Construction Of Infant Care and Service Management Simulation Training System Based on Virtual Reality Technology

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Abstract. The infant care training system utilizes virtual reality technology to create high-fidelity three-dimensional virtual environments and realistic digital human characters to replicate childcare scenarios, addressing the shortcomings of traditional training methods in providing high-fidelity simulations. The system is built on a client-server architecture, with clients equipped with virtual reality devices connecting to the server-side virtual environment rendering module. Virtual reality modeling is used to create lifelike three-dimensional scenes, while digital human generation technology is employed to create realistic virtual characters. Machine learning imparts intelligent interaction capabilities to these digital characters. The system supports multiple users simultaneously participating in immersive training within the virtual environment, allowing for the assessment of learning outcomes and feedback to optimize training programs. This system greatly enhances the immersion and engagement of training and operates smoothly and stably. The infant care training system constructed based on virtual reality technology in this study has significant technological innovation value and can effectively improve training quality, making it worthy of widespread application. This system can also be extended to other human care service training areas, offering broad application prospects.

Keywords: Virtual Reality; Infant Care; Training System

1 Introduction

Currently, virtual simulation technology is widely applied across various industries, offering new approaches to professional training by addressing the challenge of simulating real-world environments that traditional training methods struggle with. To address the issue of insufficient scene simulation in infant care training, it is essential to employ virtual technology to enhance training effectiveness. This study constructs a high-fidelity virtual training system. The virtual scenes, digital characters, and interactive tasks within the system greatly enhance the realism of immersion and scene experience. Additionally, the system includes a Q&A feedback module to provide better guidance for training. In terms of technology, cutting-edge techniques such as virtual reality and digital human generation are used to ensure the system's sophistication. Test results indicate that the system achieves its design objectives and effectively enhances training quality. This paper provides a detailed explanation of the requirements, design, implementation, and testing of the training system, offering valuable insights for future research. Overall, this study serves as a successful example of the

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integration of virtual technology and infant care training and provides a reference for other professional training areas [1].

2 Research on Relevant System Technologies

2.1 Virtual Reality Technology

Virtual reality technology can create realistic virtual environments, immersing individuals in a lifelike experience. Current virtual reality technology has matured, projecting high-definition three-dimensional images through headsets or glasses, coupled with full-body tracking systems, enabling the construction and experience of highly realistic virtual scenes to support childcare scenario simulation within the system. Mainstream virtual reality devices such as HTC Vive and Oculus Rift already offer resolutions of 2K or even 4K, with mobility continually improving. In the future, as hardware performance advances, virtual reality technology will be able to deliver even more finely detailed and realistic effects [2]. As shown in Figure 1.

Figure 1: Virtual Reality Technology

2.2 Digital Human Technology

Digital human technology, based on computer algorithms, can generate virtual digital human characters. By controlling the appearance, movements, and expressions of these digital characters, it is possible to create lifelike virtual individuals. Currently, digital human technology is widely applied in fields such as gaming and animation, enabling the creation of realistic virtual characters. Deep learning-based digital human technology is also rapidly advancing, providing virtual characters with more intelligent behaviors and interaction capabilities. This supports the inclusion of virtual roles such as virtual teachers and healthcare professionals within the system [3].

2.3 Data Collection and Processing Technology

The system requires the collection of user interaction data within the virtual environment to enable assessment and feedback functionality. Different data collection sensors have various advantages, and the choice of appropriate devices depends on the specific usage scenarios. Furthermore, preprocessing of collected data is necessary [4]. See Table 1 for details.

Table 1: Comparison of Different Sensor Technologies for Collecting Interaction Data

Sensor type	Collect data	precision	Use restriction
Data glove	Hand movement	high	Higher damage rate
Eye tracker	Eye movement	Very high	Inconvenience to wear
Space sensor	Integral action	In the	Device sensitive

Data Preprocessing Algorithms:

Input: Raw motion capture data

Output: Processed data with noise filtered out

Procedure Preprocessing(rawData)

Remove outliers

Apply noise filtering

Normalize the data

Return processed data

3 System Framework Design

3.1 Network Architecture Design

The system adopts a C/S (Client/Server) network architecture. Clients are equipped with virtual reality devices (headsets and handheld controllers) and the system's client software, and they connect to the server through a high-speed local area network (LAN). The server side is deployed with high-performance servers capable of graphics rendering, virtual environment modeling, rendering, and game logic operations. The use of cloud servers allows for easy scalability [5]. As shown in Figure 2.

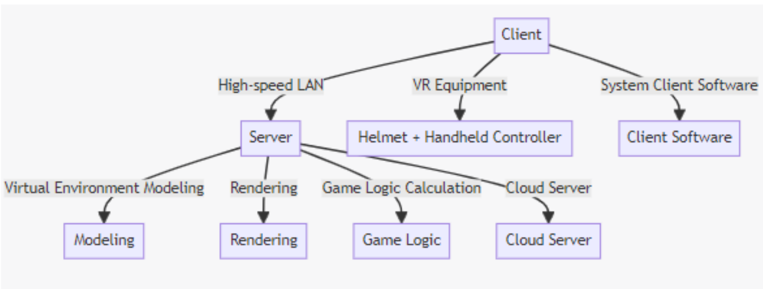

Figure 2: Network Architecture Diagram

3.2 Module Design

The system primarily consists of the following modules:(1) Virtual Environment Module: Responsible for constructing and rendering immersive virtual childcare scenes, such as virtual kindergartens, households, and environments. It supports users in freely observing and moving within the scenes. (2) Character Module: Implements the generation of various virtual human characters, such as teachers and nurses. It controls character appearance, movements, speech, and provides a lifelike sense of realism. (3) Task Module: Designs various interactive tasks, such as feeding and diaper changing, and evaluates user performance in completing them. (4) Feedback Module: Analyzes user performance in executing tasks, enabling assessment and real-time feedback [6].

3.3 Database Design

The database needs to store user information, virtual environment model data, digital human character data, generated interactive tasks, user completion status, and feedback assessments, among other data. The primary table structures include user tables, environment tables, digital human tables, task tables, feedback tables, and more [7]. As shown in table 2.

Table 2 System content design

module	Content description
Scene module	Including the modeling of nurseries, families and other scenes; Fine modeling and detail textualization of objects such as clothes, toys and furniture in the scene;
Task module	Basic nursing tasks such as feeding, washing, and soothing infants; Require users to use the right tools and processes to complete the operation;
	Emergency handling tasks such as sudden vomiting, fever and feeding difficulties of infants; Students need to use the knowledge to respond comprehensively;
	The completion conditions and evaluation criteria are set for each task to assess the trainees' operation process;
Personalized training	Design different content systems for different user roles; Implement personalized training programs;

3.4 Key Algorithms

Digital Human Generation Algorithm:

Input: Raw motion capture data

Output: Processed data with noise filtered out

Procedure Preprocessing(rawData)

Remove outliers

Apply noise filtering

Normalize the data

Return processed data

This generation algorithm, by controlling various parameters such as character, movements, expressions, etc., can render different virtual characters of digital humans [8].

4 Implementation of the System

4.1 Implementation Environment

Regarding client hardware, the HTC Vive Pro headset was utilized, with a resolution of 1440x1600 pixels and a 110-degree field of view. Coupled with the Vive controllers, it allows for six degrees of freedom spatial positioning and operation control. The server side is deployed on a physical server equipped with an Intel Xeon Gold 6240 processor, offering 18 cores and 36 threads with a base frequency of 2.6GHz, which adequately meets the requirements for virtual rendering. The server is equipped with an NVIDIA Quadro RTX 6000 GPU for accelerated graphics processing. The network utilizes gigabit fiber optic connectivity. For development, C++ was employed for low-level virtual reality rendering, while Python was used for advanced interaction logic development [9].

4.2 Function Validation

The virtual childcare scenes created by the system achieve a near-realistic effect through meticulous material design and environmental modeling, allowing users to freely observe environmental details. The static elements in the scene reach a precision of 25 million triangles, while dynamic elements such as virtual human characters reach 500,000 triangles. Two highly realistic virtual human characters, a teacher and a nurse, were designed to perform natural movements and engage in rule-based voice interactions. Users can naturally complete over 10 virtual tasks, including tasks such as holding a baby, feeding, and singing. The task evaluation module can accurately assess the correctness of user actions and operations [10]. The total triangle precision formula for the scene is as follows:

$$S = S_s + R \times S_d \tag{1}$$

Where S represents the total triangle precision of the scene, Ss is the triangle precision of the static elements in the scene, Sd is the triangle precision of the dynamic elements in the scene, R is the number of virtual human characters, and T is the number of virtual tasks that users can complete.

4.3 Performance Testing

Multiple loading tests have shown that the scene initialization time is less than 10 seconds, with a smooth frame rate of 90 frames per second. Network communication latency can be controlled within 50 milliseconds, ensuring a satisfactory user interaction experience. The system supports simultaneous connections from 20 clients for independent virtual teaching and training, demonstrating reliability and stability. The overall performance formula for the system is as follows:

$$P = \frac{F \times C}{I + D} \tag{2}$$

Where I is the scene initialization time, F is the scene's smoothness (frame rate), D is the network communication latency, and C is the number of supported clients.

5 Conclusion

This study addresses the issue of the lack of realistic scenarios in current infant care training by utilizing virtual reality technology to construct an immersive training system. The system provides a realistic and credible childcare scenario experience and interactive task training through high-fidelity virtual environment simulation and digital human character generation. Employing a C/S network architecture, virtual reality devices coupled with rendering servers simulate the scenes, and modules for characters, tasks, and feedback are designed. The system integrates cutting-edge technologies such as virtual reality, digital humans, and machine learning, demonstrating strong technological innovation. Tested and validated, the system meets its design objectives in terms of virtual environment effects and interaction performance, effectively enhancing the experiential and interactive aspects of current infant care training. In summary, this system fills the gaps in traditional training methods and offers an effective means to enhance the quality of infant care training, making it suitable for widespread application. Further optimization of technical details and the expansion of scene and task scales can be pursued in future work.

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