Interactive Virtual Reality Indoor Space Roaming System Based on 3D Vision

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Abstract. Due to the low performance of traditional virtual reality roaming systems, three-dimensional vision technology is used to optimize the design of interactive virtual reality indoor space roaming systems from the three aspects of hardware, software, and database. The optimization of the hardware system is mainly aimed at the connection structure of the rover and the interactive module. Collect all relevant data of indoor space and system operation, and store them in a certain format to get the design results of the system database. With the support of hardware equipment and database, the function of interactive virtual reality indoor space roaming is realized through the steps of creating virtual scene of indoor space, determining the roaming mode of 3D virtual reality and the path planning of indoor space roaming. Through the system test experiment, it is concluded that compared with the traditional roaming system, the designed interactive virtual reality indoor space roaming system has a higher success rate and better interactivity.

Keywords: 3D vision · Interactive · Virtual reality · Interior space · Roaming system

1 Introduction

Virtual reality is a higher level of multimedia technology development, and a higher level of integration and penetration of these technologies. It can give users more real experience and provide great convenience for people to explore the macro and micro world. Due to various reasons, it is not convenient to directly observe the movement law of things. In essence, virtual reality is an advanced computer user interface. It provides users with various intuitive and natural real-time perceptual interactive means such as vision, hearing and touch, so as to maximize the convenience of users' operation, so as to reduce the burden of users and improve the working efficiency of the whole system. One of the most basic functions of virtual reality applications is the roaming function of the virtual environment. The virtual roaming system is a simulation of imaginary or real space. It takes the real environment as a reference and virtualizes the scene in the space. It enables visitors to roam or look around. Visitors can also make corresponding behaviors to make the environment have a certain Artistic characteristics [1]. Users can

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plan and operate the landscape and various facilities through the network, observe the corresponding virtual objects in the process, and get the feeling of being on the scene. Virtual roaming system is based on geography, virtual reality, multimedia, broadband and other technologies, combined with the content of attributes and geospatial information, and constructs a realistic virtual campus environment. Users can access the landscape in the space through the computer network, and use the terminal computer to carry out roaming and corresponding search in the virtual space environment and query.

The establishment of the current indoor roaming system is actually the application of virtual reality technology to the field of indoor space. For traditional indoor roaming systems, an object-oriented approach is generally adopted, combined with virtual reality and other related knowledge to simulate indoor scenes. The system still has shortcomings in terms of human-computer interaction and code reuse, especially in terms of code reuse, it does not fully realize code reuse, and the interactivity is not strong [2]. The 3D entities in the existing indoor roaming system are static and developed in advance. Although the whole indoor scene can be observed from different directions by controlling the mouse and keyboard, it is impossible to dynamically add other 3D models to the scene after the scene is created, and the location, size and other attributes of these models cannot be changed there are also limitations in the rapid construction and reuse of three-dimensional model, so the whole application system still has deficiencies in flexibility control and later expansion.

In order to solve the problems in the above-mentioned traditional methods, three-dimensional vision technology is used to realize the optimized design of the interactive virtual reality indoor space roaming system. Design the hardware system through the connection structure of the rover and the interactive module, store all the relevant data of the indoor space and system operation, design the system database, use the 3D vision technology to create the indoor space virtual scene, determine the 3D space virtual reality roaming method and indoor Complete the system software design by steps such as space roaming path planning. The design of an interactive virtual reality indoor space roaming system based on three-dimensional vision is completed through hardware, software, and database. Finally, simulation experiments verify the effectiveness of the system designed in this paper.

2 Hardware System Design of Virtual Reality Indoor Space Roaming

The system must be able to represent the three-dimensional model of indoor space terrain undulations, scene buildings and other objects. It is very realistic in terms of form, lighting, texture, etc., so that participants can roam in the constructed lifelike virtual environment. In order to meet this requirement, The overall design must follow the principles of reality, interactivity, imagination and efficiency [3]. In order to ensure that the whole roaming system can run smoothly on the computer and achieve realistic scene rendering effect, according to the design ideas and design principles, the overall framework of the roaming system can be obtained, as shown in Fig. 1.

As can be seen from Fig. 1, each function in the system is relatively independent and interrelated through the data interface. In order to ensure the optimal design effect

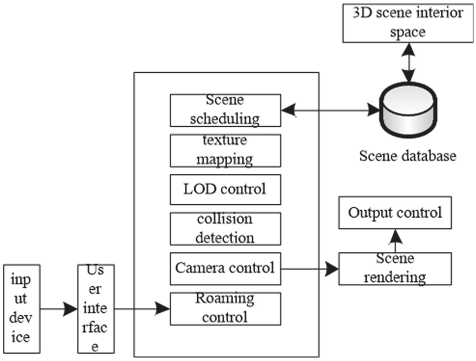

Fig. 1. The overall structure of the indoor space roaming system

of roaming system, the specific optimization design is carried out from three aspects of hardware, database and software.

The parts of the hardware system that need to be optimized include rover, interactive communication mechanism and so on. For different scenes and different roaming methods, you can choose roamers. For example, you can use trackball-based roamers for general roaming; when you are in a large-scale terrain scene, you can use terrain rovers; if you want to simulate real vehicles, Such as cars, airplanes, etc., you need to consider driving realistic scenarios at this time, you can use driving rover [4–6]. These rovers use real-time correction of the scene camera observation matrix to achieve smooth roaming. In the design of the rover, we mainly focus on the correctness and suitability of visual motion, that is, how to move the observer to the specified position and posture smoothly and accurately. The roaming operation is mainly controlled by three parameters: viewpoint, observation point and up direction.

The commonly used rover is the trackball rover, and its interaction is realized by mouse movement and the positioning of the trackball. This article implements the rotation function of the rover based on the principle of trackball, as shown in Fig. 2.

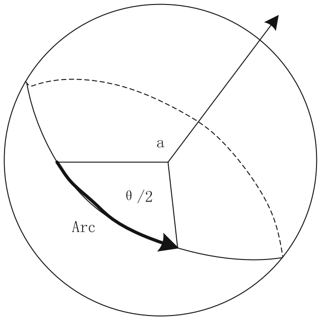

Fig. 2. Working principle of trackball Rover

The left mouse button realizes rotation, the middle mouse button realizes translation, and the movement direction of the mouse is the translation direction, and the mouse wheel and right button realize the scene zoom function.

In order to optimize the interaction of roaming system, the hybrid network structure is selected. This communication network structure combines the advantages of centralized directory structure of central control network and point-to-point structure of distributed network. In the network, some nodes are used to store the information of adjacent nodes. The whole network is divided into several autonomous subnets according to these nodes, and different subnets adopt pure point-to-point structure.

3 Database Design of Virtual Reality Indoor Space Roaming System

While describing a large-scale virtual environment based on real terrain data, virtual scene often involves the specific structure and detailed state of each entity in the virtual scene. Therefore, the relationship between the virtual entity model and the spatial model in each scene should be determined according to the geometry model of the virtual scene. The establishment of the scene database adopts the tree structure hierarchy to organize and manage the scene data, which can easily realize the hierarchical structure management of the model when modeling. The data mainly involved in the system includes user data, scene and model data, model information data, and user communication information data. The entity relationship of the virtual scene module in the entity relationship diagram can be obtained according to the attributes of each data and the relationship between them, thereby establishing a database table. In this roaming system design, the database table is divided into user information table, user communication data table, roaming data table, scene data table and other parts.

4 Software Function Design of Virtual Reality Indoor Space Roaming System

In this process, the virtual reality indoor space roaming system can establish the 3D scene model, and meet the function of view selection and view control. The design follows the idea: take the indoor space of a building as the environment, select several representative scenes from it, use 3D vision technology to model, use 3D texture mapping to draw the scene, and finally interact in the system development environment Control, so as to realize the design of the virtual reality indoor space roaming system function.

4.1 3D Vision Technology to Create Indoor Space Virtual Scene

In order to create an environment that enables users to feel immersed and immersed in it, one of the necessary conditions is that all objects in the objective world can be vividly displayed in the virtual reality system as required. It is not only required that the displayed object models are very similar to the real objects in appearance, but also that they are very realistic in terms of shape, illumination, texture, etc. The modeling of virtual environment is the foundation of the whole virtual reality system, including three-dimensional visual modeling and three-dimensional auditory modeling. Among them, visual modeling includes geometric modeling, motion modeling, physical modeling, object behavior modeling and model segmentation.

4.1.1 Collect Indoor Spatial Data

Define the constraint relationship between two monocular virtual cameras A and B. Firstly, define the distance D between two monocular virtual cameras and the angle of sight θ to give a three-dimensional virtual camera model. According to the principle of binocular parallax forming three-dimensional vision, the distance between the two viewpoints of the binocular camera is calculated, that is, the observation parallax is:

$$D = |P_{ea} - P_{eb}| \tag{1}$$

In the formula, P_{ea} and P_{eb} are used to describe the viewpoint of camera A and B respectively. Then calculate the angle of the camera's line of sight, you can get:

$$\sin\left(\frac{\theta}{2}\right) = \frac{|P_{ea} - P_{eb}| - |P_{ta} - P_{eb}|}{2|P_{ea} - P_{tb}|} \tag{2}$$

Where P_{ta} and P_{tb} represent the implementation direction of camera A and B respectively [7]. The line of sight length of the two cameras is the same, so the following relationship should be satisfied:

$$|P_{ta} - P_{ea}| = |P_{tb} - P_{eb}| \tag{3}$$

The three-dimensional vision camera equipment built above is used to collect image data in the indoor space.

4.1.2 Camera Calibration

One of the basic tasks of stereo vision is to use the photo taken by the camera to process the image to obtain the distance of the object from the camera and some three-dimensional information of the object. The computer establishes the model of the relationship between the image and the object. After this model is completed, the point in the object can be obtained from a certain point in the image. This model is called the camera imaging geometric model. There are many parameters in the model. These parameters are called the camera's internal and external parameters. In most cases, the parameters of the camera can only be obtained through experiments, which is called camera calibration. Therefore, the purpose of camera calibration is to determine the camera position, attribute parameters and establish the imaging geometry model, so as to determine the corresponding relationship between the object point in the space coordinate system and its image point on the image plane. Camera calibration needs to determine the internal geometric and optical characteristics of the camera, as well as the three-dimensional position and direction of the camera coordinate system relative to a world coordinate system.

4.1.3 Image Preprocessing and Feature Extraction

In the case of image shooting, due to various reasons, the image contains noise or even distortion. In order to improve the image effect and make the image clearer, it is necessary to eliminate these noise factors which are not conducive to image clarity. This kind of processing is the image preprocessing. After the preprocessing, the image can also be conducive to the future work, such as image feature extraction, etc. Processing, weakening or eliminating some unnecessary information in the image, making the image more conducive to computer recognition. Image preprocessing technology includes image contrast enhancement, weakening or noise elimination [8]. The image contains a lot of information. Some information is useless or not very important. In order to simplify the future work, useful and important information should be extracted from the image, and this information should be distinguished from other objects. The process is feature extraction. The extracted features usually include point features, linear features, and regional features. The point features are relatively small, such as corner points. After feature extraction, more point features can be extracted, but because they are small-scale features, Therefore, the amount of information is very small, and some constraints or some matching strategies need to be added in the next stereo matching; while the regional features are just the opposite. Regional features are relatively large features. After feature extraction, the extracted regional features are compared. The regional feature is a large-scale feature, which contains more information, which is conducive to future matching work.

4.1.4 Stereo Matching

Stereo matching means that the camera uses a certain algorithm to find the corresponding points in the two photos taken by the camera at the same time. Stereo matching is a key technology in binocular vision, because the camera is easy to shoot objects in two different perspectives. Affected by factors such as illumination, image shooting angle, noise and distortion, and camera characteristics. Therefore, it is very difficult to accurately match images with so many disadvantageous factors. The effectiveness of stereo matching method depends on the solution of three problems, that is, selecting the correct matching features, finding the essential attributes between features and establishing a stable algorithm that can correctly match the selected features.

4.1.5 Viewpoint Control and Conversion

The basic control operations of viewpoint, such as translation, rotation and scaling, are based on matrix transformation. The viewpoint coordinates can be obtained by multiplying the original vertex coordinates by the corresponding viewpoint transformation model viewpoint matrix. The attributes of the viewpoint mainly include the position coordinate (VPx, VPy, VPz) and the sight direction (VLx, VLy, VLz). By changing the attribute parameters of the viewpoint, the position of the viewpoint and the viewing direction of the viewpoint can be controlled, so as to realize the free control of the viewpoint. The principle of scene model flipping during viewpoint transformation is shown in Fig. 3.

As can be seen from the figure, in general, the angle between the line of sight direction and the axis is large, and the vector changes little. In the graph, the angle between the

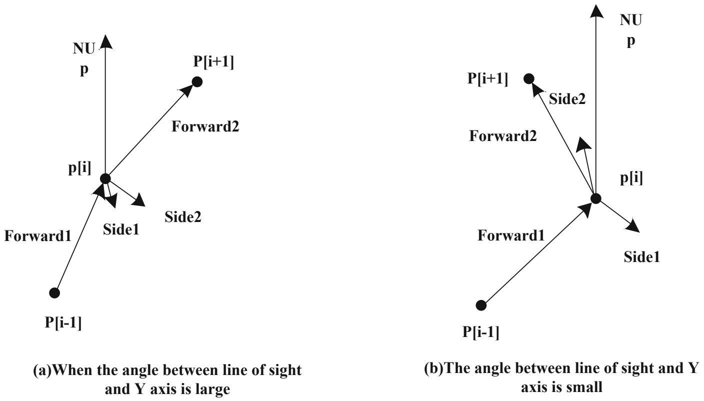

Fig. 3. Schematic diagram of the scene inversion when the viewpoint is changed

line of sight direction and the axis is small. As the current path point, the vector changes greatly, that is, the angle between the vector and the vector is obtuse angle, so the direction of the vector finally obtained is opposite to that of the previous state. Therefore, the line of sight after the viewpoint transformation is opposite in the direction, and the scene is flipped.

4.1.6 3D Scene Display of Indoor Space

The material settings are mainly realized through the material editor tool in 3ds max. The material editor is used to select and manage materials and maps. The common parameters that affect the material of the model mainly include the basic parameters of shading, Blinn, expansion and mapping, etc. in order to better express the attributes and characteristics of objects, different parameters should be used together. In the actual setting of the object properties, since the values of the parameters cannot be determined, a gradual fine-tuning method can be used until the external characteristics of the actual object are similar. At the same time, the color difference of the computer itself needs to be considered. In addition, it is necessary to set the lighting effects in the three-dimensional indoor space scene. The lighting is an integral part of a complete three-dimensional scene. The authenticity of the three-dimensional scene is inseparable from the illumination of the light. The model in the scene is visible, and the materials attached to the model are displayed correctly, so as to show the characteristics of objects in the real world, which greatly ensures the reality of the scene [9]. There are skylight, target spotlight, target parallel light, floodlight and so on. Finally, the lightingmap rendering and baking method is selected to obtain clear texture texture, and finally get the 3D scene of virtual reality interior space.

4.2 Determine the Three-Dimensional Virtual Reality Roaming Method

There are two ways to roam in 3D space: interactive roaming and automatic roaming. Interactive roaming can control the viewpoint through mouse, keyboard and other input devices, so as to realize human-computer interaction. Automatic roaming only needs to set the starting point and ending point of roaming, and the viewpoint moves according to the designed motion mode. During the process, the roaming picture can be output without inputting any parameters. Interactive roaming realizes users' free operation, while automatic roaming realizes browsing of given path.

4.3 Roaming Path Planning in Indoor Space

To calculate the collision between the viewpoint and each surface of an object is actually to calculate the relationship between the distance between the viewpoint and the triangular patch and the step size. For example, if the vertex coordinates of the triangle are (x_1, y_1, z_1), (x_2, y_2, z_2) and (x_3, y_3, z_3), then the plane where the triangle is located should be calculated first. Generally, the plane equation is defined as:

$$Ax + By + Cz + D = 0 \tag{4}$$

Among them, D represents the distance from the origin to the plane. The specific calculation process is as follows:

$$\begin{cases} p_1 = (x_1 - x_2)i + (y_1 - y_2)j + (z_1 - z_2) \\ p_2 = (x_1 - x_3)i + (y_1 - y_3)j + (z_1 - z_3) \\ n = Normalize(p_1 \times p_2) \\ d = n \cdot (x_1 i + y_1 j + z_1 k) \end{cases} \tag{5}$$

Where p_1 and p_2 are vectors of vertex 1 pointing to vertex 2 and vertex 3 respectively, n is the normal vector of the plane where the triangle vertex is located, and d is the distance from the triangle patch to the origin. The positional relationship between the camera sphere and the triangular patch mainly includes three situations: intersection, in front of the triangular patch and behind the triangular patch. When calculating the plane of the triangle, the distance from the current camera's position coordinate to the plane is needed to determine the position relationship between the camera and the plane, and to determine whether there is a current collision.

4.4 Realize the Function of Interactive Virtual Reality Indoor Space Roaming

In order to realize the interactive roaming function of virtual reality indoor space roaming, interactive scripts are added to the built 3D visual scene. Bind the camera to the virtual character to set the character's movement speed, add gravity and other parameters, and modify the virtual character's action name to add scripts. Modify the name of the button and add scripts, such as music playback, camera selection, character actions, animation playback, etc. [10]. Double click the object in the indoor space environment, click the action button on the right side of the window to open the "distance trigger", set the trigger distance, select the trigger object as the virtual character, click "trigger action script on entry" to pop up the script editor, then select "insert statement", find the animation command, and finally click to play the rigid body animation and write the script. In this way, the command to trigger the cultural relic animation distance is completed.

The interactive roaming function of indoor space roaming requires keyboard and mouse control. The keyboard roaming commands include: turn left, turn right, forward, back, rise, fall, look up, look down, move left, move right, move acceleration, move deceleration, Rotation acceleration, rotation deceleration, zoom in and zoom out. Finally, under the control of each peripheral device, the switching of the roaming mode is realized, and then the roaming function of the interactive virtual reality indoor space is realized.

5 System Testing

To test the roaming function of the designed interactive virtual reality indoor space roaming system based on 3D vision, the system test experiment is designed.

5.1 System Development Tools and Test Environment

In order to allow this system to run on an ordinary machine, this computer configuration was selected during the test. In the system test environment, the processor device used Intel (R) core (TM) i5 M430 2.27 ghz dual core, and the hard disk space was 500 GB, the graphics card is 512 discrete graphics cards, the virtual reality simulation software is VR, and the development tool for system interaction functions is VC++. In addition, the 3D indoor space scene creation environment uses the 3DS MAX software. The software function design results of the interactive virtual reality indoor space roaming system based on 3D vision are converted into program codes that can be directly recognized by the computer, and the running interface of the roaming system is displayed. The running scene interface of virtual reality indoor space roaming system is shown in Fig. 4.

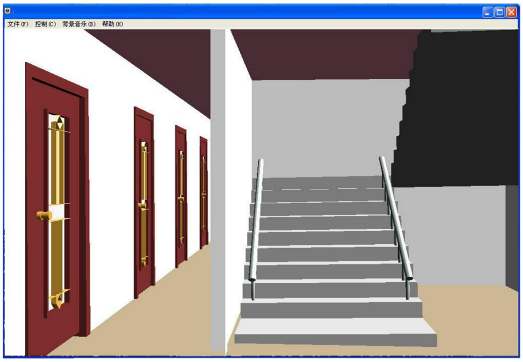

Fig. 4. Virtual reality indoor space roaming system interface

5.2 Select Interior Space Sample

In order to ensure the credibility of the system test results, multiple indoor spaces were selected as experimental samples during the test. The experimental samples selected in this experiment included museums, residential buildings, large shopping malls, etc., and each sample was numbered as the experimental number.

5.3 System Testing Process

This system test experiment is mainly to test the roaming function of the system, which is mainly aimed at different functional modules, such as the completeness of 3D scene construction, collision detection accuracy, and the execution level of roaming control commands. In order to form an experimental comparison, a traditional roaming system (document [2] system) is set up as a comparison system in the system test experiment, and it is developed and operated in the same environment.

5.4 System Function Test

The calculation method of the success rate of the function operation is the ratio of the number of commands that the function runs successfully to the total number of commands. The test comparison results of each function module of the comprehensive system test are shown in Table 1.

Table 1. System function test results

Test function module	Number of test commands/piece	Number of successful commands of traditional system	Design system successfully run the number of commands/piece
3D scene construction	300	258	277
Perspective shift	300	265	289
collision detection	300	244	278
Keyboard control roaming direction	300	273	294
Mouse control roaming direction	300	268	291

Based on the test results obtained in Table 3, it can be seen that the number of successful commands of the traditional roaming system can reach up to 273, and the average success rate of its functions is 87.2%, while the number of successful commands of the designed system can reach up to 294. Its average function operation success rate is 95.3%.

6 Conclusion

The interactive virtual reality indoor space roaming system truly realizes the interaction between people and the virtual scene, giving users a real feeling of being on the scene and immersed in it. Users can simply click the mouse to carry out a variety of sightseeing modes, such as bird's-eye view, overlooking, first and third person autonomous roaming, etc., to display the internal spatial structure of the indoor environment and observe various objects in the space closely; by using the virtual reality system, people can visit different indoor spaces without going out of the house, and get real experience; and thoroughly break the space, the space, the space and the objects in the space can be fully displayed The limitation of time has certain practical significance.

This paper designs an interactive virtual reality indoor space roaming system based on 3D vision from three aspects of hardware, software and database. The hardware system is designed for the connection structure between the walkthrough and the interactive module, and all the relevant data collected from the indoor space and the system operation are stored. The system database is designed. The system software design is completed through the steps of creating the indoor space virtual scene, determining the 3D space virtual reality roaming mode and indoor space roaming path planning through 3D vision technology. Finally, the effectiveness of the interactive virtual reality indoor space roaming system based on 3D vision is verified by simulation experiments.

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