

Research Article

Development and Design Case Function Comparison of Panoramic Roaming System of Virtual Museum Based on Pano2VR

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The development of modern information technology gives birth to virtual museums. The exhibition of physical museums is evolving into online virtual exhibition, allowing users to have an immersive experience of museums without leaving home. Through content analysis, this study analyzes the status quo of online virtual museums in China and discovers two major problems: the exhibits are mainly brief introductory graphs and texts, and the exhibition module is independent of the panoramic roaming module. To solve the problems, Pano2VR was used to develop and design a virtual museum panorama roaming system for Hubei Museum. After realizing the map navigation of the museum, photos of the museum were taken on the site and prepared into a panorama. Then, the panorama roaming of the virtual museum was achieved based on Pano2VR. Finally, the results were displayed on the virtual web page of the museum, and real interactive virtual exhibitions were conducted on the website platform. The proposed system enhances the research value of the cultural relics of the Hubei Museum and increases the interaction with users.

1. Introduction

With the development of the computer industry, web page construction and virtual roaming technologies are increasingly mature. Virtual roaming provides an important means for cultural dissemination in modern society, owing to its interactivity, imaginativeness, and immersiveness [1]. It is now a popular practice to fully apply virtual roaming to museum exhibitions. Many domestic and foreign scholars have studied virtual roaming technology, trying to offer users an immersive experience without leaving home [2–6]. At present, no camera can take panoramic photos of a huge scene. This gives rise to various panorama stitching algorithms [7, 8]. Chen et al. [9] took photos with an ordinary camera and created a 360° panoramic photo in the horizontal direction. But viewers cannot observe freely in the vertical direction. Wu and Hu [10] designed a novel algorithm to obtain a relatively complete panorama. Some results have been achieved by combining virtual roaming with

panoramic photos on virtual campus [11, 12]. Although the virtual roaming technology involves disadvantages such as high cost, poor security, and many restrictions, the biggest advantage is that the objects to be roamed are real objects in the real world. Based on the data related to the real objects, a virtual roaming scene is created and realized remote virtual roaming. In the multidimensional information space, virtual roaming technology creates a virtual information environment based on real objects. After logging in to the system, users can watch various virtual scenes as if they were there and interact with the virtual scenes through corresponding operations. Receive the feedback information of the virtual scene, prompt the user to mobilize the subjective consciousness to think during the viewing process, and form a memory or impression of the relevant information of the virtual scene.

Focusing on the most simple and feasible practical methods, this study adopts Pano2VR, a panoramic roaming production tool Pano2VR, to design and realize a three-

dimensional (3D) virtual museum roaming system through image modeling. The first part of this paper introduces the current situation of the construction of online virtual museums. Through comparative analysis, it is concluded that the virtual museum needs to be equipped with interactive modules for top-level design and transformation. The second part analyzes the realization basis of virtual museum panorama roaming through four aspects: virtual panorama roaming technology, panorama stitching software, characteristics and image stitching algorithm, Pano2VR, and HTML5 web page production. The third part takes Hubei Museum as an example, uses Pano2VR software to design the system, and finally realizes the panoramic roaming of the virtual museum. In the fourth part, the experimental analysis is carried out, and it is concluded that the Pano2VR technology development museum roaming system has good three-dimensional display and interactive functions.

2. Status Quo of Online Virtual Museums

Content analysis was performed to reveal the status quo of online virtual museums in China. The friendly links to other museums were collected from the websites of 12 national and provincial museums, and the overlapping ones were analyzed in Window 7. 360 Explorer and Internet Explorer (IE) 9 were tested separately at the normal speed of the campus network. Table 1 lists the status quo of online virtual museums. Out of the 12 museums, 10 have established virtual museums.

- (1) From the perspective of the expression form of museum exhibits, the Palace Museum, Shanghai Museum, and Anhui Museum introduce the details of the exhibits purely in graphs and texts. The other museums display the exhibits with the help of virtual reality (VR) technology. In most cases, panoramic roaming is adopted, and introductory graphs and texts are embedded in interactive hotspots.
- (2) From the perspective of smoothness, most virtual museums can be browsed very smoothly. Only two virtual museums are loaded slowly. But the browsing is smooth as well after the webpages are fully loaded.
- (3) From the perspective of compatibility, the authors checked the cross-browser compatibility and the need to download and install the corresponding VR plug-ins. All virtual museums support mainstream browsers like IE, 360, Firefox, and Chrome-based browsers. In terms of plug-in support, the Palace Museum requires users to download and install a large high-definition image browser plug-in. Nanjing Museum requires users to download and install the NJMUSEUMPLAYERXP VR browser plug-in. Wuhan Museum requires users to download and install the CrystalWHMuseum 3D VR browser plug-in. But the panoramic roaming VR system cannot work after the plug-in is installed in Chrome-based browsers and the web page is refreshed. Shaanxi History Museum requires no browser plug-in, yet its web page cannot be opened in Chrome-based

browsers: in the panoramic roaming system of the halls, users can merely click on an exhibit and view its information.

- (4) From the perspective of interactivity, the virtual versions of Nanjing Museum, Henan Museum, Shaanxi History Museum, Shanxi Museum, and Hunan Museum are relatively well designed: all of them have designed map navigation and operational instructions. However, Hunan Museum is the only one that has set up a feedback module and embedded it in the panoramic roaming system. In addition, the message board module of most museums lacks the question and answer (Q&A) mechanism, a necessary function of virtual museums. Through content analysis, this study investigates the independent message board modules of the 12 museums and uses the ROST content mining system to capture the data from the message boards. The captured web data were subjected to semantic cluster analysis of high-frequency words. The analysis shows that most messages on the message board ask about the reservation system, venue opening hours, personal collection appraisal and consultation, venue service consultation, personal donation consultation, etc. However, the virtual exhibition is separated from the interaction module, and the message board is not related to that module. The virtual museums only provide photos of events and video playbacks of relevant theme lectures. The design of the virtual museums gives no consideration to interactivity or feedbacks. Online visitors could only browse the general information about exhibits. Overall, the virtual museums are badly in need of an additional interactive module, which could be arranged through top-level design and transformation.
- (5) From a technical perspective, National Museum, Palace Museum, Henan Museum, etc. have adopted the latest Internet technology, combined with VR technology, LOD technology, etc., to maximize the sense of reality, immersion, and interaction of the exhibition hall. Shanghai Museum and Shanxi History Museum have developed virtual museum collection management systems based on Basic or dBase (Fox Base), but the technology cost for the image files in the exhibition hall is very high. Guangdong Museum, Shanxi Museum, etc. have adopted the combination of computer network technology and CMIS technology. Due to the huge amount of data resources required by this technology, the effect is very poor due to the influence of network transmission speed, and it is not suitable for online communication. Nanjing Museum and Wuhan Museum use Web3D technology to realize a 720-degree panoramic tour, which is an all-round tour mode without dead ends in the virtual exhibition hall. In addition to the several virtual museums mentioned above, Zhejiang Museum, Hunan Museum, Anhui Museum, etc. have adopted VR

TABLE 1: Status quo of online virtual museums.

Name of museum	Virtual museum? Yes/No	Form of online exhibits	Smoothness	Compatibility	Interactivity	Education module? Yes/No
National museum	Yes	Panoramic roaming embedded with graphs and texts	Smooth	Compatible	Navigation and operational instructions; no feedback module	No
Palace museum	Yes	Graphs and texts	Slight lag	Plug-in needed	Week navigation; no operational instructions or feedback module	No
Shanghai museum	No	Graphs and texts	—	—	—	—
Nanjing museum	Yes	VR 3D embedded with videos	Smooth and slow in loading	Plug-in needed	Clear and detailed navigation and operational instructions; no feedback module	Yes
Guangdong museum	Yes	Panoramic roaming embedded with graphs and texts	Smooth	Compatible	Navigation; no operational instructions; poor image operability; no feedback module	No
Wuhan museum	Yes	Panoramic roaming +3D	Smooth	Plug-in needed	Navigation and operational instructions; no feedback module	No
Henan museum	Yes	Panoramic roaming embedded with graphs and texts	Smooth and slow in transition	Compatible	Clear navigation, guide, and operational instructions; no feedback module	No
Zhejiang museum	Yes	Panoramic roaming	Relatively smooth	Compatible	Navigation; no operational instructions; no feedback module	No
Anhui museum	No	Pure graphs and texts	—	—	—	—
Shaanxi history museum	Yes	Links to graphs and texts and panoramic roaming	Smooth	Hall not displayed	Theme guide; graphic instructions; no feedback module	No
Shanxi museum	Yes	Panoramic roaming embedded with graphs and texts	Smooth and slow in loading	Compatible	Visual navigation map; no feedback module	No
Hunan museum	Yes	Panoramic roaming embedded with graphs and texts	Smooth	Compatible	Logical theme navigation and signs; feedback module	No

technology, Internet technology, and multimedia technology, etc., to realize the virtualization and spatialization of exhibition halls and shorten the exhibition hall and tour. The distance between the users and the excellent exhibition halls of our country will be displayed to users all over the world through the Internet.

3. Realization Basis for Panoramic Roaming of Virtual Museums

3.1. Virtual Panoramic Roaming Technology. The panoramic roaming system simulates and digitally reproduces the museum and related scenes. The virtual or real images produced by the computer are used to reproduce the real world. Then, online visitors can use the mouse and keyboard to freely browse in the virtual scenes, and engage in human-computer interactions (HCIs) [13–15]. Pano2VR is a popular panoramic roaming tool.

The VR is developed based on the virtual panorama roaming technology. Virtual panoramas are stitched together from a series of similar images on the same scene. In recent years, the VR has been widely applied, and combined with various techniques into a novel virtual environment technology.

Before the panoramic roaming of the virtual museum, the main preparatory works include shooting panoramas, understanding the mainstream panorama stitching software and their features, implementing Pano2VR, and web exhibition.

3.2. Mainstream Panorama Stitching Software and Their Features and Image Stitching Algorithm. Before realizing the virtual panoramic roaming of Hubei Museum, it is important to prepare the panorama, i.e., the panoramic photo that conforms to the normal effective viewing angle of human eyes. First, the photos with basically the same tone and small overlaps were taken consecutively in the horizontal or vertical direction. Then, these photos were stitched into a widescreen photo. The stitching of the panorama makes up for the defect of the existing imaging devices: the inability to take a 360° panoramic photo of a huge scene [12]. Table 2 summarizes the mainstream panorama stitching software and their features.

Panoramic image stitching occupies an important position in the field of image processing. Commonly used panorama image stitching algorithms include Harris, SURF, SIFT (scale-invariant feature transfer form) and other feature point detection algorithms. Among them, the stitching algorithm based on Harris corner points, due to the scale sensitivity of Harris corner points, the stability of the feature corner points is insufficient, resulting in false dislocation of the stitched images. Based on the SURF stitching algorithm, although the calculation speed of SURF is better than that of SIFT, when the image details with rich texture are stitched and stitched, the texture expression accuracy of SURF is slightly inferior to that of SIFT, which will result in a higher mismatch of matching points. Image stitching based on the

SIFT algorithm, although feature points have the advantages of scale invariance and feature description accuracy, but there are problems such as long search time for feature points and insufficient optimization and filtering of incorrectly matched feature points. In view of the problems of the above methods, an improved fast panoramic image stitching algorithm based on SFIT is proposed, which improves the stitching efficiency, and purifies and improves some mismatched points, which has stronger robustness.

3.3. Pano2VR. Pano2VR is a panorama image conversion and application software based on the flash animation technology. The development of the software is reported in Figure 1. The main function of Pano2VR is to convert the panorama images of multiple formats into the corresponding image files for display. The files can be outputted as flash animation files or brand-new HTML5/CSS3 files. Besides, Pano2VR supports multiresolution progressive zooming of panoramas and is compatible with the animation display function of different platforms. Thus, it truly meets the needs of cross-platform joint development and facilitates the design and development of different virtual animation systems. Pano2VR is an important software for making flash panorama. As the mainstream format of panorama, flash can be easily played directly and easily on webpages. Pano2VR is a very professional panorama image converter, which mainly solves the problem of converting panorama images into quicktime, macromedia flash8, flash9, html5, and other formats, and whether it is a gigapixel panorama or a virtual image with hundreds of nodes Roaming can be achieved perfectly. The software also has the ability to take plane, cylinder, sphere, cube, intersection, T, strip, and quicktime VR as input formats and additions and provides an easy way to add and edit existing panoramas and Google Street View View, in addition, the software also supports multiresolution progressive zoom panorama and re-optimization of the engine to generate a more fluent flash, even compatible with JPEG, TIFF, PNG, BigTIFF, Photoshop PSD/PSB, and other image formats and Panorama output in HTML5/CSS3 format.

3.4. HTML5 Web Page Construction. HTML is a markup language for depicting web files. The language has won the favor of many users, thanks to its various excellent properties, such as ease of operation, scalability, and platform independence. HTML5 is a new HTML standard, which improves multiple aspects of web terminals, such as semantics, interactivity, system function calls, and multimedia. HTML5 solves many of the problems in previous standards, namely, HTML4. Moreover, many new features are added to HTML5, e.g., audio, video, and image embedding functions, client-side data storage, interactive files, etc. Specific rules are provided for handling all HTML elements and restoring them from errors [20]. In addition, HTML5 further enhances interactivity and effectively reduces development cost. Specific implementation steps: (1) Web page display content design, that is, the theme to be displayed on the page and the functions to be implemented. First of all, it is

TABLE 2: Mainstream panorama stitching software and their features.

Name	Description	Features
PTGui	PTGui [16] is a multifunctional panorama image stitching tool.	The software is powerful, supporting multiple types of stitching, without obvious stitching traces.
Canon utilities PhotoStitch 3.1	Canon utilities PhotoStitch 3.1 [17] is a panorama production software released by Canon with its digital cameras.	The operation interface is beautiful and simple, and the merging speed is fast. But the ability of hue control is weak.
Autopano giga	Autopano giga [18] is used for 360° panorama and can export panorama to flash.	The stitching accuracy is high, and the color and fusion are well controlled. But the thread and CPU usage is high during APG rendering.
Photovista	PhotoVista [19] is based on a powerful engine that automatically calculates seams and then produces seamless 360° panoramas, using various methods.	PhotoVista is a tool that can prompt the number of photos that match the lens settings, and the operation process is simple.
Adobe photoshop CS6	Adobe photoshop CS6 [16] is the 13th generation of adobe photoshop.	There are no obvious stitching traces. The tone is roughly the same. It is a relatively common mainstream software with a huge volume.

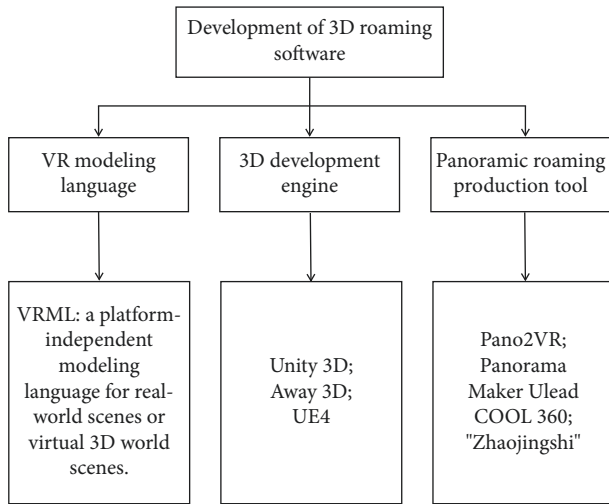


FIGURE 1: Development history of roaming software.

necessary to clarify the needs of customers, and second, to consider the type and nature of virtual museums on the basis of satisfying customer needs. (2) Create a web page. First, you need to plan the site, you can draw sketches on paper to complete the layout, arrange text, pictures, and even animations on the specified position of the page, determine the general outline of the page, and then compile the HTML5 script code on the computer to design the blueprint become a reality, of course, you can also use visual development tools, such as Dreamweaver, Fireworks, and so on. (3) The overall effect design of the web page. Pay attention to the collocation effect of the elements of each page. The elements on the page must construct the entire page through the combination and collocation of points, lines, and surfaces. The use of CSS technology can achieve good results. (4) Page optimization: generally speaking, text and pictures are the largest elements in a web page, so it is very necessary to use CSS style sheets to specify the style of text. As for the optimization of the picture, on the premise of ensuring the browsing quality, the size of the picture should be reduced to the minimum, which can double the download speed of the web page, or the large picture can be cut into several small

pieces by using image processing software, and carried out separately. Optimized, its file type can be GIF or JPEG.

4. Pano2VR-Based Realization of Panoramic Roaming of Virtual Museum

Taking Hubei Museum, for example, this study designs the virtual museum by Pano2VR: (1) realizing the map navigation of the museum; (2) taking photos of the museum on the site, preparing them into a panorama, and realizing the panorama roaming of the virtual museum based on Pano2VR; and (3) displaying the results on the virtual web page of the museum and conducting real interactive virtual exhibitions on the website platform.

The virtual museum mainly includes (1) digital knowledge warehouse of cultural relics. The digital knowledge warehouse of cultural relics is the foundation of other application platforms. It contains digital cultural relics organically composed of information resources such as high-definition images, audio, video, text data, three-dimensional data, remote maps, and related research results required by each application platform. (2) Cultural relic display and dissemination platform. All data of the cultural relics display and dissemination platform comes from the digital knowledge warehouse of cultural relics, and the combination of various data adapts to the needs of different dissemination methods. It can be divided into in-library communication platform and out-of-library communication platform. The communication platform in the museum includes a large-screen multimedia cultural relics display module and a touch-screen stereoscopic display module. The communication platform outside the museum includes a virtual exhibition module of cultural relics, a mobile digital device access module, etc. (3) Cultural relics academic research platform. The platform includes the acquisition and remote interaction of digital cultural relics information resources. Experts who have obtained control can perform operations such as flipping, zooming in and out of research objects, and extracting relevant information materials.

For the virtual Hubei Museum, factors such as smooth operation mechanism, clear operation method, perfect

functional system, and practical visiting experience are particularly important. To narrow the feeling gap between virtual tours and physical tours, it is necessary to restore the functions of the physical exhibition halls as much as possible in the design of the system, and on this basis, design a virtual museum system with good interactivity. At the beginning of the design, the following design elements should be considered: (1) data resource combination design. For the virtual resources of museum exhibits and information, museums should integrate and design them and store them as background resources, and at the same time, classify and manage exhibits and information by period, type, size, etc. This saves time and cost for post-data management of the virtual museum. (2) Operation design of the exhibition hall. For the tour of virtual museum projects, various service items for VR display should be determined at the beginning of design, which should include basic operations such as exhibits display, information introduction and explanation, and human-computer interaction. After the design of these functions is completed, the basic framework of the virtual museum system will be built and then expanded according to the requirements of each part of the function. (3) Visiting route and perspective design. When designing the visiting route of virtual roaming, it should be based on the structure of the physical museum and at the same time consider the habits and characteristics of users when visiting and design a variety of tour methods for users to choose. This part of the design can greatly improve the basic application functions of the museum.

4.1. Map Navigation of Virtual Museum. To realize the map navigation function of the Virtual Hubei Museum, code was written in MyEclipse using the application programming interface (API) of Baidu Map, creating a map embedded in the web page. Three kinds of maps can be generated. The first is the static GIF image, which can be directly and dynamically acquired from Baidu Map. It is more convenient than loading a complete map. The second is the dynamic map, which can be dragged and zoomed from a point. Figure 2 shows the dynamic map centering on the museum. The third is the navigation function of Baidu Map. Online visitors can identify their current positions and check the routes to the museum in three different navigation modes, completing the path planning for visiting the museum.

4.2. Panoramic Roaming of Virtual Museum. The panoramic roaming of the Virtual Hubei Museum can be realized in the following steps:

Step 1. Shoot panoramic photos of the museum, stitch them into a panorama of the virtual museum, and combine other technologies to prepare the panorama into a more suitable panoramic roaming map.

Step 2. Based on Pano2VR, create interactive hotspots and make the panoramic roaming map more realistic.

Step 3. Add the function of virtual roaming interaction, which enables visitors to roam in the virtual scenes of the museum. Ensure the user experience by allowing

online visitors to walk forward, backward, left, and right by pressing the up, down, left, and right keys, to change the perspective through the headset, or to choose running, walking, and other modes. This function can be realized as follows:

```
void Update( )
{float movev=0; float moveh=0;
if(Input.GetKey(KeyCode.UpArrow))
{Movev-= m_speed * Time.deltaTime; }
If(Input.GetKey(KeyCode.DownArrow))
{Movev+= m_speed * Time.deltaTime; }
if(Input.GetKey(KeyCode.LeftArrow))
{ Moveh+= m_speed * Time.deltaTime; }
if(Input.GetKey(KeyCode.RightArrow))
{Moveh-= m_speed * Time.deltaTime; }
this.transform.Translate(newVector3(moveh,0,
movev)); }
```

4.2.1. Preparing 3D Panorama. The panoramic photos of Hubei Museum were captured by combining the following devices: digital single lens reflex (DSLR) camera, tripod head, tripod, ultra-wide-angle lens, etc. The photos were all shot on the site of the museum. Out of the various panorama stitching software, Autodesk 3ds Max was adopted for 3D modeling of the museum, and the panorama output function was called to directly generate the panorama. First, the camera was configured in the 3D scene, and the camera view was chosen. Then, panorama was selected in the rendering menu. The software would automatically stitch a panorama, merge the layers, and save the photo. Note that the maximum resolution was selected for rendering output, aiming to ensure the definition and resolution of panoramic roaming prepared by Pano2VR.

4.2.2. Creating Pano2VR Project File. The panorama roaming map was developed by Pano2VR. Once the 3D panorama was prepared, Pano2VR was adopted to output the panoramic roaming in the format of flash. The specific steps are as follows:

Step 1. Click on the desired file → click to open the file → select the flash panoramic map(s) generated in the file or drag the image directly from the input of the window to the input box or the display area.

Step 2. Click on the desired attribute in the main interface → enter the input (select type).

There are more than 10 types of inputs, such as automatic, rectangular spherical projection, cubic map, column chart, panel image, QuickTime VR, cross type, and T type. If automatic is chosen, the software will automatically determine the input type according to the input image.

Step 3. Click the image, zoom the pixels, drag left and right to set the initial angle of the default playback, and set the horizontal view.



FIGURE 2: 3D dynamic map centering on Hubei Museum (Figure 2 is from Google Maps).

If it is not a 360° column panoramic view, please set the corresponding horizontal view angle. Click OK after modifying the parameter.

Step 4. Return to the main interface, find the addition option, and select the output format.

Normally, the output format is either flash or HTML. The output format can be further modified.

Step 5. Select the name and format of the output file and the path for outputting the file.

Pano2VR is embedded with the HTML output function, which can automatically output and display the flash file on the web page.

Once all settings are complete, direct click to confirm. Then, the swf file would be generated, which can be called by JavaScript.

4.2.3. Realizing Interactive Hotspots. Interactive hotspots need to be added to the panoramic roaming process, to realize the interaction between visitors and the roaming scene, giving them an immersive feeling. By clicking the hotspots, visitors can jump from one panoramic map to another panoramic map. The specific steps are as follows:

Step 1. Open Pano2VR, import panoramic map(s), configure the parameters and process each map simply, and select the interactive hotspot.

Step 2. Open the interactive hotspot to see three tabs. The first two tabs are responsible for adding interactive hotspots, and the third one is responsible for managing the added hotspots. We mainly focused on the first tab. Select the hotspot type, double click the hotspot of the panorama, and add a hotspot URL (the panoramic map that will be opened by clicking the hotspot).

Step 3. The hotspot list mainly manages the added hotspots and displays the added hotspots. A hotspot can be added by clicking the green plus in the lower area, but the position of the additional hotspot cannot be specified. Hence, the addition function here is basically not used.

Step 4. Return to the third tab to see two main types of interactive hotspots: hot points and hot areas. On the panel, the key is the switch between the two kinds of hotspots. The polygonal interactive hot areas can be added to a map on the wall, when the picture exhibition or panorama is of low resolution. Then, a single clear image can be called from the outside and controlled by skin ID. Also, it is possible to make the following setting: when the cursor moves to a hot area, a piece of music will be played. Overall, the panel is very flexible to use.

In order to make the panorama more vivid, it is necessary to add roaming hotspots, voices, and texts to the panorama. Hotspots are equivalent to the hyperlink between two panoramas. If the hot point is chosen, a red hot point will appear by double clicking the image. Then, please enter the caption, e.g., Hubei Museum. (In the generated panorama, the caption is displayed when the cursor stops on the red roaming button.) After that, enter the URL: enter the flash file to be linked, such as fangwu.swf. To set multiple hotspots, just double click the position where we want to add them. After completing the setting, click to confirm. By clicking audio modification, the dialog box of panoramic audio editor will appear. Double click a certain area to view the interface and add the desired audio file by choosing it in the file name. After completing the setting, click to confirm. The skin editor allows users to add texts and offers some function buttons.

For interactive voice design, the string of output recognition results should be evaluated by an independent voice recognition system. In general, the recognition rate is measured by the word error rate (WER). To ensure the consistency between the recognized word series and the standard word series, it is necessary to replace, delete, or insert some words. The total number of these words divided by the total number of words in the standard word series is the WER:

$$\text{WER} = 100 \times \frac{S + D + I}{N} \%, \quad (1)$$

where S , D , and I are the number of replaced, deleted, and inserted words, respectively; N is the total number of words in the standard word series.

Step 5. Set the pattern and then set the action of the interactive hotspot. Select the action modifier. We can open the panel and set the action source (event) and the action. Then, the panorama could complete the corresponding operation. Figure 3 shows the final output of the panoramic roaming results of Virtual Hubei Museum. Click the left and right buttons to rotate the screen; click the plus and minus signs to zoom in and out. The full-screen button and refresh button are responsible for full-screen playing and replay, respectively. By clicking on the interactive hot area, we can switch to another panoramic map.

Step 6. Make reasonable use of tracking and registration technology of computer vision.

In the current VR systems, there are two main categories of tracking and registration technologies [21]. The first category is based on computer vision. The other is based on hardware-like sensors and global positioning system (GPS). The computer vision-based techniques can be further divided as augmented reality (AR) with manual labels and AR without manual labels [22–24]. In most AR systems, the tracking and registration module is realized with manual labels [25]. This paper adopts the AR with manual labels to achieve tracking and registration. As shown in Figure 4, the adopted method can be implemented in four steps.

- (1) Capture video images by video collection equipment. For real timeliness and accuracy, the AR-VR system calls the camera of mobile devices to capture real-world video images.
- (2) Preprocess the collected images. The collected color video images are binarized into black and white binary images. For any pixel (x, y) in a binary image, if the gray value $S(x, y) \geq t$, the pixel belongs to the background; otherwise, the pixel belongs to the region of interest (ROI). After thresholding, the image can be defined as

$$S(x, y) = \begin{cases} a_0, & f(x, y) < t \\ a_1, & f(x, y) \geq t \end{cases}. \quad (2)$$

By setting $a_0 = 0$ and $a_1 = 1$, binary images can be obtained. Then, all ROIs are searched for in these

images through image segmentation and edge detection.

- (3) Using the pattern recognition and matching algorithm, each labeled image is compared with the labeled templates in the database to judge if the label is legitimate. If the matching succeeds, an ROI is found.
- (4) After template matching, determine the unique ID of the current object, and the object is thus recognized.

4.2.4. Generating Web Roaming System. Through web page design and production, the above realization results were displayed on the virtual web page of the museum, achieving the web page display of the virtual part of the museum. Pano2VR supports roaming systems of various formats, e.g., flash and HTML5. Take the flash format as an example. By clicking the add button in the output, the output settings dialog box will automatically open. A large pixel value is recommended for the window size, aiming to ensure the display effect of the image during roaming. The roaming experience can be improved by setting various parameters, such as automatic rotation, motion inertia, mouse sensitivity, and roaming scaling. After returning to the main interface, click the creation button to generate the final swf and HTML roaming files. Figure 2 presents the flash version of the main interface of panoramic roaming.

After the completion of the virtual system, the HCI could be realized to give online visitors an immersive experience. They would feel as if they were really walking in the museum. They can freely rotate in any direction, visit the physical objects of the virtual scene, and appreciate the artistic atmosphere of the scene. Figure 5 shows the final realization results of web page display. Some exhibits are displayed virtually on the web page. The VR technology is fully utilized, and the unique image query technology was implemented to vividly present the exhibits to visitors (Figure 6). The system relies on MyEclipse and the online API of Baidu Map to fulfil map navigation and displays the panoramic roaming flash file based on Photoshop, Pano2VR, and HTML5 [26].

By visiting the Virtual Hubei Museum, people have a deeper understanding of every aspect of Hubei, including the collections and books of the museum, the special buildings in Hubei, the history of the Chu culture, as well as the folk customs and human landscapes of the Chu state.

5. Experiments and Results Analysis

Based on the Unity3D platform, our panoramic roaming system was developed by Vuforia SDK and passed the test on an Intel Core 2 Quad CPU, Q8200@3.22 GHz, 4 GB, with NVIDIA GT9800 graphics card.

Once the Pano2VR-based roaming system starts, the VR system test was carried out. The online visitors can tour the museum as they like and appreciate the landscape outside the museum or enter the museum to view the collections. The exchanges and interactions between visitors and exhibits are very frequent. After switching to the AR system, the system needs to call the camera of the display terminal. In



FIGURE 3: Panoramic roaming results of Virtual Hubei Musuem (Figure 3 is from Hubei Museum).

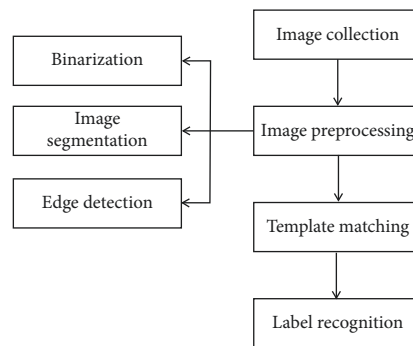


FIGURE 4: Flow of label recognition for tracking and registration.

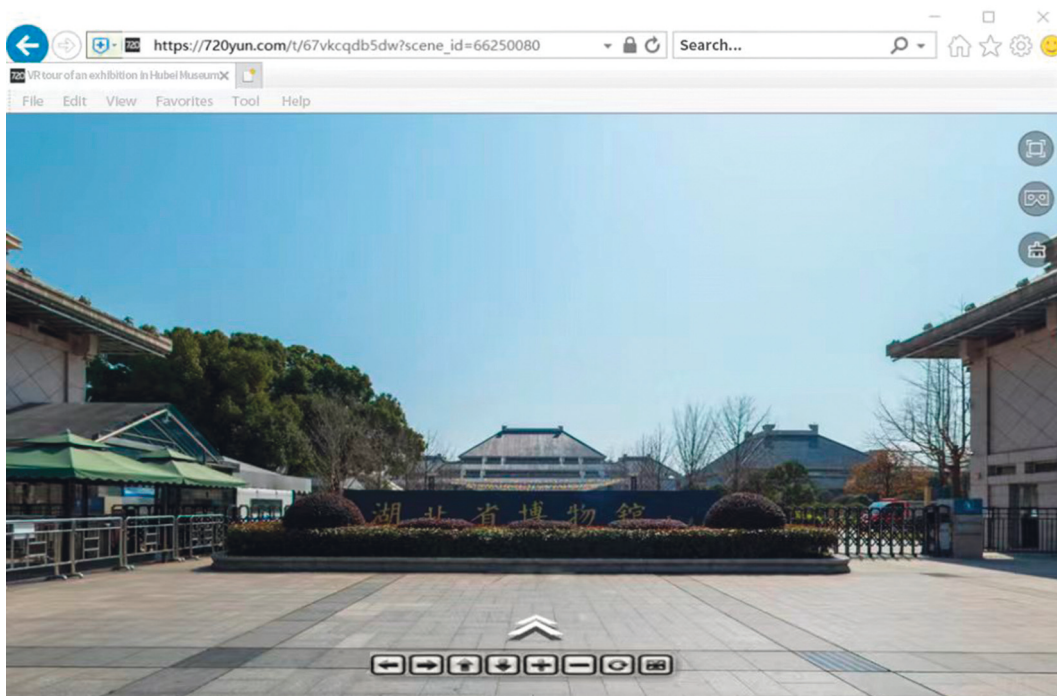


FIGURE 5: Panoramic roaming HTML5 page of Virtual Hubei Museum (Figure 5 is from Hubei Museum).



FIGURE 6: A virtual exhibit of Hubei Museum (Figure 6 is from Hubei Museum).

our experiments, the camera was used to shot the markers from different angles, and the generated 3D digital images were analyzed to see if the image quality is affected by the shot angle. The registration performance was verified with the extreme angles of 0° and 90° . Small images were selected for the performance test, because field AR module testing is impossible, given the special historical status and high degree of protection of Hubei Museum.

Experimental results show that, when the shot angle was 90° , the system could collect the feature information contained in the marker image; when the angle was 0° , the system could also collect that information. That is, the system realizes real-time tracking. In addition, multiple tests reveal that the proposed system can acquire accurate tracking and registration data, according to the marker information, a sign of high robustness.

Through the above experiments, it is concluded that the Pano2VR-based roaming system of Hubei Museum has a good 3D display and interactive functions. Online visitors can roam in the virtual museum. When they are interested in a certain exhibit, they can immediately switch to the AR or VR system to observe the details. The marker is not affected by complexity and can be tracked well through characteristic point detection.

6. Conclusions

This study provides website viewers with highly intuitive and realistic museum information through programming, panoramic roaming production, and virtual exhibition web production. By surfing the proposed virtual website, the public can learn about the specific location of Hubei Museum on map, interact with the panoramic roaming system using mouse and keyboard, and understand the basic structure, theme arrangement, and atmosphere by moving through the halls. The exhibits and collections of the museum are fully displayed on the

webpages. In this way, our system enables Hubei Museum to hold virtual panoramic exhibitions and digitalize its official website. This paper has mastered the key technologies required to build a virtual museum system.

The main tasks are as follows: (1) implementation of multiview exhibition hall browsing: to build a three-dimensional and multiview virtual Hubei Museum, which can satisfy users' freedom of walking in the virtual museum and 360 views. View all kinds of exhibits and related materials in the museum in an all-round way. (2) Realization of exhibition hall roaming mode: a variety of exhibition hall roaming methods have been realized, and different exhibition hall roaming methods have been designed and developed according to the different needs of different audience groups. (3) Implementation of human-computer interaction in the exhibition hall: realize a series of interactive operations that users need to perform when roaming the exhibition hall. For example, if users want to watch a cultural relic exhibit in detail, they need to select, translate, and rotate the cultural relic; and pictures, video click interaction, small scene loading interaction, small game interaction, etc. (4) Implementation of collision detection algorithm: in order to solve the collision problem between dynamic objects and static objects in the virtual exhibition hall, a collision detection algorithm with good performance is researched and selected.

Through this study, the emerging technologies are fully integrated into the museum development, giving people a deeper understanding of every aspect of Hubei, including the collections and books of the museum, the special buildings in Hubei, the history of the Chu culture, as well as the folk customs and human landscapes of the Chu state. Suffice it to say that this study offers valuable experience for the spread and exploration of the Chu culture, as well as the protection of natural and cultural heritages in Hubei.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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References

- [1] X. Y. Zheng and Y. Peng, “Analysis of the application effect and application points of virtual roaming technology in industry training,” *Journal of Inner Mongolia Agricultural University (Natural Science Edition)*, vol. 31, no. 4, pp. 250–254, 2010.
- [2] B. Y. Yin, “Application of virtual reality technology in public facility design,” *Packaging Engineering*, vol. 40, no. 16, pp. 271–274, 2019.
- [3] C. Gherbi, “Internet of things and heterogeneous networks technologies: Concepts, challenges and perspectives,” *Ingénierie des Systèmes d’Information*, vol. 26, no. 4, pp. 403–408, 2021.
- [4] J. Luo and S. L. Deng, “Design of 3D virtual building space experience system,” *Modern Electronic Technology*, vol. 41, no. 24, pp. 137–140, 2018.
- [5] D. Marques and R. Costello, “Concerns and challenges developing mobile augmented reality experiences for museum exhibitions,” *Curator: The Museum Journal*, vol. 61, no. 4, pp. 541–558, 2018.
- [6] N. Capuano, A. Gaeta, G. Guarino, S. Miranda, and S. Tomasiello, “Enhancing augmented reality with cognitive and knowledge perspectives: A case study in museum exhibitions,” *Behaviour & Information Technology*, vol. 35, no. 11, pp. 968–979, 2016.
- [7] Z. Qu and X. L. Li, “Algorithm of eliminating image stitching line based on improved IGG model,” *Computer Science*, vol. 44, no. 12, pp. 274–278, 2017.
- [8] H. Y. Dai and F. P. Ran, “Fast panorama stitching algorithm for mobile devices,” *Computer Applications*, vol. 34, no. 9, pp. 2673–2677, 2014.
- [9] H. Chen, A.-Q. Long, and Y.-H. Peng, “Building panoramas from photographs taken with an uncalibrated hand-held camera,” *Chinese Journal of Computers*, vol. 32, no. 2, pp. 328–335, 2009.
- [10] L. P. Wu and Y. Hu, “Virtual reality technology of image smoothing in cylindrical panoramic image mosaic,” *Science Technology and Engineering*, vol. 17, no. 31, pp. 271–276, 2017.
- [11] Z. Ji, “Applied research on interaction design based on VR virtual roaming technology,” *Modern Electronic Technology*, vol. 42, no. 15, pp. 86–89, 2019.
- [12] A. Razia Sulthana, A. Arokiaraj Jovith, D. Saveetha, and A. K. Jaithunbi, “A game based virtual campus tour,” *Journal of Physics: Conference Series*, vol. 1000, no. 1, p. 012131, 2018.
- [13] G. Z. Huang, “Research on interactive campus roaming system based on Pano2VR,” *Software Engineering*, vol. 11, no. 1, pp. 17–18, 2015.
- [14] E. E. Reding, *Adobe Photoshop Cs6 Revealed*, Cengage Learning, Boston, 2012.
- [15] A. Joukhadar, N. Ghneim, and G. Rebdawi, “Impact of using bidirectional encoder representations from transformers (BERT) models for Arabic dialogue acts identification,” *Ingénierie des Systèmes d’Information*, vol. 26, no. 5, pp. 469–475, 2021.
- [16] A. Cosentino, “Panoramic infrared reflectography. technical recommendations,” *International Journal of Conservation Science*, vol. 5, no. 1, pp. 51–60, 2014.
- [17] L. Rittié, D. L. Sachs, J. S. Orringer, J. J. Voorhees, and G. J. Fisher, “Eccrine sweat glands are major contributors to reepithelialization of human wounds,” *American Journal Of Pathology*, vol. 182, no. 1, pp. 163–171, 2013.
- [18] L. Barazzetti, M. Previtali, and F. Roncoroni, “3D modelling with the Samsung Gear 360,” *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XLII-2/W3, no. 2W3, pp. 85–90, 2017.
- [19] D. Yi Xiao, “Experiencing the library in a panorama virtual reality environment,” *Library Hi Tech*, vol. 18, no. 2, pp. 177–184, 2000.
- [20] R. Y. Cheng, “Analysis of Responsive Web Design Based on HTML5 Technology,” *Electronics World*, vol. 22, pp. 79–80, 2017.
- [21] H. F. Kwok, A. Giorgi, and A. Raffone, “Improving interpretability: combined use of LVQ and ARTMAP in decision support,” *Journal of Telecommunications and Information Technology*, vol. 6, pp. 129–132, 2005.
- [22] X. Zhang and G. Chen, “Detection of dense small rigid targets based on convolutional neural network and synthetic images,” *Traitement du Signal*, vol. 38, no. 1, pp. 61–71, 2021.
- [23] S. C. Bulusu, M. Faezipour, V. Ng, M. Nourani, L. S. Tamil, and S. Banerjee, “Transient ST-segment episode detection for ECG beat classification,” in *Proceedings of the IEEE/NIH Life Science Systems and Applications Workshop*, pp. 121–124, IEEE, Bethesda, MD, USA, April 2011.
- [24] Y. Tadepalli, M. Kollati, S. Kuraparthi, and P. Kora, “EfficientNet-B0 based monocular dense-depth map estimation,” *Traitement du Signal*, vol. 38, no. 5, pp. 1485–1493, 2021.
- [25] J. S. Sahambi, S. N. Tandon, and R. K. P. Bhatt, “Wavelet based ST-segment analysis,” *Medical, & Biological Engineering & Computing*, vol. 36, no. 5, pp. 568–572, 1998.
- [26] Z. P. Ma, B. B. Guo, H. D. Li, and J. Zou, “Realization of Pano2VR based panoramic roaming of Ningxia virtual museum,” *Modern Electronic Technology*, vol. 44, no. 8, pp. 149–153, 2021.