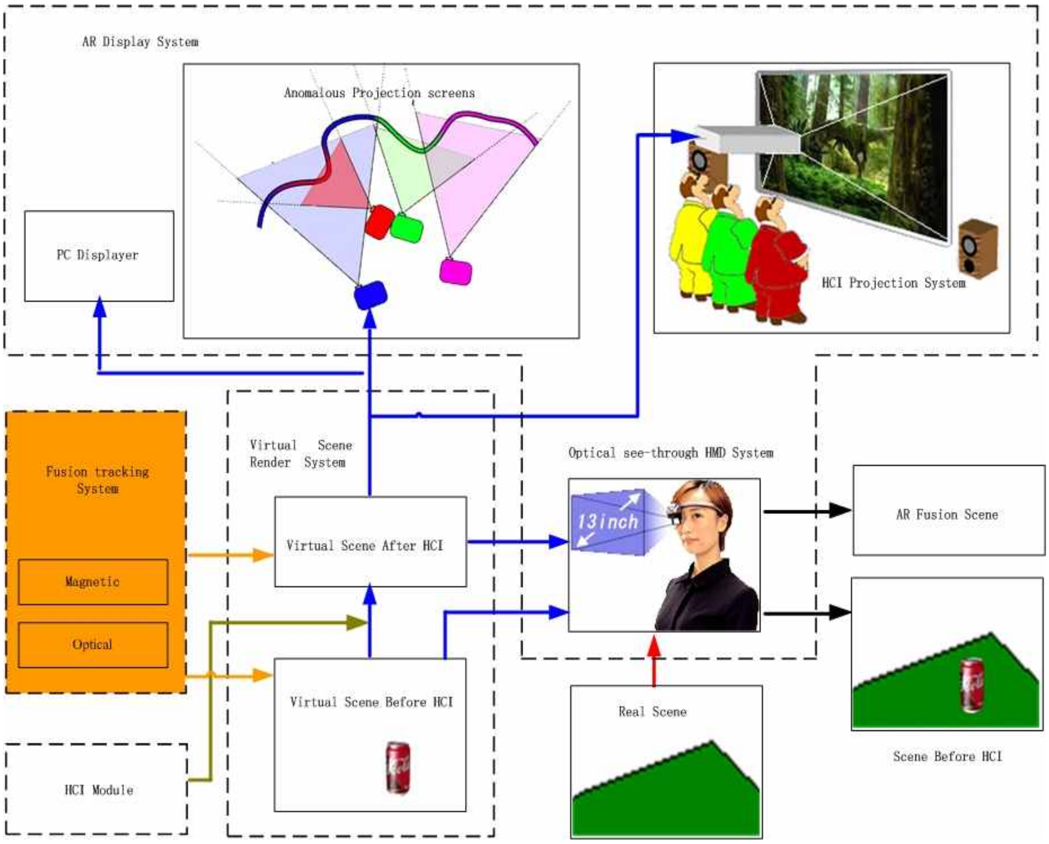

Fig 1. The sketch map of the structure of AR system

The system includes a subsystem for real-time optical see-through HMD augmented display, a subsystem for real-time virtual holding, throw checking and real-time throwing animation, and a subsystem for multi-special shaped screen interaction.

The system modules are as follows: System interaction performed by HCI system which includes AR system and application programs on projection system; local motion catching system, which catches hand motion and head motion; real-time collision detection system; AR rendering control platform;

graphical user interface (GUI) platform to control and manage system; projection interface system to interact with projection system. The structure of the system is shown in Fig.2.

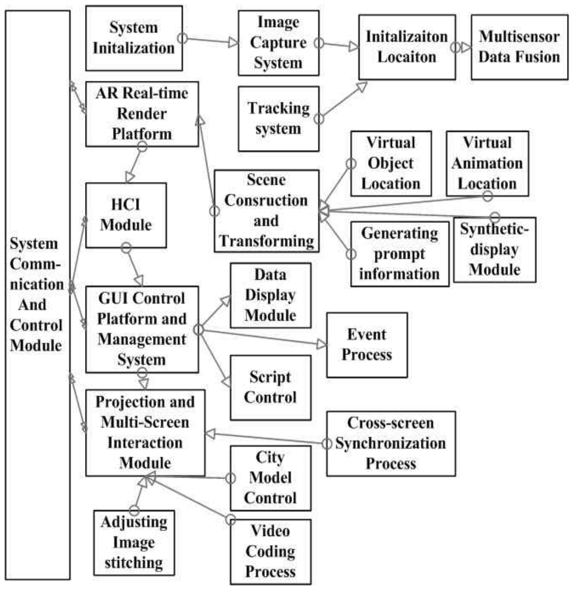

Fig.2. The structure of system

3. The design and realization of the AR platform

The interaction module in AR is the core as well as one of the characteristics of the system. This module processes all sorts of signals which come from the input equipment such as data glove, magnetic tracker and video tracker. Then it collects the data from the real-time tracing system and sensors. Finally, it transforms and sends the coordinate of data to the communication module. It can also receive the feedback data from the communication module and send message to sensors.

This paper proposes a system which realizes the functions such as real-time augmented display of reality, real-time motion recognition of HCI and multi-projection communication. The system processes the real-time throwing animation across screens, and fuses the images which depict the throwing process. It utilizes the network platform to realize the distributed preprocessing. The system, which realizes the real-time virtual holding, the throwing motion checking and the algorithm to create the real-time throwing animation, consists of magnetic trackers, videos with telescope and personal computers. And also, it is a multi-sensor system with visual and magnetic trackers. The design process is as follows:

The system achieves image segmentation according to the skin statistic. Then it converts images into skeletons, and filters the pre-built holding classic models in order to get the motion type. If the holding process succeeds, the system will check the throwing motion, and create the corresponding throwing animation.

4. The design of real-time human-computer interaction and emotion recognition system

In order to realize the real-time human-computer interaction and motion recognition, we perform calculus of differences to the frames of dynamic images with the help of the images which are divided by the optical see-through HMD augmented display system. After skeletonizing, we work out motion character, including the finger curvature and the palm angle, and then compare them with the stored database index to get the motion success rate. Then we compute the coefficients such as the acceleration and the direction variable to check the throwing motion. If they are greater than the trial statistic average, we reckon that the throwing is successful.

In order to catch the real hand motion and to locate the virtual hand, we need the joint work of magnetic tracker and data glove. According to literature [11], firstly we put the magnetic tracker receiver on the wrist. Then we get the location and Euler Angle in the world coordinate of the wrist and get the Homogeneous Transformation Matrix according to DH algorithm. After that, we construct local coordinate at all of the joints and deduce the coordinate transformation matrix for i coordinate transforming to i-1 coordinate. After matrix multiplication, we can get the coordinate of the hand joints and fingertips in the world coordinate.

There is no rotating from wrist to finger joint, so the transformation matrix is simple. We just need measurement. However, it is hard to get the transformation matrix for the part from finger joint to fingertip.

Both the constructed coordinate and No.1 coordinate have characteristics that the z1-axis points outward, the x1-axis rightward, and the y1-axis upward.

If the rotating coordinate OUVW rotates around the axis of reference coordinate OXYZ, we premultiply the basic rotating coordinate matrix. Otherwise, if the rotating coordinate OUVW rotates around its own axis, we postmultiply the basic rotating coordinate matrix.

Based on this theory, the rotating method is as follows: To get the first matrix, we rotate the x1-axis 90 degrees around z1-axis toward y1-axis. Then the x1-axis becomes x2-axis. To get the second matrix, we rotate the y1-axis 90 degrees around x2-axis toward z1-axis.All the rotations are relevant to matrix.

And then the finger bends at angle of θ and rotates around z2 from the view of coordinate 2. It is put at the end of the multiplication in the following formula:

$$\begin{bmatrix}0&-1&0&0\\1&0&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}\times\begin{bmatrix}0&0&0&0\\0&0&-1&0\\0&1&0&0\\0&0&0&1\end{bmatrix}\times\begin{bmatrix}c&-s&0&0\\s&c&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}=\begin{bmatrix}0&0&1&0\\c&-s&0&0\\s&c&0&0\\0&0&0&1\end{bmatrix}$$

The finger rotates around x1 from the view of coordinate 1. It is put at the head of the multiplication in the following formula:

$$\begin{bmatrix}1&0&0&0\\0&c&-s&0\\0&s&c&0\\0&0&0&1\end{bmatrix}\times\begin{bmatrix}0&-1&0&0\\1&0&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}\times\begin{bmatrix}1&0&0&0\\0&0&-1&0\\0&1&0&0\\0&0&0&1\end{bmatrix}=\begin{bmatrix}0&0&1&0\\c&-s&0&0\\s&c&0&0\\0&0&0&1\end{bmatrix} \quad (1)$$

Results of the two methods are identical with each other.

The next step is to compute the rotation angle of the fingers. The data glove can only get the bend degree of the proximal interphalangeal (PIP) joint. The bend degree of the distal interphalangeal joint is 2/3 of the PIP according to some literature. However, the relationship with metacarpophalangeal joint is ambiguous. The common data glove can't get the angles (which isφ) of two fingers while the finger is extending. It should be noticed that the thumb has the DOF of 5 which is the key of collision detection and occlusion in the crawl. Therefore, the magnetic tracker and data glove can't get the accurate location of the thumb if we just depend on Diffie-Hellman Algorithm. In order to amend the matrix we try to get the approximate location of the thumb by magnetic according to times of experiment.

5. The analysis of Throw action

By using magnetic tracking, we can get hand's moving path of throw action. However, the path is similar to normal hand action path. Thus, other features of throw must be found. Since differences of the intervals between points in path show that velocity is changing throughout the whole throw process. Records of path illustrate that the velocity climbs up and then declines during throw process. Details are described in literature [11]. So the throw action can be detected by velocity feature observation.

6. The design of real-time multi-special shaped screen interaction system

The multi-special shaped system screen interaction system partitions the image content. The background is fixed on the screen. The interaction content is handled with script and rendered by distributed multi-PC. It preprocesses the splicing part so that the cross-screen animation can be rendered in time.

Because the screen is composed of many sub screens, the control software needs to make sure the content of the sub screens is synchronous. Therefore, the master terminal must have the reliable synchronous playing function. The Synchronization control is realized by software. The synchronous playing can be realized by asynchronous feedback technique with the help of the multithread Technology. The job of the master terminal is testing the consistency of the playing statue which is feedback from playing terminal and deciding whether to send control instruction by the consistency of the playing terminal. The feedback of the playing terminal ensures the synchronization in the LAN.

The Deformation Correction Technology for image is one of the key in multi-screen splicing with no gap. The system takes the deformation correction to the image by software rather than projector. It is real-time and nonlinear distortion correction which is used to correct the image projected onto the special-shaped screen such as a ball screen or a circarama.

It is one of the key technologies influencing the final effect of the system that how to splice the images from different projectors with no gap and to remove the bright edge or shadow so that the whole screen is perfect. There are some popular splicing methods such as forced stitching, simple overlapping, edge blending. This paper takes the third method. It removes the edge shadow by image splicing edge fusing technology. Compared with simple overlapping, the brightness of right overlap in left projector is linear attenuating while left overlap in right projector linear increasing. It makes the brightness of the whole image identical.

Compared with other technologies, the method realized in this paper has the conspicuous advantage that it is highly real-time, popular and economical and it has the function of real-time AR interaction display.

7. The design of the communication platform

The communication module is the base of the synchronization of the whole system. The real-time communication protocol in LAN includes multi-computer synchronization information, hardware control instruction information, sensor information and rendering instruction information etc.

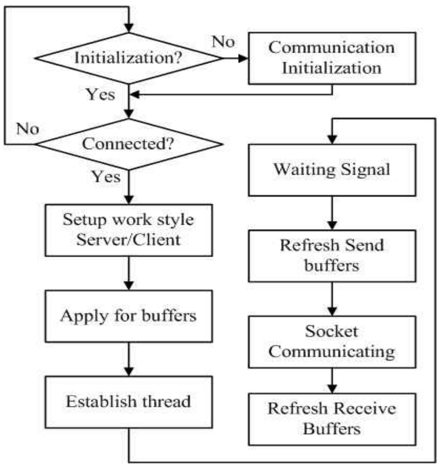

Fig 3. The flow chart of multi-thread synchronous communication

The communication module is initialized before being called. In initialization, the module collects the information from sub modules to determine the size of the receive buffer. If the socket in this module is not connected with the corresponding socket, it tries to connect. Otherwise, it determines the work model by checking with the socket map container and applies the buffer. Then it constructs the communication thread and implements the communication body. One communication process is that the server sends message firstly, the client sends it back to the server after the message received and the server finally accept it. Finally, the communication module deals with the multi-thread synchronization by waiting for the event of rendering main thread.

The timing of network module makes sure that every frame sends only one group of data while rendering scene. It uses block model and event synchronization mechanism. Therefore, it deals with the phenomenon of discordance in sending and receiving because rendering speed varies with computers. Moreover, it can minimize the network bandwidth.

8. The analysis of experiment result

A complete AR system is realized by joint work of close connected real-time hardware and related software system. In order to break the limit of complexity in drawing the scene by PC graphics, to deal with more than 20,000 complex model of polygon and to get the rendering speed of 24 frame per second, the system deals with the real-time performance by using distributed graphic processing technology which is based on PC-Cluster and parallel graphic processing technology.

The reference range of tracking is set to 1.5M*1.5M*1.5M. And it is able to make the virtual object compatible with the video information in real environment. The interaction is real-time.

The error range of the vision location of tracking audience in helmet and the direction pre-estimation angle is limited to ±2.5 degree. And the relative error of coordinate of key point tracking interaction motion coordinate is limited to 3%.

As is shown in Fig.4, the system collects real hand video by camera and produces virtual image by AR rendering platform. The hand motion interacts with the virtual object. Deformation will happen to virtual objects given some collision. It realizes the effect of interaction without any feedback force.

Fig 4. The responding process of real-time virtual real interaction

Fig 5. System runtime rending diagram

9. Conclusions and future work

This paper focuses on the research of constructing some virtual scene of city life by special-shaped screen. The users who wear 3D stereo glasses are in big changing multi-media scene. They can touch the buildings and experience the new life in the future city with the help of VR technology and gesture needed in real-time interaction. The vision effect is based on immersing city environment and future residents' life. The system realizes the VR changes in big special-shaped screen and adds 3D animation or 3D image in stereo glasses. In addition to colorful multi-media image and multi-sound channel, the system constructs a set of big special scene by the video sound set and light controlling set. This huge technology integration project allows many people to get involved. The project opens a new world to people, which is the fusion of virtual information and reality, and is highly immersing and interactive.

10. Acknowledgements

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