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Design of Virtual Reality Visualization Display System Based on Big Data Technology

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With the widespread application of computer network technology, a large amount of data is generated in computer networks, leading to the era of big data. The construction of big data informatization has always been a focus of digital development, because the big data industry provides an indispensable technical support to industry, commerce, government, health, and other sectors of society. The development of social science and technology has led these various sectors to adopt big data technology, resulting in the emergence of technologies and their applications in various industries. Virtual reality (VR) is one such technology. Because traditional visualization display methods are unable to effectively display visual data, this study has explored existing visualization display methods by combining big data technology with VR visualization technology. This study used big data technology to design a VR visualization display system that can present to the user images from multiple perspectives. The proposed method can improve the speed of visual data processing which, subsequently, can improve the smoothness of data conversion images. The experimental results showed that the proposed visual display system increased the frame count by 14.7 frames, with a high level of smoothness and clear and smooth dynamic effects. With the continuous development of technology and VR visualization display systems, the field of VR will continue to be improved, and other fields can provide effective references when using big data technology.

Keywords: big data technology; virtual reality; visualization technology; system design; data processing

1. INTRODUCTION

In today's digital society, the amount of data being generated by various sectors is increasing significantly every minute. Effective utilization of data can achieve technological innovation and provide important data analysis materials for the development and research of modern technology. Big data technology is widely used in the modern information age, and converting a large amount of data into images is an important technological foundation for the development of modern animation and VR. This technology can improve the smoothness of screen transitions and enhance the sensory effects on the user experience. Therefore, the design of a VR visualization display system based on big data technology is very significant [1].

VR technology is constantly being applied in new fields and has shown its unique advantages when applied to emerging industries. It is gradually improving through continuous application. Johnston believes that the VR visualization of scientific data is crucial not only for scientific discoveries, but also for disseminating science and medicine knowledge to experts and the general audience [2]. Kim considered that VR has received a lot of attention in the development of modern technology and is considered a revival era of virtual display technology in the industrial and academic fields [3]. Malik explored the technological development of VR in people-oriented production system design, integrating human-machine simulation with VR [4]. Rubio Tamayo analyzed and studied the dynamic representation of configuration data interaction of new disciplines such as interaction design, human-computer interaction and user experience of VR visualization, so that they could be implemented in education

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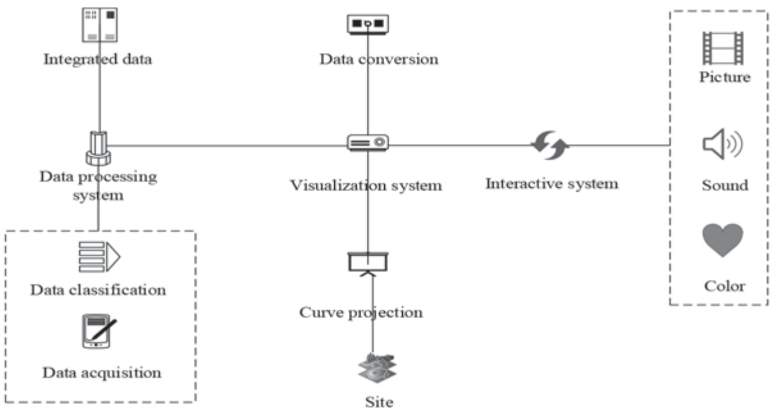


Figure 1 Design of virtual reality visualization display system.

and other environments [5]. George proposed a method for analyzing and enhancing industrial workplaces using immersive VR, which allows the tracking of multiple users performing virtual assembly tasks within the system [6]. Goo believed that three-dimensional cardiac imaging technology is leading to the medical use of advanced visualization technologies. As the data source for these new visualization technologies, accurate non-invasive visualization of patient specific cardiovascular anatomical structures is crucial for the diagnosis and treatment of coronary heart disease [7]. The processing power of big data is crucial to the development of VR technology, because the high-quality visualization system of VR technology relies on advanced data processing technology to achieve its immersive experience.

VR technology has great advantages that can be applied in various fields. Therefore, it has led to extensive research by many experts. Su stated that the latest developments in VR technology in the business sector have led to the availability of affordable consumer grade and reliable VR hardware and software tools [8]. Reski compared three different input technologies in interactive VR environments, and the entire system was able to open data from multiple online sources through visualization technology in a unified interface [9]. Pettersen argued that the next generation of interactive visualization programs for visualization and informatics resources not only bring significant performance and graphical enhancements, but also support new fields such as VR, optical microscopy, and medical imaging data [10]. The purpose of Tea's research was to develop and evaluate real-time multi-user VR applications that can be used for design review processes, and to introduce a method for developing real-time multi user immersive applications [11]. Yu believed that traditional VR technologies and augmented reality can create human experiences through visual and auditory stimuli, replicating sensations related to the physical world [12]. Egliston stated that VR is an emerging spatial computing technology that relies on capturing and processing information data about users, such as their bodies, their interfaces with hardware, or the surrounding environment [13]. Ahmed overlaid information from augmented reality and VR into the real world, utilizing the potential opportunities of augmented reality and VR to effectively and efficiently solve various construction management problems [14]. It is necessary to apply visualization technology in VR systems, laying a theoretical foundation for the further development of VR systems.

To solve the problems of immature traditional data technology, slow data processing, and error prone data analysis, this article analyzes and studies existing big data processing technologies. Subsequently, based on the needs of VR visualization display and the combination of big data technology, the clarity and smoothness of VR visualization screen display are improved, and the sensory experience of viewers is enhanced. In this study, a VR visualization display system is designed based on big data technology. This design not only analyzes big data technology, improves the system's data processing ability, but also enhances the smoothness of VR visualization display, laying a theoretical foundation for promoting the development of the VR field [15].

2. DESIGN OF VR VISUALIZATION DISPLAY SYSTEM

The prospects of VR visualization technology in future development are very broad, and with the development and maturity of this technology, it is being applied in various industries. VR visualization technology can combine sound, images, colors, and mathematical space theory to display a virtual world that can appear to be realistic according to the different needs of different industries and fields. This technology has various effects on people's sensory perception, and enables the user to experience a realistic and immersive feeling in the illusory world by means of their eyes only. In this study, a VR visualization display system is designed based on big data technology, which not only improves the smoothness of images, sounds, and actions, but also plays an important role in advancing VR technology.

The design of the VR visualization display system is shown in Figure 1. Big data is classified and collected through a backend processing system, and the processed data is integrated. The integrated data of the image undergoes a transformation, and the resulting image is then displayed on a curve using a visual display system designed based on research findings.Finally, it is projected onto the site to be displayed by a projector. At the same time, users can control real-time effects such as visuals, sounds, and colors through the interactive system [16].

Table 1 Data classification types and application scenarios.

Classification	Data type	Application scenario
Field type	Text class, numerical class, time class	This classification is the most basic and is relevant to several scenarios: the system design, the data cleansing, and the establishment of a dimensional model.
Data structure	Structured data, semi-structured data, unstructured data	First, structured data constitutes the main body of traditional data, while semi-structured and unstructured data is the main body of big data. Secondly, in the design of a data platform, structured data can be processed efficiently by traditional relational database. Thirdly, in data analysis and mining, many tools require the input of structured data.
Describe things	Status class data, event class data, mixed class data	This classification is particularly important in data warehouse modeling. A data warehouse needs to store all kinds of historical data, and different types of historical data are stored in different ways.
Data processing	Original data, derived data	This classification is mainly used for the management of data. There are some differences between the management of the original data and the management of the derived data. Usually only one copy of the original data is kept, but the derived data is different, and it can be managed more flexibly. Any form can be acceptable as long as it is improves the efficiency of data analysis and mining, and generates greater data value.
Data granularity	Detailed data, summary data	There are two relevant scenarios for this classification: one is in the design of a data warehouse, and the other is when a data analyst is analyzing data.
Update mode	Batch data, real-time data	On the one hand, it can provide near-real-time data and reports to support the business, and achieve better timeliness in business scenarios. On the other hand, it also greatly increases the technical difficulties associated with data architecture, data analysis and application.

From Figure 1, it can be seen that the visualization system is the main component of the VR visualization system design, which can effectively receive the data conversion processed by the data processing system, and is responsible for organizing and managing big data as well as curve projection. The data processing system classifies, collects, and integrates the required big data, and then transforms the data through a visualization system to form images that are projected onto the prepared site in curves. During operation, users can control the data in real-time through interactive systems as needed.

3. DATA IN VR TECHNOLOGY

The development of big data applications is becoming increasingly important in the digital age. Different fields such as industry, agriculture, healthcare, and biology are increasingly relying on the necessary knowledge and information extracted from big data. However, traditional data technologies and platforms are not efficient as evident from the slow response of data platforms and a lack of scalability, high performance, and accuracy. To address the challenges of developing and utilizing complex and diverse big data technologies, various industries have developed various types of new technologies based on big data [17]. VR is a relatively new but widely-used technology in the modern information society [18]. VR visualization technology is a simulation that combines data processing and numerical simulation with human cognition and automation algorithms. The main advantage of VR in visualizing scientific data is that it allows users to intuitively explore and interact with the environment [19]. The data in the VR visualization display system is analyzed and processed through big data technology, thereby improving the data processing ability of the VR visualization display system designed in this article.

3.1 Data Classification

Nowadays, a huge amount of digital data is generated, and it is necessary to effectively classify the data when it is applied in specific fields. There are many ways to classify data, and each method holds a different level of significance depending on the context of the data work. Suitable data classification methods can be selected according to user requirements in order to better apply the data and provide accurate and adequate data support for subsequent data applications, as shown in Table 1.

There are six main ways to classify data. The first method is to classify according to fields, such as text, numerical, time, and other criteria. This classification method is the most basic and related to many scenarios. The second classification is according to the three types of data structure: structured, semi-structured and unstructured. Structured data can be processed efficiently using traditional data relationships, while semi-structured data and unstructured data need to be processed and applied by means of big data platforms. Thirdly, data can be classified according to their descriptions: status data, event data, and mixed data. There are significant differences in the storage methods used for different types of historical data. Status data needs to be stored before and after the timeline. Mixed class data is classified and stored according to the changing state. The fourth type of classification is based on data processing, which is divided into two types: original data and derived data. These two classification methods

Table 2 Data acquisition methods and advantages.

Data acquisition category	Data acquisition method	Advantage
Database acquisition	Traditional enterprises use traditional relational databases to store data. With the advent of the era of big data, databases are often used for data collection.	Enterprises deploy a large number of databases at the collection end, and carry out load balancing and fragmentation among these databases to complete the work of big data collection.
System log collection	System log collection mainly collects a large amount of daily log data generated by the company's business platform for offline and online big data analysis systems.	High availability, high reliability, and scalability are the basic features of the log collection system. The system log collection tools all adopt a distributed architecture, which can meet the requirements of collecting and transmitting hundreds of log data per second.
Network data acquisition	Network data collection refers to the process of obtaining data from websites by means of a web crawler or website disclosure. The web crawler will start from one or several initial web pages to obtain the content of each web page, constantly extracting new content from the current page and putting it into the queue until it meets the stop conditions.	In this way, unstructured data and semi-structured data can be extracted from the web page and stored in the local storage system.
Sensing device data acquisition	Sensing device data acquisition refers to the automatic collection of signals, pictures or videos by sensors, cameras and other intelligent terminals to obtain data.	Big data intelligent system needs to realize the intelligent identification, positioning, tracking, access, transmission, signal conversion, monitoring, preliminary processing and management of structured, semi-structured and unstructured massive data. The key technologies include intelligent identification, perception, adaptation, transmission and access for large data sources.

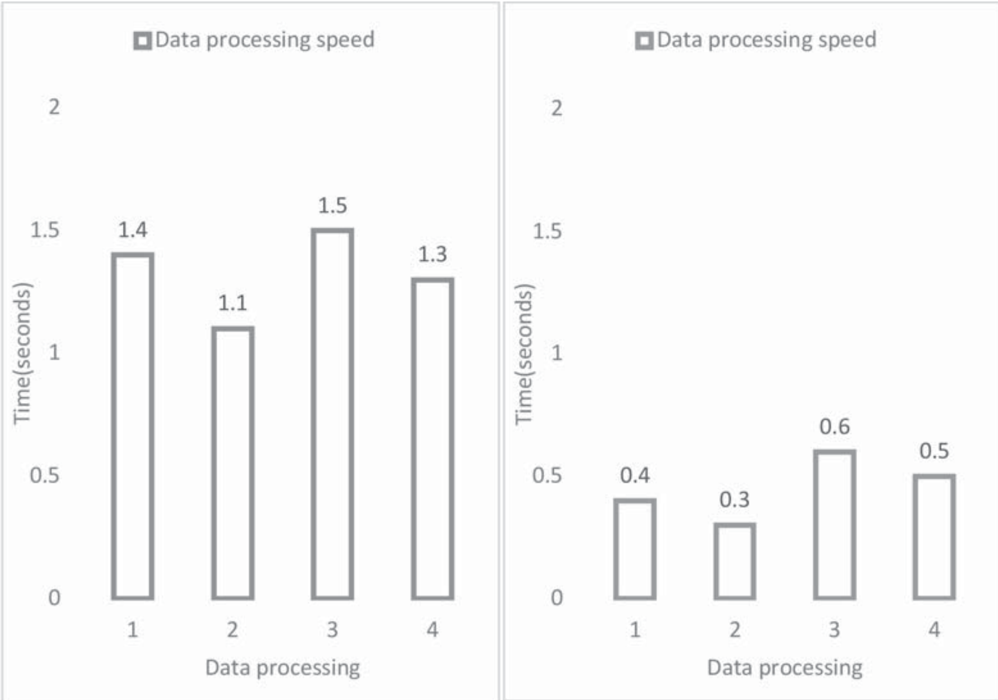
are commonly used in data management, which not only improve work efficiency, but also can be applied in various forms. The fifth type of classification is based on the type of data granularity: detailed data and summary data. In the design of a data warehouse, the detailed data can maintain the balance between efficiency and cost. Summary data facilitates the selection of appropriate data when analyzing data to improve analysis efficiency. Lastly, the sixth method involves classifying data according to the update method, which is divided into two types: batch data and real-time data. This not only improves work efficiency, but also reduces the technical difficulty associated with data application.

In summary, each of the six commonly-used data classification methods has its own application fields and unique advantages. An appropriate data classification method, chosen according to user requirements, not only enables the preparation of data backup libraries for emergencies, but also facilitates comprehensive and diverse data preparation when designing VR visualization display systems, enabling timely database updates and improving the flexibility and applicability of VR visualization display systems. The data classification method used for this VR visualization display system should prioritize flexibility, so the sixth data classification method is a better choice.

3.2 Data Collection Methods

After data classification, a unique database suitable for VR visualization display systems is created. The data in the database is vast and diverse, and it is very important to collect the real-time data needed in a large number of data centers. Therefore, it is necessary to study the data collection methods and select those that are suitable for the VR visualization display system, laying a data foundation for the subsequent design of the visualization display system, as shown in Table 2.

There are four main methods of data collection. The first type is database acquisition. With the advent of the big data era, databases are also commonly used for data collection. A database, which is a commonly-used data storage system, has two advantages. The first is that the system has a large memory and a single function, mainly used for storing large amounts of data. The second advantage is that the system has a long storage time and is not very convenient to carry. The second type is system log collection, which has the basic characteristics of high availability and scalability. The advantage of the system log collection method is that it has a distributed architecture that can classify and process data according to different needs. Moreover, multiple types of data processing work can be independently carried out without



2a: Traditional data processing system

2b: Visualization display system based on virtual reality

Figure 2 Comparison of data processing results of two data processing systems.

interference, not only saving time, but also providing fast transmission.

The third type is network data acquisition which has the advantage that unstructured data and semi-structured data can be extracted from web pages and stored in the local storage system. When users search for data on the network, this collection method is the most suitable for filtering and extracting data. This method can quickly extract the required data information from a large and complex network database. The fourth type is data acquisition via a sensing device. The key technologies of sensing device data collection include intelligent identification, adaptation, and access to big data sources, which are relatively flexible and practical collection methods. This collection method is suitable for various operating devices or systems that process data. During the operation of the device, various situations may occur, and the collection method designed for intelligent processing can flexibly respond, which has great advantages for the stable operation of the device and system.

In summary, the four commonly used data collection methods all have their own advantages and characteristics, and the data collection method in big data technology is used to collect the necessary data for use. The VR visualization display system is a principle of device design. VR visualization displays sound, images, colors, and other aspects from multiple angles, and requires advanced data collection technology for the rapid conversion of images into data. It also requires the use of intelligent data collection technology that is more flexible and suitable for various needs. Therefore, the fourth method of data collection for perception devices is the best choice. After classifying and collecting data, VR visualization technology is used to transform and design dynamic images.

3.3 Data Processing Speed

There are various types of big data technologies, including data processing, data analysis, data classification, and so on. It has a huge database with suitable usage data for various fields, which can effectively address the time required for data collection and data classification, thereby greatly improving work efficiency. The VR visualization display system integrates sound data, action data, color data, and other data to transform them into dynamic images that can be viewed. The data that needs to be processed is huge and complex, and accelerating data processing speed can improve the overall work efficiency of the system and enhance the user's sensory experience.

A database is randomly selected and processed separately through traditional data processing systems and designed VR visualization display systems, including data classification, data collection, data transmission, and data access. These four aspects are represented by 1, 2, 3 and 4 respectively. The experimental data was recorded and the experimental results were analyzed, as shown in Figure 2.

Figure 2a shows the time required for data processing using traditional data processing systems, while Figure 2b shows the time required using a designed VR visualization display system. Figure 2a shows that the time is between 1 second and 1.5 seconds, with a minimum value of 1.1 seconds and a maximum value of 1.5 seconds. The overall time for data processing is just above 1 second. The times shown in Figure 2b range from 0.3 seconds to 0.6 seconds, with a minimum value of 0.3 seconds and a maximum value of 0.6 seconds. The overall time required for data processing is below 1 second. The overall speed has been effectively improved, indicating that after analyzing the VR visualization display system through big data technology, the system has improved the speed of data processing, thereby saving a lot of time for subsequent data conversion work, and enhancing people's sensory experience.

In summary, big data technology is used in order to select the required data quickly and process it effectively. Therefore, prior to designing a VR visualization display system, it is important to analyze and study the data processing system as an initial step. Firstly, a suitable data classification method should be chosen to classify the data in the database as needed. Secondly, a suitable data collection method should be selected to intelligently, conveniently, and efficiently collect the classified data as needed for image conversion. The development of better data processing methods has accelerated the speed of data processing and the efficiency of the overall VR visualization display system.

4. VR AND VISUALIZATION TECHNOLOGY

In the context of industry 4.0 and digital factories, digital twins and VR represent key technologies for designing, simulating, and interacting remotely or collaboratively with networked physical production systems [20]. To meet customer requirements and create dynamic and immersive virtual environments, it is necessary to combine the ability of digital twins to perform production system simulations with the interactive capabilities of immersive virtual environments [21]. In the digital society, big data technology is applied in various fields. Here, it is necessary to combine mature big data technology with VR technology to design a highly practical visual display system.

4.1 Visualization Technology

4.1.1 Spatial Projection Technology

The visual display system designed in this study involves spatial projection technology and data calculation methods, and is a relatively complex system design project. The final presentation of VR visualization projection is presented in a three-dimensional manner. Analyzing and researching spatial projection technology only enhances the spatial sense of the image, but also provides a strong sensory experience for the viewer, thereby fully displaying the visualization technology effect of VR.

4.1.2 Projection cylindrical equation

The equation for the spatial curve D is:

$$\begin{cases} A_1(a,b,c)=0 \\ A_2(a,b,c)=0 \end{cases} \tag{1}$$

where a, b, c are the values of the length, width, and height of the space, respectively, and A is the projection point.

In Equation (1), variable c is eliminated to obtain Equation (2):

$$A(a,b)=0 \tag{2}$$

This equation does not contain c, so it is a cylindrical surface with a generatrix parallel to the o axis. Because the coordinates of the points on curve D satisfy this equation, the points on curve D are all on this cylindrical surface, which is the projection cylindrical equation of curve D about the coordinate plane.

4.1.3 Projection curve equation

The intersection line between the projection cylinder equation and the coordinate plane is the projection curve equation of curve D on the coordinate plane. The equation is:

$$\begin{cases} A(a,b)=0 \\ c=0 \end{cases} \tag{3}$$

Similarly, if the variables a or b are respectively eliminated from Equation (1), the projected cylindrical surface of the curve is obtained:

$$H(b,c)=0 \tag{4}$$

or

$$I(a,c)=0 \tag{5}$$

The equations for the projection curve of curve D on the coordinate plane are:

$$\begin{cases} H(b,c)=0 \\ a=0 \end{cases} \tag{6}$$

and

$$\begin{cases} I(a,c)=0 \\ b=0 \end{cases} \tag{7}$$

4.1.4 Visual Projection Clarity

After analyzing and researching the visual projection technology, experimental analysis was conducted to determine the outcome achieved by the proposed system. Four projection segments were randomly selected, with each segment labelled 1, 2, 3, or 4. Two types of projection technologies were used on each of the four segments: : one was the traditional visual projection technology and the other was the proposed visual projection technology. Data is recorded and the clarity of the projection during the projection process is analyzed, as shown in Figure 3.

Above, Figure 3a is a record of experimental projection using traditional visualization technique, while Figure 3b is a record of experimental projection using visualization techniques designed using VR system. It can be clearly seen that the clarity value of Figure 3a is between 86% and 89%, while the clarity value of Figure 3b is between 96% and 99%. Overall, Figure 3b has a higher clarity value than Figure 3a, so it can be concluded that using the proposed visualization technology for projection can improve the clarity of the image, thereby improving the overall performance of the VR visualization display system.

3a: Traditional visualization technique

3b: Visualization technology based on virtual reality

Figure 3 Comparison of visual projection clarity.

4.2 Calculation Methods for Visualization Data

Perspective projection is the process of converting the vertebral body into a standard cube. The distances between the projection points on the clipping plane are (a, b, c, d), and the distances from the far and near clipping planes to the camera viewpoint are (R_x, R_y). Therefore, the projection transformation matrix E is:

$$E = \begin{bmatrix} \frac{2R_y}{d-c} 0\ 0\ 0 \\ 0\ \frac{2R_y}{a-b}\ 0\ 0 \\ \frac{d+c}{d-c}\ \frac{a+b}{a-b}\ \frac{R_x}{R_y-R_x} - 1 \\ 0\ 0\ \frac{R_y \cdot R_x}{R_y-R_x}\ 0 \end{bmatrix} \quad (8)$$

$$\frac{a}{A} = \frac{b}{B} = \frac{c}{C} = \frac{d}{D} = \frac{R_y}{R'_Y} \quad (9)$$

The calculation of projection transformation can be directly replaced by parameters in the projection space:

$$C_1 = \frac{K_1}{2} - M \quad (10)$$

$$D_1 = \frac{K_1}{2} - M \quad (11)$$

$$B_1 = -\frac{F}{2} - N \quad (12)$$

$$A_1 = \frac{F}{2} - N \quad (13)$$

$$R_{y1} = \frac{K_2}{2} + R \quad (14)$$

Incorporating the Equations (10)–(14) into Equation (8) yields a frontal projection transformation E_a:

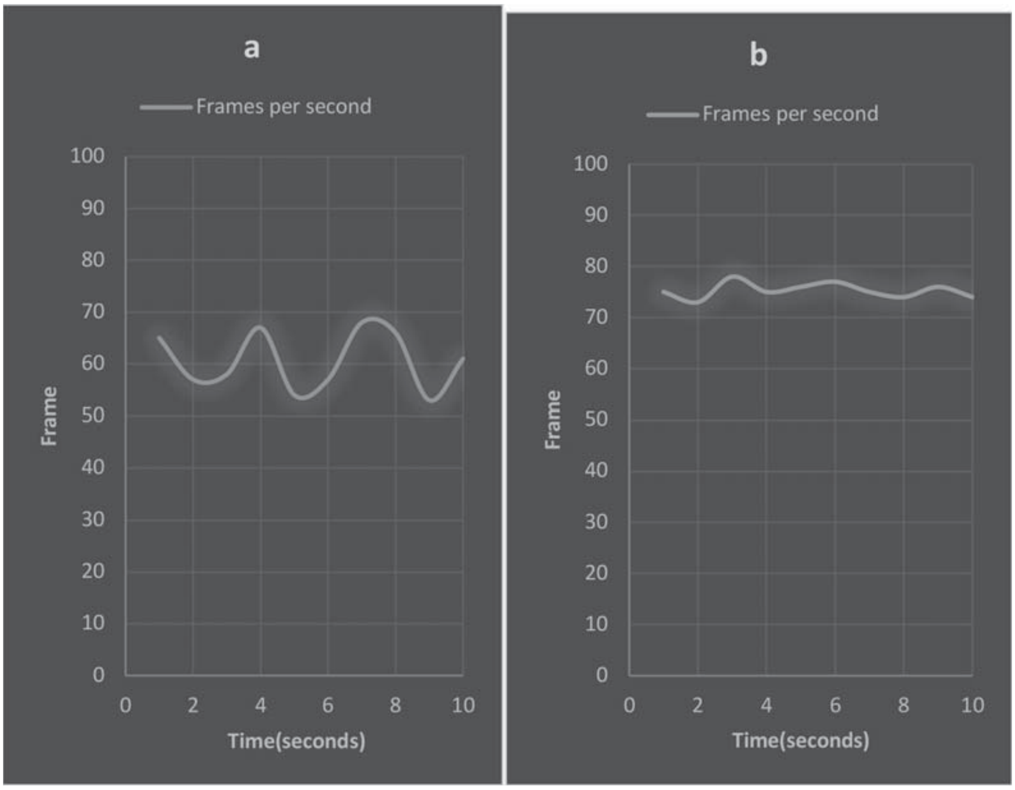
$$E_a = \begin{bmatrix} \frac{K_2+2R}{K_1} 0\ 0\ 0 \\ 0\ \frac{K_2+2R}{F}\ 0\ 0 \\ \frac{-2M}{K_1}\ \frac{-2N}{F}\ \frac{R_x}{R_y-R_x} - 1 \\ 0\ 0\ \frac{R_y \cdot R_x}{R_y-R_x}\ 0 \end{bmatrix} \quad (15)$$

By using the same method, a fast calculation equation for other projection transformations can be obtained, which can calculate the projection matrices of each channel in real time.

4.3 Smoothness of Visual Display

After analyzing and researching the visualization projection technology, experimental analysis was conducted on the effectiveness of the designed VR visualization display system. A segment of projection content was randomly selected and the projection was performed in two stages. In the first stage, traditional visual projection technology was used for projection, and in the second stage, the proposed visual projection technology was used for projection. During projection, ten second segments were randomly selected for data recording and to analyze the smoothness of the projection, as shown in Figure 4.

Figure 4a shows the smoothness analysis when displaying images using traditional visualization techniques, while Figure 4b shows the smoothness analysis when displaying images using designed visualization techniques. According to the values of the waveform and the range of fluctuations, it can be clearly seen that when displaying the image, the number of flow smoothness frames in Figure 4a ranges from 53 to 68, with a significant fluctuation in the number of flow smoothness frames, indicating poor system smoothness.



4a: Image fluency in traditional visualization

4b: Image fluency after visual design

Figure 4 Comparison of the fluency results of the visualized images.

The difference between the maximum and minimum values is about 15 frames, and the average value is 60.6 frames, indicating that traditional visualization techniques have poor fluency in regard to image display. Figure 4b shows that when displaying the image, the flow smoothness is between 73 and 78 frames, and the overall display frame number of the image is above 73 frames, indicating a high smoothness. The average value is around 75.3 frames. The average value in Figure 4b is about 14.7 frames higher than the average value in Figure 4a. Therefore, it can be concluded that the proposed visualization technology can improve the smoothness of image display, thereby contributing to the development of VR image technology.

In summary, there are many aspects of visual technology design, making it a complex task. By analyzing the projection cylinder, projection surface, and data calculation methods for the spatial projection of visualization technology, a systematic analysis and design of visualization projection technology have been carried out from multiple perspectives. This not only improves VR visualization technology, but also lays a theoretical foundation for the design of visualization display systems.

5. CONCLUSIONS

VR technology is widely used in modern digital society. Big data technology is used to design and research visual display systems, which not only facilitates the analysis and research of visual display systems, but also improves the practical applicability of visualization technology in VR. Therefore, it is necessary to use big data technology to analyze and design VR visualization display systems. The aim of this study is to provide several suggestions for the improvement of VR technology by addressing the shortcomings of VR visualization systems. This study uses big data technology to explore the VR visualization display system, analyzing and exploring data classification and collection methods, as well as visualization technology and calculation methods. Based on this, a design scheme for the VR visualization display system is designed. The actual test results show that the data processing speed, clarity of visual projection, and smoothness of the system have significantly improved, providing a theoretical reference for the research of VR visualization technology.

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