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Design of Three-Dimensional Visualization Platform for Stationery Based on Digital VR Technology

Zhongxuan Tan[1,a,*]

[1]*College of Media and Art Design, Guilin University of Aerospace Technology, Guilin, 541004, Guangxi Zhuang Autonomous Region, China*
[a]*tanzhongxuan0602@guat.edu.cn*
[*]*Corresponding author*

Abstract: *With the continuous progress of society, people pay more attention to cultural goods, but because of the small influence of traditional technology on the dissemination of cultural products, the coverage is small. At the same time, cultural goods are also suffering from the impact of fast-paced life and the invasion of foreign popular culture, which leads to certain difficulties in the maintenance of cultural goods. Therefore, based on the digital VR (Virtual Reality) technology, this paper used its own interactive technology to design a three-dimensional visualization platform for cultural goods with real visual effects, rich and diverse cognition and vivid and interesting functions to complete the three-dimensional data visualization and digital real-time interaction. Through experiments, it can be found that the accuracy of recognition and classification of the 3D visualization platform studied in this paper for stationery data was more than 96%, while the accuracy of classification of the platform based on traditional technology was less than 89%. At the same time, the platform studied in this paper was based on VR technology, which can display cultural goods in an all-round way, improve the interactivity and immersion between users and cultural goods. Therefore, user satisfaction was also higher, more than 92%.*

Keywords: *3D Visualization Platform, Cultural Products, Digital VR Technology, User Satisfaction*

1. Introduction

With the continuous development of science and technology and the increasing demand of society, the use of computer technology to design the platform has become a relatively mature model and has been recognized by most people. VR technology has brought a new operating mode for the design of three-dimensional (3D) visualization platform. As a new type of electronic computer interaction technology, VR technology has been widely used in various virtual scenes because of its many advantages. In recent years, the rapid development of graphics technology has expanded from the two-dimensional field to the three-dimensional field, and its scientific research has become more and more mature. Three-dimensional visualization technology is the use of today's mature image processing technology to describe the objects in the real world in a three-dimensional way in a virtual environment, and can accurately express the three-dimensional information of real objects, and complete the real-time interaction of three-dimensional visualization and digitization. As an important application of graphics technology in the field of simulation, 3D visualization technology creates a bridge between the real world and the imaginary world. However, with the increase of data input from the traditional 3D visualization platform, the efficiency of the platform decreases, the display effect of cultural goods decreases, and the user's sense of experience is reduced. Therefore, in order to solve these problems, this paper designs a 3D visualization platform of cultural goods based on digital VR technology, so as to improve the user's sense of experience and satisfaction, and improve the accuracy of platform classification.

With the progress of society, people pay more attention to cultural goods and begin to pay more attention to spiritual and cultural construction. Many experts have studied the 3D visualization platform of cultural goods in order to make cultural goods develop better

There are also many research results. Astuti, Tiwi Nur believed that 3D visualization programs paved the way for the development of virtual reality. It produced a three-dimensional visualization program in virtual reality to increase the critical thinking ability and scientific attitude of senior high school students, and collected the critical thinking ability of students through chemical tests [1]. Yao, Zhihang built a 3D city model based on an open data model, which is usually used for various complex GIS simulation and analysis tasks. These tasks would go far beyond pure 3D visualization, so an open source and platform-independent software suite has been developed to promote the development and deployment of 3D city model applications [2]. Satish, C. J has built a 3D visualization tool, which generates a 3D call graph for systems using non-invasive virtual reality. A control experiment was conducted to test the effectiveness of the tool in performing the change impact analysis task. The research results showed that subjects who use the tool can perform more tasks more accurately and faster than those who do not use the tool [3]. Ren, Shilei proposed to build a customized interactive experience platform for museum cultural products, which can promote the development of museum cultural products and the inheritance and preservation of museum culture. By sorting out the existing documents, he analyzed the mode and characteristics of the existing cultural product customization platform, and finally combined the customization experience with the existing electronic tracking platform system according to user needs [4]. Few researchers have considered the research of 3D visualization platform based on digital VR technology. Therefore, it is meaningful to research the theme based on digital VR technology.

Digital VR technology has been very well used in many fields, and its application to 3D visualization platform is also one of the hottest topics at present. Many experts and scholars have conducted in-depth research on this aspect, and research results are everywhere.

Li, Rui proposed a design method of a dynamic 3D visualization system of sea area flow field based on virtual reality technology. The dynamic 3D visualization system of sea area flow field was based on embedded development software technology. In the virtual reality design of the dynamic 3D visualization system of the sea area flow field, he used the visual simulation technology to simulate the dynamic 3D visualization system of the sea area flow field [5]. Bogomolova, Katerina systematically evaluated the role of stereo vision in the learning of 3D visualization technology. Stereovision was an important distinguishing element of 3D visualization technology. When used in an interactive three-dimensional environment, it had a significant positive impact on the acquisition of anatomical knowledge [6]. Vertemati, Maurizio developed an interactive and user-friendly virtual reality environment for 3D visualization of specific organs of patients and established a workflow. He transferred the 3D model from the imaging data set to the virtual reality environment. Based on open source software and mobile hardware, it has proved to be an effective and highly appreciated system [7]. Chen, Jipeng proposed a case study of the platform based on virtual reality visualization and introduced the functions of the platform. He found that the platform has significant advantages in reducing the design cycle and cost, and can also reduce the threshold of experiments and improve the training of new designers [8]. Experts and scholars have carried out various researches on VR technology. Therefore, there is a theoretical basis for this study.

With the rapid development of computer technology, digital VR technology plays an important role in many industries [9]. Three-dimensional visualization technology can project people or things in the real world onto the electronic display screen to realize three-dimensional visualization of these things and things, which would help the managers of the visualization platform to make stronger predictions and thus save costs. According to the digital VR technology, this paper designed a three-dimensional visualization platform for cultural goods to improve the accuracy of the classification of the three-dimensional visualization platform for cultural goods. At the same time, VR technology was used to improve the customer’s experience and improve the user’s satisfaction with the platform.

2. Methods of Three-Dimensional Visualization Platform for Stationery

2.1 Visualization Platform

The purpose of visualization is to enable scientific computing to be visualized, that is, data information visualization technology [10]. This also enables experts to understand how the data changes during the calculation process. Contemporary data visualization technology is a very special data technology. With the increase of data information and people’s desire for data, a new visualization technology, information visualization technology, has gradually formed. It refers to the visualization of abstract data. This technology enables people to read many key information hidden behind the data [11].There are essential differences among knowledge visualization, data visualization and information visualization. The essential differences among the three are shown in Table 1.

The key of 3D visualization platform is to use 3D visualization technology to build a system

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software for 3D application [12]. The platform is based on the transport layer and the computer operating system layer, including the engine layer and the service layer. In recent years, it has become more and more common to have 3D interactive functions and to visualize complex 3D scenes. With the increasing demand of users for the practicability and realism of 3D system operation, the visualization platform with better performance has gradually become a hot spot. In order to improve the efficiency of 3D visualization application and development, the speed of platform operation, and the sense of experience for platform users, based on digital VR technology, this paper scientifically studies the 3D visualization platform architecture and the 3D visualization platform operation management framework.This paper combines the 3D visualization service platform with cultural goods to establish a 3D visualization platform for cultural goods to promote the cost and display of cultural goods.

Table 1 Comparison of the essential differences between the three visualization technologies

Classification object	Data visualization	Information visualization	Knowledge visualization
Visual objects	Spatial data	Non-visible data	Human knowledge
Visualization method	Computer graphics	Computer image	Drawn knowledge chart or sketch
Visualization purpose	Express abstract data in an intuitive way	Discover new information from a large amount of abstract data	Promote the dissemination and innovation of group knowledge
Applicable topic	Mind map, news display, data display	User-centered information display	The display of the knowledge semantics

2.2 Virtual Reality Technology

Virtual reality technology, also known as spirit technology, is a high-end human-computer interface with immersion as its essential feature [13-14]. It has developed and utilized a variety of technologies to simulate the functions of visual organs such as visual perception, auditory system and touch, so that people can immerse in the virtual realm generated by the computer. Real-time interaction can be carried out through natural ways such as language expression and action, creating a humanized multi-dimensional information space. In the virtual reality environment system, users can not only feel the same feeling as in the real objective world, but also get the experience that is difficult to experience personally because of the influence of the objective physical environment, so it has a broad application prospect. Although the exploration of virtual reality is not very long, its research results have already begun to slowly affect people’s daily life, and have made great achievements in many fields. From a technical point of view, virtual reality technology has the following three basic characteristics. These three features enable people to not only immerse in the virtual world, but also interact with it, and finally achieve a real feeling. The relationship between the three basic features is shown in Figure 1.

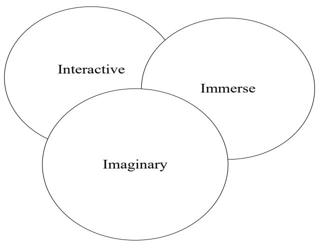

Figure 1 Relationship between the three features

(1) Interactivity

With the improvement of living standards, the functions of products become more colorful. People begin to care about the feeling of new products in user experience, and interactivity is the key element of user experience. The interactivity of VR technology means that users use special virtual interactive devices

Information can be communicated and exchanged in a natural way, which has a richer feeling than two-dimensional interaction [15]. VR technology has a good interactive evaluation standard, which has many advantages.

(2) Immersion

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Immersion of VR refers to the most vivid and realistic feeling of users in the virtual environment, which depends on the computer information technology to simulate an infinitely close virtual environment on the device, so as to “fool” users’ five senses and achieve the function of stimulating users’ physiology and psychology [16]. These functions are to display the virtual interface visually according to the display system, infiltrate stereo sound into the auditory system depending on the sound effect, and simulate the smell of the released gas in the air. So far, users’ synaesthesia such as seeing, hearing, smelling and touching have fully realized the authenticity brought by the virtual world, and have an unprecedented immersive experience for users.

2.3 Cultural Goods

As a value existence to meet people’s spiritual and cultural needs, cultural products have become more and more diverse in modern society, and constitute an extremely important industrial form. As a unique cultural value bearing method, cultural goods’ value core has a vital impact on people’s spiritual world. Cultural goods are different from other goods. This article analyzes the value of cultural goods from the core, and the value of cultural goods is mainly composed of four aspects, corresponding to the necessity of personal cultural spirit in four dimensions. Cultural goods are not only simple copies of culture, but also creative cultural secondary processing products. It can be either an entity, can be sold directly, or it can be a spiritual commodity. It can be spread according to electronic products, video and audio equipment and Internet technology for spiritual trading. Cultural goods themselves have the advantages of complex value, multiple shapes and flowers, functional combination and creative richness. It is the core idea of re-development of artistic creativity on the basis of a certain culture to form diversified and multi-level cultural products.

2.4 Design of Three-Dimensional Visualization Platform for Stationery

For 3D engine, in addition to providing detailed 3D graphics optimization algorithm, it can also be applied to digital VR technology. The application of 3D engine to develop 3D visualization platform can simplify the workload of development staff. At the same time, it is beneficial for developers to use the underlying 3D graphics to design the platform conveniently. The relationship between 3D visualization platform and 3D engine is shown in Figure 2.

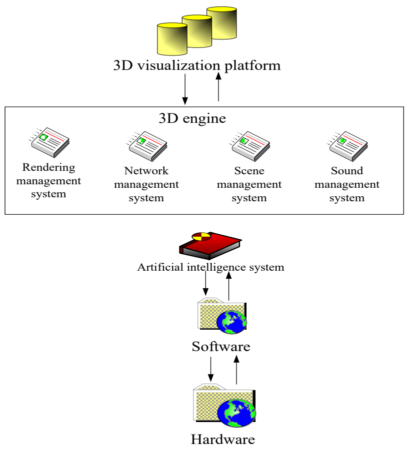

Figure 2 Relationship between 3D visualization platform and 3D engine

2.4.1 VR Visualization Framework Design

This paper uses digital VR technology to research and design the three-dimensional visualization platform framework of cultural goods, which integrates many aspects. Some of them can be used as the prerequisite model of the visualization platform framework for 3D rendering. In order to reduce the waste of time in the process and the low efficiency of the platform, this research uses digital VR technology as a means of supporting the model to accelerate the speed of visualization. According to the 3D modeling software, the data format can be converted, and then the processed data can be imported into the 3D service platform [17-18]. The 3D visualization framework studied in this paper integrates a variety of functions, which can ensure that customers get a good 3D visualization experience, and can also integrate the original model data obtained by the system software that cannot be directly applied. Through the transformation of data format, this paper unifies the data through the

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file format and then imports it into the experimental platform. The specific flow of 3D visualization framework is shown in Figure 3.

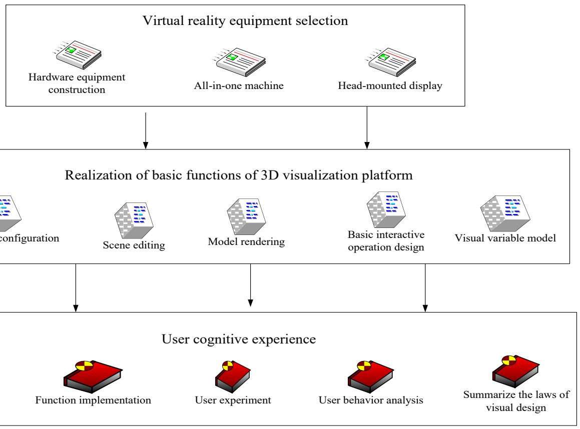

Figure 3 Specific flow chart of 3D visualization framework

To realize the three-dimensional visualization of cultural goods, it is necessary to study the user's psychology and analyze the user's behavior. Whether the system software can clearly acquire user behavior data would directly affect user feelings. Therefore, in order to ensure that the system platform can accurately obtain the information of user behavior, in-depth analysis of user behavior should be carried out, and the calculation method is as follows:

$$Q_{split} = Q_{intersect0}\left(\frac{2(h_a+h_b)am_1}{h_ah_b+h_ch_b} - \frac{(h_a+h_b)am}{h_ah_b+h_ch_b} - \frac{(h_a+h_b)m_1h_c}{h_ah_b+h_ch_b}\right) + Q_{intersect} \tag{1}$$

2.4.2 Overall Framework of VR User Behavior

Users would have different personal actions and behaviors in the VR environment, and the actions of these users can directly reflect the real intentions of users. In order to better meet the needs of users, it is very important to explore and analyze the content of users in virtual reality. The data mining analysis method selected in this study is digital VR technology. This method can not only carry out statistical analysis of data, but also deal with deeper problems. In the interpretation of user's personal behavior in virtual reality, it is reflected in the relationship between user's personal behavior and their cognitive ability management decisions. The user behavior analysis process in VR environment is shown in Figure 4.

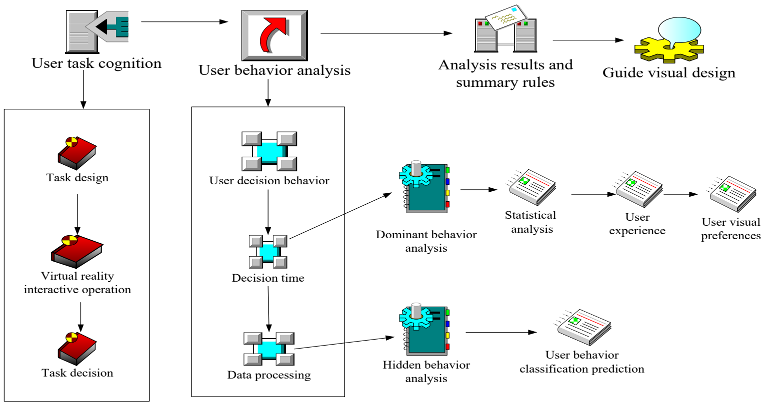

Figure 4 User behavior analysis process in VR environment

According to the analysis of the relationship between the two, the user's personal behavior can be associated with their cognitive ability, which can make users have a better experience, better understand cultural goods, and truly feel the charm of cultural goods in the virtual environment. Therefore, for the design of the 3D visualization platform of cultural goods, the user's behavior analysis in the VR environment is very important. The specific calculation formula is as follows:

$$\begin{cases} H_i = \frac{\nabla f}{2}\left[sin\left(\pi k - \frac{\pi}{2}\right) + 1\right] + \nabla f sin(2\pi k) & (\nabla f > 0, 0 \le k \le K) \\ H_i = \frac{\nabla f}{2}\left[sin\left(\pi k - \frac{\pi}{2}\right) + 1\right] & (\nabla f \le 0, 0 \le k \le K) \end{cases} \tag{2}$$

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The analysis process of user behavior using digital VR technology generally uses statistical methods to record the data in user behavior in real time. In order to verify the applicable scope of the cognitive pattern classification of stationery users in the virtual scene, some steps need to be taken. After the establishment of the behavior analysis process, it is necessary to use scientific and reasonable statistical analysis methods to solve the user's personal behavior data, and obtain the probability model of the service node being selected in an iteration process. The calculation formula is as follows:

$$H_j = \frac{Q_i * BK_i * LBF_j^{\beta}}{\sum_M Q_i * BK_i * LBF_j^{\beta}} \tag{3}$$

In the formula, H_j represents the probability of selecting the jth service node, Q_i represents the running speed of the 3D visualization platform of stationery during the ith task assignment, and β represents the weight factor of LBF_j.

According to its characteristics that are not easy to be affected, VR technology can well solve the problems of the color of the stationery platform during visual design. This method can complete the setting of color variables very quickly. The calculation formula is:

$$h_j(y) = \frac{y - r_{min}}{r_{max} - r_{min}} * (F_{max} - F_{min}) + F_{min} \tag{4}$$

r_{max} is the maximum value of data; r_{min} is the minimum value of data.

Compare the number of effective intervals of each layer to the total effective number to get the impact of the data of each layer on the overall.

$$T_i = \frac{R_i}{\sum_{i=0}^{m-1} R_i} \tag{5}$$

Model loading is the basis of scene browsing. By loading the model to build the 3D scene of the platform, complete the construction of the 3D scene of the entire platform, thus improving the loading and rendering speed.

$$Q_{max} = |H_a'| + |H_b'| + |H_c'| \tag{6}$$

$$Q_{min} = |H_a'| - |H_b'| - |H_c'| \tag{7}$$

3. Experimental Analysis of Visualization Platform Design Based on VR Technology

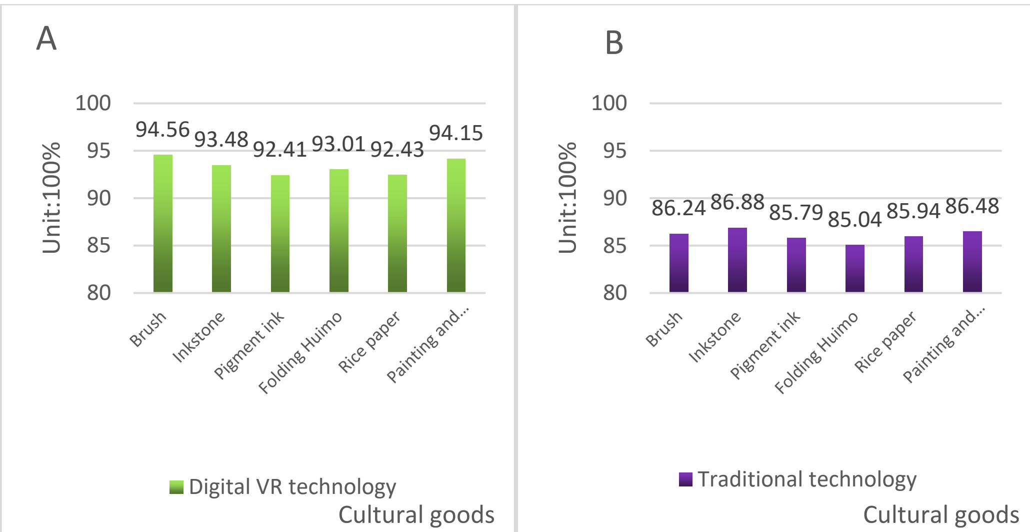

Figure 5A: Digital VR technology *Figure 5B: Traditional technology*

Figure 5 Comparison of the satisfaction rate of cultural goods between the two platforms

For cultural goods, the variety is very rich, including handicrafts, cultural and creative products, etc. The three-dimensional visualization service platform for cultural goods produced by traditional technology is mostly distributed in the form of pictures and words, and the mode of transmission is relatively small. Its interest and interactivity are relatively weak, resulting in low overall user satisfaction. The 3D visualization platform of cultural goods based on VR technology has overcome the

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shortcomings of the current 3D visualization platform of cultural goods to some extent. Using VR technology, it can dynamically display cultural goods in multiple directions, bring users an immersive viewing experience, improve users' interest in products, and improve users' satisfaction. In order to better verify the impact of the three-dimensional visualization platform of cultural goods based on digital VR technology on user satisfaction, this paper compares it with the platform based on traditional technology. This article is mainly to evaluate the user's satisfaction with six different types of cultural goods, including brush, inkstone, pigment ink, folding ink, rice paper and calligraphy and painting supplies. The specific satisfaction rate is shown in Figure 5.

As shown in Figure 5, the 3D visualization platform of cultural goods based on digital VR technology has a higher user satisfaction rate. The user satisfaction rate of different cultural goods on the platform is higher than that of the platform based on traditional technology. As shown in Figure 5A, the satisfaction rate of the platform based on digital VR technology is above 92%, while as shown in Figure 5B, the satisfaction rate of the platform based on traditional technology is below 87%. The satisfaction rate of users on the platform based on digital VR technology is the highest, 94.56%, which is 8.32% higher than that on the platform based on traditional technology. The platform users based on digital VR technology have the lowest satisfaction rate with pigment ink, only 92.41%, which is 6.62% higher than the platform based on traditional technology. The satisfaction rate of users of the platform based on traditional technology is the highest, with 86.88%, but it is still 6.6% lower than the platform studied in this paper. The satisfaction rate of users on the platform based on traditional technology is the lowest, only 85.04%, which is 7.97% lower than the platform studied in this paper. The difference between the satisfaction rates of users of the two platforms for rice paper is the smallest. The platform studied in this paper is 6.49% higher than the platform established by traditional technology. Based on digital VR technology, it can improve the experience of platform users and make people feel better about the performance and specific use effect of cultural goods.

The 3D visualization platform for cultural goods is designed to help platform users better understand cultural goods and spread cultural spirit. Different cultural goods belong to different types. It is very important to identify and classify a large number of cultural goods. The accuracy of identification and classification is also one of the effective means of testing the performance of a platform. In order to verify how the three-dimensional visualization platform based on digital VR technology can identify and classify cultural goods, this paper conducts experiments with the platform based on traditional technology. In this paper, 5000 cultural goods are sampled and 10 experiments are conducted on 5000 cultural goods. The specific classification accuracy is shown in Figure 6.

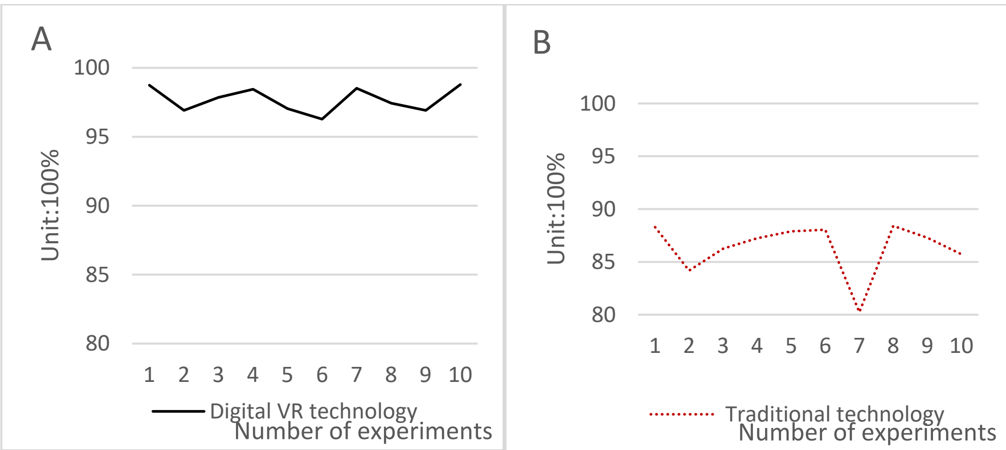

Figure 6A: Digital VR technology *Figure 6B: Traditional technology*

Figure 6 Comparison of the accuracy of identification and classification of cultural goods between the two platforms

As shown in Figure 6, the classification and recognition accuracy of ten experiments on the 3D visualization platform of cultural goods based on digital VR technology is higher than that of the platform based on traditional technology. The accuracy of platform recognition and classification studied in this paper is more stable, and the fluctuation is smaller. As shown in Figure 6A, the recognition and classification accuracy of the 3D visualization platform studied in this paper for cultural goods data is above 96%. As shown in Figure 6B, the accuracy of platform classification based on traditional technology is below 89%. The platform studied in this paper has the highest accuracy in the 10th experiment, 98.79%, which is 13.07% higher than the recognition and classification accuracy

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of the platform based on traditional technology. The platform studied in this paper has the lowest accuracy in the sixth experiment, only 96.28%, but it is 8.24% higher than the platform established by traditional technology. The platform based on traditional technology has the highest accuracy of recognition and classification in the 8th experiment, 88.41%, but it is still 9.03% lower than the platform studied in this paper. The platform based on traditional technology has the lowest accuracy of recognition and classification in the 7th experiment, only 80.24%, but it is still 18.28% lower than the platform studied in this paper.

The established platform is very important for the accuracy of the classification of cultural goods, but the length of the classification time is also very important. It would take a long time to classify different types of cultural goods data from the platform last time. This is not conducive to the update of the content of the platform. In order to verify the time required for the platform to classify different cultural goods, this paper compares it with the platform based on traditional technology. It mainly refers to the 5000 cultural goods data, which are uploaded to the two platforms at the same time and classified according to the five categories of learning cultural goods, office cultural goods, religious cultural goods, artistic cultural goods and national cultural goods. This paper compares the time required for their classification, and the specific results are shown in Figure 7.

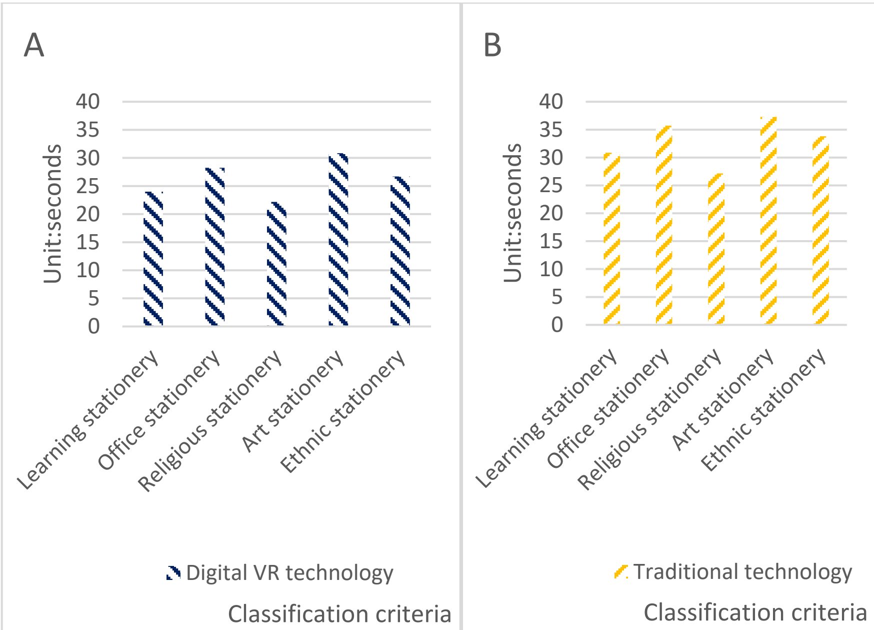

Figure 7A: Digital VR technology *Figure 7B: Traditional technology*

Figure 7 Comparison of classification time of cultural goods between the two platforms

As shown in Figure 7, for the classification of the extracted cultural goods data, the platform studied in this paper takes less time to classify it than the platform based on traditional technology. Both platforms take the shortest time to classify religious cultural goods in the extracted data. The platform studied in this paper takes 4.97 seconds less than the platform established by traditional technology. The two platforms take the longest time to classify art and cultural goods in the extracted data, but the platform studied in this paper takes 6.44 seconds less than the platform established by traditional technology. The two platforms spend the most time on the classification of office stationery. The traditional technology of the platform studied in this paper takes 7.47 seconds to build the platform. The data shows that the 3D visualization platform based on digital VR technology has shorter classification time for different types of cultural goods, and the accuracy of classification is also guaranteed. The performance of the platform is better than that of the platform based on traditional technology.

4. Conclusions

By integrating digital VR technology into cultural goods, this new form of cultural and artistic expression would arouse people’s attention to cultural goods again. The 3D visualization platform displays cultural goods to users in the form of 3D visualization, and it is equipped with more professional cultural knowledge interpretation and multi-dimensional dynamic practical operation.

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Users can observe any place of cultural goods in an all-round way without dead angle. In recent years, with the continuous improvement of scientific and technological progress, VR technology has been widely used. In this paper, a three-dimensional visualization platform for cultural goods was created based on digital VR technology. It can not only improve the originality and interest of users' experience of cultural goods, but also ensure that users can better understand the cultural knowledge and values behind cultural goods. This would help cultural goods to spread better, so as to meet the cultural and spiritual needs of users. Relying on the 3D visualization platform of digital VR technology, users can observe cultural goods at any time, increasing the way of cultural heritage, and comparing with the platform based on traditional technology. Its classification accuracy of different cultural goods is better, and the classification speed is also faster, which is also conducive to improving the user's sense of experience and improving the user's satisfaction with the platform.

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