Research on Information Visualization Design Strategies of Art Museums for Digital Transformation

Abstract: Under the digital transformation, the information system of the art museum largely determines the level of development of art. Firstly, it constructs the sub-module consisting of collection manager, Prometheus collection center, collector and file exchange component to realize the collection of art information. The basic operation within the art museum is completed through real-time monitoring, alarm management, configuration management, data statistics and analysis, maintenance management, and system management. On the basis of the scene segmentation algorithm, three-dimensional visualization scene modeling is carried out, and in this information visualization system, the collected data information is presented through three-dimensional visualization scene model. It is verified that the number of information searched by the information visualization system in this paper has the highest similarity with the real number and the accuracy rate reaches 99.74%. The scene segmentation algorithms for painting, sculpture, and photography require only 51 ms, 39 ms, and 30 ms, respectively, which is much smaller than other comparative methods. The visualization design strategy in this paper can facilitate the jumping of scene interfaces and the speed of 3D scene generation.
Keywords: Digital transformation, art museum information, scene segmentation algorithm, 3D visualization, design strategy.

1. Introduction

Digital transformation is the process of conforming to the trend of the new round of scientific and technological revolution and industrial change, continuously deepening the application of a new generation of information technology of cloud computing, big data, Internet of Things, artificial intelligence, blockchain, building to enhance the ability to survive and develop in the information age, accelerating the optimization and upgrading of business and innovation and transformation, transforming and upgrading the traditional kinetic energy, fostering the development of new kinetic energy, and realizing the transformation and upgrading and innovation and development [1-2]. The 21st century is the the era of information technology, and the process of informatization and digitization of all activities of human society has been accelerating, constantly changing people's production and life style. The same is true in the field of culture, in the context of the global era of information technology, art museums are also fully enjoying the dividends of this technological progress, the construction of information technology for the management of paintings is in the ascendant, and the formation of a new technology and trend of cultural inheritance and dissemination [3]. China's art museums have used information technology to enhance the concept of painting management, optimize also do management mode, and constantly promote the digital application of information resources. The degree of informatization of painting management has become an important reference standard for measuring the management level of art museums [4].

In order to improve the informationization level of art museums, many scholars have conducted corresponding research. The researchers of literature [5] designed an art museum collection information management system in their research, adopting the standard B/S structure. With iBASE Internet Gear Framework as the application development platform, around the management of collection information, to realize the information flow as a clue to the system framework structure, with powerful and perfect function and openness, standardization and convenience, easy to use and so on. Literature [6] in the article designed the art museum digital cultural relics information management system, the whole system includes collection cataloging management platform, collection source management platform, collection research management platform, collection storage management platform, collection media information management platform. It comprehensively realizes the automated management of the basic business of collection cataloging, collection, research collection, media collection, protection and restoration, circulation service and so on. The researchers of literature [7] believe that through the information visualization system, the relevant departments of art museums can search for professional information such as cataloguing, origin, research, etc., and custodial circulation information such as exhibition, movement, shooting, restoration, etc., of the collections of art museums for logging in, editing, searching, and visualization statistics. The researchers of the literature [8] were the first to propose the concept of orientation and to summarize the five spatial elements of paths, edges, nodes, landmarks, and regions in their study. Literature [9] in its study proposed the visualization of art museum information as a dynamic spatial problem solving behavior. Literature [10] in its research on the development of the whole guide design, process, principles and so on aspects of the narrative is very clear, put forward from the black box theory to the guide signage association and describe the essence of the link between the two. Literature [11] in the study not only exhaustively compared the status quo of the relevant countries' guide system with case studies, but also put forward the prospect of the development form of guide design. It is believed that although China's public guide signs started late, with the economic development and urban construction, China's public guide system will be a highly potential development field.

Combined with related research, this paper designs the system functional modules on the basis of the art museum information data collection technology architecture, while analyzing the roles of six modules, namely, real-time monitoring, alarm management, configuration management, data statistics and analysis, maintenance management, and system management, respectively. User interface layer, business logic layer and data access layer are taken as the system software architecture to analyze the roles of the three layers. The User Interface Layer mainly realizes the user interface and the system interface in the browser, while the Business Logic Layer is responsible for processing all kinds of data provided by the Data Access Layer and at the same time providing these data to the User Interface Layer. The data access layer mainly collects all kinds of data in the art museum through Dao Interface and Dao Factory. Analyzing the information visualization technology of art museums, while continuously optimizing and perfecting the visualization technology, it provides good guidance for the practical operation of the information management system of art museums, and gives more comprehensive and credible technical theoretical support to the related personnel.

2. Museum information visualization system

2.1 Technical Architecture of Art Museum Information Data Acquisition

In the context of digital transformation, the information visualization design of the art museum information includes and is not limited to four sub-modules: collection manager, Prometheus collection center, collector, and file exchange component. Art museum information is collected through its internal components, and the data collection process of art museum information is shown in Figure 1. The Prometheus collection center in the Zone III network summarizes the information collected at each collection point and transmits the summarized information to the collection manager, which reads the transmitted data information. The collection manager in the Zone III network submits the read information to the exchange catalog. The collection manager of Zone III network submits the read information to the exchange catalog. At the same time, the Prometheus collection center of Zone I network summarizes the information collected by each collection point and transmits the summarized information to the collection manager, which reads the transmitted data information. The collection manager of Zone I network submits the read information to the exchange directory, and the exchange directories of the two network zones exchange files through the isolation device. The collection manager of Zone III network acquires the exchanged data information. The manager obtains the exchanged data information and reports it to the database, at which time the data collection is completed.

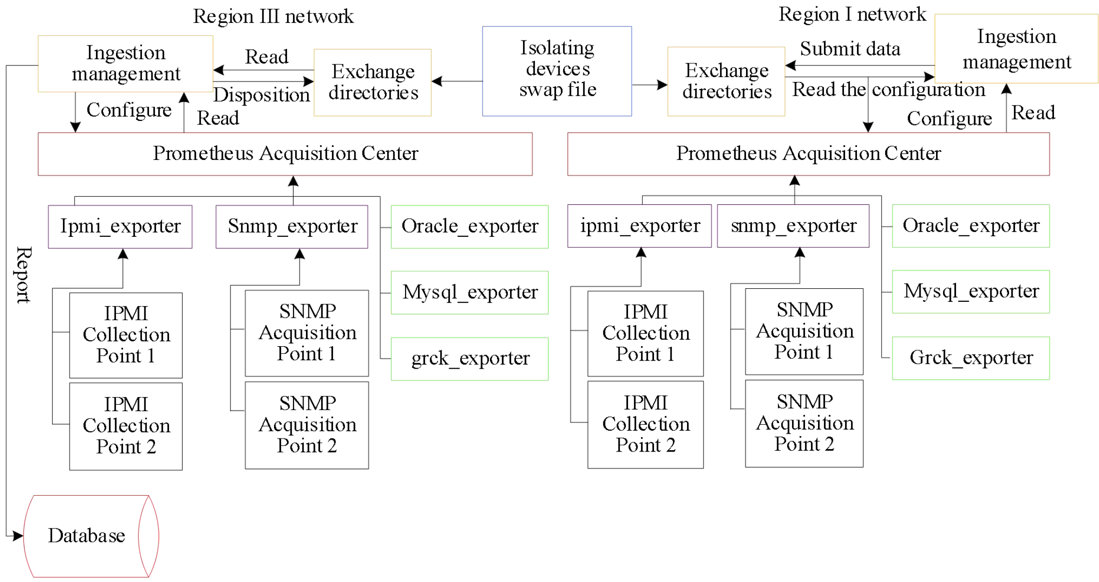

Figure 1 Art museum information data collection process

2.2 System Requirements Analysis

In order to realize the visualized operation and maintenance of art museum information, this paper develops the system design and testing based on software engineering theory. In software engineering theory, in order to ensure the efficiency of the system design, it is necessary to firstly carry out the system requirement analysis, analyze the feasibility of the system design, and clarify the functional requirements of the system. The final realization effect of this system is to provide a 3D visualized monitoring interface for the staff and exhibitors of the art museum, and at the same time, it can complete the telescopic view of the key areas of the art museum based on this interface. In addition, the system can also automatically identify the warning information in the museum, automatically alarm, and realize intelligent operation and maintenance.

2.3 System function module design

Based on the above analysis, the functional modules of the system are established, and the functional module division of the art museum information system is shown in Figure 2. The art museum information system covers real-time monitoring module, alarm management module, configuration management module, data statistics and analysis module, security management module, maintenance management module, and system management module, through the module to achieve the visualization of the art museum information system operation and maintenance [12].

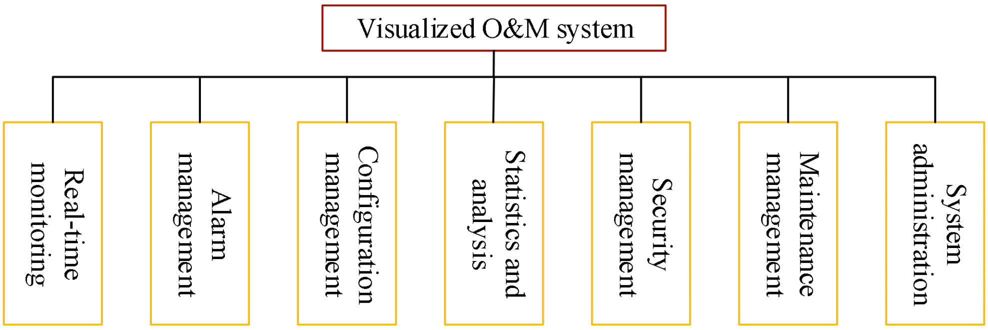

Figure 2 Functional module division of art museum information system

The module functions are as follows:

(1) In the art museum, it contains a variety of information that needs to be monitored, such as all kinds of paintings and the fire environment of the art museum, which all need to be monitored in real time. Therefore, it is necessary to complete the convenient switching mode for the situation of many viewpoints in the museum. And the monitor can also complete the switching of each area and zoom of the image with just the mouse.

(2) Based on the alarm level of the museum equipped with alarm processing, the museum information system alarm can be realized in two ways, one is to clarify the event process, the other is to remind the alarm in the monitor, the alarm can be automatically located to the alarm location [13].

(3) In the configuration management module can be analyzed to display information such as the content of the painting, the author of the painting, the time of the painting, the inner meaning expressed by the painting and the value of the painting. It can also display the basic attributes and status information of the paintings and support online editing.

(4)Data statistics and analysisThe main role is to obtain the database data in the information system of the art museum and analyze the obtained data.

(5) In maintenance management, users can arbitrarily designate viewing routes, set viewing cycles, and dynamically display the status of paintings in the area. At the same time, when the internal staff of the art museum find abnormalities in the art

museum, they can carry out remote maintenance through this module.

(6) The daily work of the system management module is to maintain the normal operation of the information system of the art museum, and to coordinate and allocate the authority of the staff in the art museum [14].

2.4 System software architecture design

Art museum information system has more functional modules, and in order to ensure that each module gives full play to its role, the software used in this paper is a three-tier structure that covers the user interface layer, business logic layer and data access layer at the same time. Art museum information visualization system software architecture shown in Figure 3, the user interface layer can show the system interface through the interface. The business logic layer, on the other hand, needs to process the relevant information delivered by the access layer and deliver the processed information to the user interface layer, while the data access layer mainly collects all kinds of data in the art museum through the interface [15].

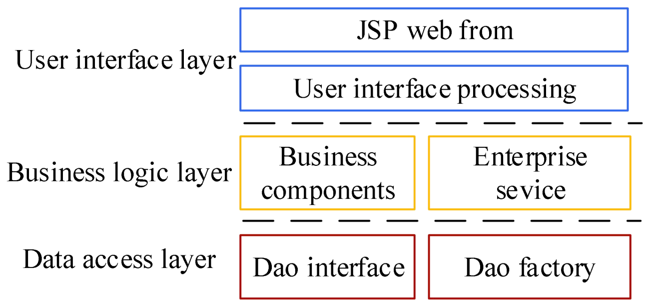

Figure 3 Software Architecture of Art Museum Information Visualization System

3. Visualization system realization of museum information

3.1 Scene segmentation algorithm

In the process of running the information system of the art museum, it is necessary to run and manage the scenes in the tube. There are a lot of paintings, sculptures, photographs and other exhibits inside the museum, so there are many kinds of scenes, and the amount of visualized scenes even reaches tens of thousands due to the large number of exhibits. In the environment of a large number of scenes will be divided into dynamic and static objects, at this time there are many intrinsic links between the scene and the object, the three-dimensional rendering of the various scenes is extremely time-consuming, so we need to improve the system for the problem of scene management [16]. The system scene management usually adopts the bifurcation space segmentation method or the enclosing body hierarchy method. For the visualization of the museum information, on the basis of data adjustment to promote the formalization of the original data, the form of the form in the visual mapping conditions transformed into a visual structure, through the processing of view transformation, complete the user visible form [17].

Because the scene in the art museum is more diverse, and the operation of the art museum needs to rely on interaction, resulting in the traditional scene of oil painting, sculpture, calligraphy and photography and other exhibits related to the calculation method can not be directly adopted [18]. Based on this, this paper takes the cost function as the main calculation method to manage the exhibits in multiple scenes in the art museum, and the premise of the calculation method of the cost function is to construct the required function and select the most suitable spatial plane segmentation factor.

The spatial scene segmentation is shown in Fig. 4, $V(AABB)$ which indicates that the space is covered by an $AABB$ box scene. The length of the box in the three directions of X,Y,Z is l_x,l_y,l_z, and the coordinates of the center of the box $V(AABB)$ in the three-dimensional coordinate system are $O(O_x,O_y,O_z)$. Assuming that from traversing the center of the box $V(AABB)$ perpendicular to the XOZ -plane, *VlVr* exists in the segmentation plane divided into two parts to the left and to the right, respectively, V_l,V_r. Noting that the distance from the center of the coordinates to the segmentation plane is x, the surface areas of V_l,V_r are $S(V_l)$ and $S(V_r)$, respectively.

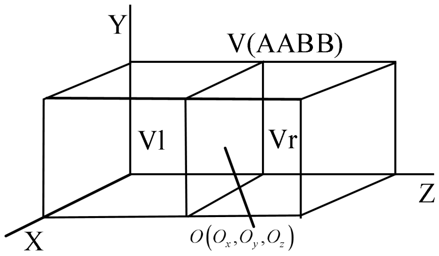

Figure 4 Spatial scene segmentation

Assuming that there are uniform and parallel rays of light in the space, and noting that Pl and Pr, are the probabilities that the rays of light hit the left and right spaces, respectively, then:

$$P_l = \frac{S(V_l)}{S(V)} = \frac{l_x l_y + l_x x + l_y x}{l_x l_y + l_x l_z + l_y l_z} \tag{1}$$

$$P_r = \frac{S(V_r)}{S(V)} = \frac{l_x l_y + l_x (l_z - x) + l_y (l_z - x)}{l_x l_y + l_x l_z + l_y l_z} \tag{2}$$

In the scene segmentation algorithm, the segmentation needs to calculate the computational resources consumed by the gallery traversing the scene, which is written as the traversal cost function $C(V)$. For the painting inside the gallery, the traversal of the scene is C_t, and the cost incurred by the intersection of the triangles and the straight line in the scene is Ci, which is the cost of the whole space at this time:

$$C(V) = C_t + P_l \times C(V_l) + P_r \times C(V_r) \tag{3}$$

In scene segmentation, in order to realize the dynamic control of the real-time nature of the paintings, it is necessary to use the paintings as the smallest management unit. When spatial segmentation is carried out, the integrity of the enclosing drawing box should be ensured. Therefore, the segmentation factor should be selected reasonably [19]. Assuming that there exists a total of $V_1, V_2, ..., V_m$ enclosing box in the space, the cost function of each subspace segmentation can be obtained. At the same time, the partial derivative of this cost function in the X -direction is calculated:

$$C_x^{'} = \left(\frac{2l_m + 2l_n}{l_m l_n + l_m l_p + l_n l_p} \times y - \frac{l_m n + l_n n}{l_m l_n + l_m l_p + l_n l_p} \right) \times C_{si} \tag{4}$$

The partial derivatives can characterize the rate of change of the cost function in the X -direction and enhance the efficiency of the selection of the segmentation plane during spatial segmentation.

3.2 3D visualization scene modeling

3.2.1 Single Bar Graph

The single bar graph can be combined with flat images to show the key data in the information visualization system of the museum, so that the staff inside the museum or visitors to the exhibition can understand the ideas expressed in the paintings more intuitively, and thus formulate a more accurate information visualization strategy. However, the single bar graph can only show the two-dimensional plane effect, and the image presentation is not three-dimensional enough to grasp the comprehensive information of the art museum visualization system. Upgrading on the basis of two-dimensional visualization and efficiently using three-dimensional visualization technology can break through this limitation. The method of using single bar graph shows more key technical indicators in the information visualization of art museums [20].

In the drawing process of single bar chart, both the structure of bar chart elements and the step of element type are eliminated, which simplifies the process and greatly improves the efficiency of information visualization in art museums. By comparing the undisplayed visualization values with them through the uniform coordinate attribute, and then sorting them in order from big to small, the main bar and the secondary bar in the single bar graph can be located in the same position for intuitive display. If you do not need to dynamically compare the value of the bars, you can fully display the process of the 3D single bar graph in the human-machine interface, displaying the bar with the largest value and calculating its proportion in the graph, placing it at the top. Single bar graphs can show either a single element or a perspective rotation of the whole graph [21].

3.2.2 3D rotation of shapes

Graphics three-dimensional rotation technology can show the values in the museum information visualization system in the form of three-dimensional graphics, through multi-angle, multi-dimensional observation can be an all-round understanding of the operational status of the visualization system, and the possible existence of the system failure to judge, and efficiently exclude the safety hazards of the visualization system [22]. In the application of three-dimensional rotation technology to the graphics, the method of geometric transformation can be utilized, if the rotation is counterclockwise when B is a positive number, counterclockwise B is a negative number, in order to carry out calculations, that is:

$$x_1 = x_0 \cos B - y_0 \sin B \tag{5}$$

Or:

$$y_1 = y_0 \cos B - x_0 \sin B \tag{6}$$

Three-dimensional rotation, as shown in Figure 5, transforms the three-dimensional image into a new graphic through translation and rotation, takes the coordinate origin and axis as the core object, transforms the geometric information of the three-dimensional graphic, and directly converts the coordinates. Before running, the relevant staff in the Museum of Fine Arts need to do a good job of processing the type of graphics, accurate calculation of the new coordinates, and in the designated diagram to draw a good corresponding element, the staff can be based on the geometric transformation of the type of element or character for a high degree of simulation. Then connect the vertices and intersections of the line segments with each other to draw a three-dimensional rotated image, and the intersection of the vertices is geometrically changed based on pixel points. This results in a more three-dimensional, intuitive three-dimensional image that allows staff to analyze data more accurately.

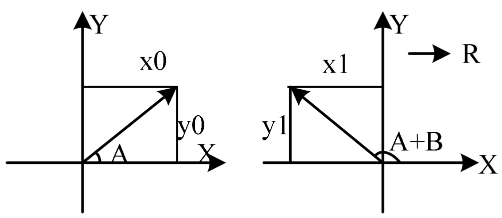

Figure 5 Three-dimensional rotation

3.2.3 3D visualization scene modeling

Two-dimensional visualization technology can analyze the image color through the method of dynamic trend, combined with the data, and determine the length of the line segment, the flow step of the graph, and confirm the number of images as well as the specific location after completing the drawing of the image. Two-dimensional visualization technology can also be through the inverse time curve, and then use the main transformer overload capacity of the visualization system for a full range of descriptions, to ensure that the visualization system can operate safely. Using the main transformer overload curve displayed in the system, the staff can grasp the actual load of the main transformer and understand the connection between the main transformer load and load time. Although two-dimensional visualization technology can be used in a variety of planes, the complex data in the visualization system to simplify the processing and make it intuitively displayed in front of people's eyes, to help people make the right decision. But the two-dimensional plane of visualization graphics and images lack of three-dimensional effect, the staff can only understand the operation of the local visualization system. In this regard, three-dimensional visualization technology can be used, through the way of a single bar graph, the visualization system in the relevant equipment and safety analysis results, such as intuitive, three-dimensional display in front of the staff.

Based on the spatial segmentation algorithm described above, the 3D visualization scene modeling of the museum information can be completed. In the actual operation and maintenance, the instrumentalization of effective operation and maintenance management tools has become one of the urgent problems for art museums. The software and hardware system can realize the functional modules including asset life cycle management, resource capacity management, energy consumption management, etc., so as to manage the museum information and optimize its performance, meanwhile make full use of the data to improve the operation and maintenance efficiency and reliability.

The core features of this technology are: to establish a three-dimensional visualization operation and maintenance scene, and to endow the scene with interactivity and interactivity, specifically including the following steps:

(1) Adopting an AABB-type scene enclosing box to enclose said three-dimensional visualization operation and maintenance scene.

(2) Establishing a cost function.

(3) Segmenting the scene by the cost function.

(4) Reconstructing a three-dimensional scene model with interface communication for Unity3D.

(5) Realize operation and maintenance work through interface communication.

The art museum information visualization and interaction technique in this paper uses a binary tree-like structure for scene association and organization management. Utilizing this structure, it is possible to make all scene accesses with the existing mature tree's preorder, middle order or postorder traversal algorithms.

4. Analysis of visualization design strategies for digital transformation

4.1 Experimental configuration

A city transformed art museum information visualization system as the main object of study, the service implementation platform for MyEclipse, J2EE 5.0, JDK for JDK1.6.29, Web services framework for JAX-WS + JAXB, service deployment server selection Weblogic 10.3, JMS server for Weblogic 10.3, the choice of the service bus Oracle Service Bus 11g, UDDI Serve for Weblogic 10.3.

According to the system functional design and functional module division, the database of this system several major table structure design is as follows:

(1) Famous artist table includes famous artist ID, name of famous artist, introduction of famous artist, photo of famous artist, unit price of works, as well as the administrator of famous artist release, entry time and number of clicks.

(2)The collection call order table includes collection call order ID, call order title, call order content, entry time, call order summary, and call order release administrator, and the number of hits.

(3) Collection table includes collection ID, collection length, collection height, collection title, writer ID, whether home page display, collection picture, collection release administrator, entry time, collection introduction, number of hits.

(4) Exhibition information table includes exhibition information ID, exhibition start time, exhibition end time, exhibition hall,, exhibition theme, and exhibition content, exhibition information release administrator, entry time, number of hits.

(5)Works table is divided into works ID, works length, works width, works title, works author ID, works picture, works profile, works classification ID, entry time, and works release administrator, whether home page displays works, number of hits.

4.2 Analysis of system effectiveness

In order to verify the effectiveness of the art museum information visualization system designed in this paper, relevant experimental analysis is needed. The two-dimensional visualization of the art museum information management system, Shape Coding visualization of the art museum information management system, the art museum information visualization system of this paper is used to test the information of an art museum in a city in 2022, and the results of the test of the information of the art museum are shown in Table 1. Now only the information visualization system of this paper searches the number of information with the highest similarity to the real number, and the accuracy rate is 99.74%, while the average accuracy rate of the information searched by the Shape Coding visualization information management system and the 2D visualization information management system is 81.77% and 67.51%, so that the system of this paper has the highest search accuracy rate. The validity results validate the constructed design strategy, which helps to better display the art works, thus attracting more tourists.

Table 1 Art museum information test results

Information content	Data type	Number of messages	Systems built	Shape Coding	2D visualization
Masterpieces	Int(4) NOT NULL	259	257	201	176
	Varchar(20) NOT NULL	259	257	201	176
	Text(16)NOT NULL	259	257	201	176

	Varchar(50)	1146	1145	833	649
	Float(8)	5763.33	5763.33	4786.41	3852.73
Collection Call	Int(4) NOT NULL	363	361	243	204
	Varchar(40) NOT NULL	363	361	243	204
	Text(16) NOT NULL	363	361	243	204
	Varchar(60)	363	361	255	227
List	Int(4) NOT NULL	307	307	269	247
	Varchar(40) NOTNULL	307	307	269	247
	Int(4) NOT NULL	214	209	168	142
	Varchar(50)	1573	1566	1373	1048
	Text(16)	307	305	265	239
Exhibit	Int(4) NOTNULL	566	564	470	423
	Varchar(40)NOT NULL	566	564	506	437
	Varchar(60)NOT NULL	566	564	506	437
	Text(16)	566	564	506	437
Average accuracy/%		—	99.74%	81.77%	67.51%

4.3 Analysis of scene segmentation algorithms

In the implementation of the interface of the 3D visualization system, the MVC architecture is used in the software architecture, which has the advantages of low coupling, high reusability, strong maintainability, and conducive to the management of software engineering. In addition, the system also uses Unity 3D technology, a professional 3D scene rendering engine developed by Unity Technologies. With this technology and scene segmentation algorithms, the museum uses Java Script to write programs and assign them to virtual objects as components. According to the scene characteristics of the art museum, the spatial segmentation of the scene management is optimized by the triangle number reduction and instantiation technology, which can display static or moving objects in multiple levels and dynamics. Using the octree algorithm, Cell-portal algorithm, deep learning algorithm, random forest algorithm, as well as this paper's visualization system for 3D scene simulation of the relevant equipment in the art museum and all the paintings, rendering to generate a 3D scene graph of the computational resources consumed in the comparison of scene segmentation algorithms are shown in Table 2. It can be seen that in the segmentation and 3D modeling of the relevant equipment in the art museum and all the paintings, our scene segmentation algorithm only needs 51 ms, 39 ms and 30 ms respectively, which is much smaller than the octree algorithm, Cell-portal algorithm, deep learning algorithm and random forest algorithm. Therefore, the visualization technique in this paper has a greater improvement in the speed of scene interface jumping and 3D scene generation, and also has a better guarantee of real-time performance.

Table 2 Comparison of scene segmentation algorithms

Algorithm	Painting	Sculpture	Photography	Calligraphy	Installation Art
Scene Segmentation	51ms	39ms	30ms	31ms	32ms
Octree	135ms	86ms	67ms	68ms	69ms
Deep Learning	77ms	79ms	55ms	62ms	66ms
Random Forest	92ms	81ms	61ma	55ms	57ms
Cell-portal	98ms	77ms	57ms	58ms	59ms

4.4 Comparison of number of visitors

Randomly counting the number of visitors of a large art museum from January to December in 2022 and simulating the designed informative visualization strategy, Figure 6 shows the results of the comparison of the number of visitors. It can be clearly seen that after the application of this paper's strategy in January-December, the number of visitors in May and October compared with the application of the former, the number of visitors increased by 40,000 and 50,000 people. It shows that the designed visualization system architecture and implementation strategy can help to attract more people to visit the museum, thus enhancing the economic benefits of the museum and expanding the degree of exposure of the artwork.

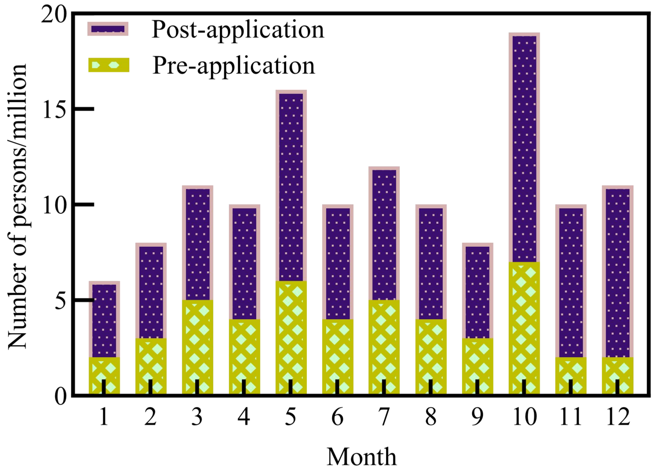

Figure 6 Comparison results of the number of tourists

5. Conclusion

In the context of digital transformation, information technology has been significantly developed, in order to manage the massive information, there is an urgent need for a set of concepts and technology better management tools. This paper carries out a relevant research on the information visualization process of art museums, and also designs a scene segmentation algorithm for the art museum field, which not only improves the accuracy of the system's search, but also reduces the time spent on the algorithm. The results show that the number of information searched by the constructed information visualization system has the highest similarity with the real number, and the accuracy rate reaches 99.74%. The scene segmentation algorithms for painting, sculpture, and photography required only 51ms, 39ms, and 30ms, respectively, which is much smaller than the other compared methods. It facilitates the jumping of scene interfaces and the generation of 3D scenes at a greater speed, and the number of visitors is increased by up to 40,000 people compared to the pre-application level. The real-time performance is also better guaranteed, which provides good guidance for the practical operation of the information visualization system of the art museum and gives more comprehensive and credible technical theoretical support to the related personnel.

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