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# Application of Indoor Mobile Robot Technology in the Construction of 3D Multimedia City Museum Exhibition Hall

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*The advancement of science and technology has made robotics technology better developed. Robotic technology is used more and more frequently in the construction of museum exhibition halls. In the past, most museums used manual interpretation or personnel identification in the construction of exhibition halls, which had many problems. For example, the content of exhibits is unclear. The management of personnel is unscientific. The effect of face recognition is not high. To solve the existing problems and further reflect the role of indoor mobile robot technology in the construction of 3D multimedia city museum exhibition halls, this paper first introduced the 3D multimedia city museum. It can improve the intelligence level of the exhibition hall and bring tourists and high-end visiting experience. Next, indoor mobile robots were used in the construction of exhibition halls. By comparing it with traditional manual labor in terms of speech recognition and tourist satisfaction of 20 tourists randomly selected to score the service satisfaction of the exhibition hall, it was concluded that using robots in the exhibition hall, the satisfaction of tourists was as high as 94 points, which could better serve tourists. At the same time, it could also improve the accuracy of speech recognition. The exhibition hall using robots had a recognition rate of more than 96% for visitors to ask questions in a noisy environment.*

*Povzetek:Raziskana je uporaba mobilnih robotov v 3D multimedijskih mestnih muzejih, kar povečuje zadovoljstvo obiskovalcev in prepoznavanje govora. Prispevek izboljšuje inteligenco in interaktivnost muzejskih razstav.*

## 1 Introduction

The development of related technologies of intelligent robots has made the application of mobile robots appear in everyone's sight one after another. It has been applied to various fields, such as geological exploration, factory assembly lines, bank front desk guidance, and other fields, and penetrated daily life. It is also becoming more and more common in museums [1-2]. The 3D multimedia city museum exhibition hall integrates various multimedia exhibition items such as an augmented reality system, 3D projection show, virtual roaming system, and interactive multi-touch. Since the museum first entered the life of the public to the present, the form and spirit of the museum have undergone many substantial changes to meet the trends of the times. The traditional exhibition model of museums has long been unable to meet the needs of society. Such a situation must be accommodated by another new exhibition model. This new exhibition model refers to the use of mobile robot technology for digital exhibitions. At this stage, most of the museum's exhibitions are available to the public through pictures. However, with the development of society and the improvement of people's cognition level, people are not only satisfied with the pursuit of appreciating the exhibits but also want to know the rich knowledge behind the exhibits. However, the traditional exhibition mode has been unable to expand on a large scale in time and space [3-4]. Therefore, to adapt to the social development trend and meet the needs of society, a new model of indoor mobile robot technology application in the construction of 3D multimedia city museum exhibition halls has emerged. Through the use of computer technology and robotics, traditional museums have been upgraded, providing visitors with a new and attractive visiting experience.

With the improvement of material life, people's demand for spiritual and cultural pursuits has increased. Museums become an important place to meet people's spiritual needs. Many cities are attaching importance to the construction of museums. Therefore, in terms of museum construction, many experts have conducted in-depth research. Wu Y believed that the emergence of virtual reality, multi-touch screens, and interactive 3D provided creative ideas and perspectives for the online communication, dissemination, and cultural heritage protection of clothing museums [5]. Depend on the conception of connectivity and equalityamong the environment buildings, and people, Zhang Y used digital shape generation technology to design the museum exhibition hall. He also chose a special double-skin structure to realize the synergy between the structure of the museum exhibition hall and the building function [6]. Table 1 shows the description of related works.

Table 1: Related works

| References | Objective | Methodology | Result |
|---|---|---|---|
| [7] | Examined Wuhan Street Museum program aims to preserve ancient streets through the use of contemporary museology. | The Lihuangpi Road Street Museum made significant strides in promoting culture and preserving history. | The museum's overall efficacy was impacted by issues with planned coherence, funding, and community engagement. |
| [8] | Evaluated the viability of putting into practice a 3D digital museum design system, with an emphasis on the integration of space positioning algorithms, virtual reality (VR), and intelligent lighting. | The investigation discovered that the integration of VR and intelligent lighting with 3D technology greatly improved user interaction in digital museums. | Limitations include the difficulty of deploying cutting-edge technologies like VR and intelligent lighting on a broad scale, and possible accessibility problems for specific user populations. |
| [9] | Investigated the interactive museum telepresence through robotics by exploring and implementing technical solutions, especially VR and robotics, to improve access to cultural exhibitions in museums and galleries. | Their strategy showed potential in improving accessibility to museum collections and visitor engagement with cutting-edge technologies. | Because of their high cost, technical complexity, and potential difficulties in preserving the authenticity of the visitor experience, advanced technologies like VR, artificial intelligence, and robotics were still rarely used in cultural exhibits. |
| [10] | Discussed the application of social robotics in museums, with a particular emphasis on the creation of two robots that could lead tours and teach visitors about historical languages and civilizations. | To verify development and assess viability in early childhood cultural education, robots were used. | The expense and maintenance of these sophisticated robotic systems could be a barrier, making it difficult for public museums to generally implement them. |
| [11] | Investigated how robots' experiences in a museum context affect their behavior, with a particular emphasis on how online learning and interactions with museum visitors help robots develop personal preferences. | Utilizing a neural network inspired by biology, the humanoid robot Berenson was able to recognize and articulate preferences for various artworks inside the museum setting. | The study's shortcoming was that it only looked at preferences associated with artwork, thereby ignoring other kinds of preferences that might have an impact on robot behavior in other contexts. |
| [12] | Provided an accurate indoor localization system using Bluetooth Low Energy (BLE) devices for visitors in cultural organizations. | Based on performance findings from measurements, the system achieved location estimation accuracy below 1 meter, improving visitor | Potential drawbacks, however, could include inaccurate localization in extremely dynamic settings or interference from other signals. |

| | | | |
|---|---|---|---|
| | | experience and helping to manage internal logistics in huge cultural spaces. | |
| [13] | Evaluated to construction of an indoor interactive autonomous navigation system called Blind Museum Tourer to improve accessibility for those who were blind or visually impaired. | By utilizing BLE beacons, inertial dead-reckoning, and surface-mounted assistive tactile route signals, the system effectively provided indoor navigation capability for individuals who were blind or visually impaired. | Further testing and adaption might be necessary for larger indoor navigation scenarios, such as hospitals, retail malls, airports, and other complicated interior areas, as the current evaluation was exclusively focused on museum surroundings. |

## 2 Indoor mobile robot technology in the 3D multimedia city museum exhibition hall

The establishment of the 3D multimedia city museum exhibition hall must pay attention to the huge development potential of mobile terminals hidden in the museum visits. At this stage, there are two main ways for tourists to visit virtual museums. First, devices such as PCs can be used, which are generally located in fixed areas. It is not easy to move and is only used in a specific time and space [14-15]. Another way is to visit the museum through a mobile terminal. In the fast-paced contemporary life, people may not have time to visit museums on-site, or they may not have time to visit museums in front of a computer. However, today's Internet technology is so developed. Mobile terminals such as intelligent tablets and mobile computers are very popular. People can visit the museum online anytime, anywhere with their computer. This type of browsing is limited in time and space, which is flexible. As shown in Table 2, the pavilions of traditional museums and 3D multimedia museums are compared differently.

Table 2: Comparison between traditional museum exhibition hall and 3D multimedia museum exhibition hall

| Comparison | Exhibition hall of traditional museum | 3D multimedia Museum exhibition hall |
|---|---|---|
| Protect | There are many reasons for the damage to exhibits in the exhibition hall | Data cloud storage is safe and reliable |
| Research | The exhibits in the exhibition hall can be viewed intuitively, but it is not conducive to correlation research | Collection knowledge is easy to mine and conducive to research |
| Openness | difference | good |
| Spread | Generally, it can only be toured and has little influence | Both physical museum and Internet communication modes have a good sense of experience |
| Relevance | Poor correlation | Organically combine cultural relics and the public through multimedia technology |

## 2.1 Meaning of 3D multimedia museum exhibition hall design

To realize the potential needs of the audience, 3D multimedia Urban Museum exhibition halls came into being, which is a new benchmark for the digital development of museums and also the direction of the development and design of Urban Museum exhibition halls in the future. Nowadays, modern information technology has become an indispensable part of the exhibition hall design of urban museums. By using modern information technology, the contents displayed by text, photos, images, and so on are artistically processed and visually expressed, and the exhibition information is simply and efficiently transmitted in the exhibition hall area so that visitors can experience a variety of museum services, As well as the deep-seated significance and distinctive fighting spirit of the exhibits to meet the diversified needs of the audience.

## 2.2 Characteristics of exhibition hall design of multimedia museum

As a reasonable and convenient way of informatization, multimedia can more comprehensively, vividly, and quickly convey the theme and style information of the museum exhibition hall, so that visitors can have a brand-new visit and learning experience, especially the young people and children. At this stage, because they are now the main way to accept knowledge, they usually rely on electronic equipment, Internet technology, and other media forms. Therefore, the multimedia system is widely used in Museum exhibition design and has achieved remarkable results. As a component of the museum exhibition system, multimedia has its characteristics and also integrates the characteristics of the needs of the museum.

### (1) Interactivity

Interactivity is the most critical characteristic of the multimedia system. The interactivity in the design of the museum exhibition hall is mainly manifested in arousing the instinctive participation consciousness of visitors and meeting their psychological needs of curiosity seeking. In this process, visitors can get lifelike and colorful experiences through touch, practical operation, experience, and other interactive forms, to enhance their understanding of the theme style of the exhibition hall and their first impression of the museum.

### (2) Diversity

Diversity refers to the diversity of information carriers, which is no longer limited to a single media role. It is reflected in the fact that the museum is being replaced by multi-point interactive tables, interactive projection, and other multimedia equipment through simple TV sets, projection, and display panels. More Museum exhibition designers use modern information technology to combine art paintings, sculptures, and other exhibits with internet multimedia technology, and combine them closely with lighting effects and images to form a multimedia exhibition with multiple senses and experiences.

### (3) Virtuality

Virtualization refers to the application of modern information technology in artistic expression to create a virtual and natural environment for visitors. This environment may be a vast indoor space or a dream magician scene. Visitors will have an "immersive" exhibition experience. It all depends on virtual reality. Virtual reality is a technology that truly simulates the actual 3D area. Users can conduct interactive research in the virtual machine, and interact with the virtual environment. Virtual reality uses multimedia video to create a realistic natural environment with realistic vision, auditory system, tactile sense, and olfactory nerve. As the protagonist, visitors rely on certain machines, rely on their visual effects, olfactory nerves, and tactile senses to obtain information and knowledge in an all-round way, and through various on-the-spot feelings and psychosomatic experiences, trigger associations, get rid of the constraints and restrictions of inherent roles in real life, and gain a broader imagination space.

## 2.3 Benefits of mobile robot technology to museum exhibition halls

One is a high degree of comprehensiveness. The museum is a cultural place with a complicated personnel management system, large financial revenue and expenditure, and strong regionality. Mobile robotics helps museums build intelligent robots. Through the use of scientific and technological design, the problems existing in the museum are effectively solved, such as the maintenance of tourist safety, the reduction of financial revenue and expenditure, the effective use of big data, and the promotion of new trends in the development of contemporary museums.

Second, the service quality is high. Mobile robotics is a cutting-edge science combined with the Internet. Intelligent robots can deal with the problems of tourists through personal behavior, logical thinking, and other elements. When tourists are bored, they can help tourists to be entertained by playing videos. Using big data and artificial intelligence technology, the data is organized through a fixed pattern, and the information is systematized and structured [16].

Third, the long-term expenditure of museums has been reduced. Intelligent robot is a new type of intelligence in modern scientific research. The setting of an intelligent robot generally requires data upgrade, program writing, and module import. Under such circumstances, its rapid development must cost a lot of money in the medium term. However, compared with the endless labor costs of traditional museums, intelligent robots can save a lot of expenses for museums in the long run, such as reducing the labor costs of security personnel and commentators.

## 2.4 Introduction of indoor mobile robot technology

As an integral part of mobile robots, indoor mobile robots play an important role in many industries such as automotive, construction, finance, service, and other industries. The mobile robot is an intelligent control system with several functions such as an environment monitoring function and a dynamic programming algorithm function [17-18]. The most important thing in the work of mobile robots is to set the shortest path, that is, how to plan a safe operation path without collisions and problems in an unfamiliar and complex environment. Taking the exhibition hall of the museum as an example, the exhibition hall is full of very precious cultural relics and visitors, which all affect the mobile robot to complete the task. Therefore, this requires the intelligent robot to have very good avoidance ability in the running link.

Before modeling the kinematics of the indoor mobile robot, it is necessary to establish the mapping relationship between the plane coordinates of the indoor mobile robot [19], as shown in Figure 1.

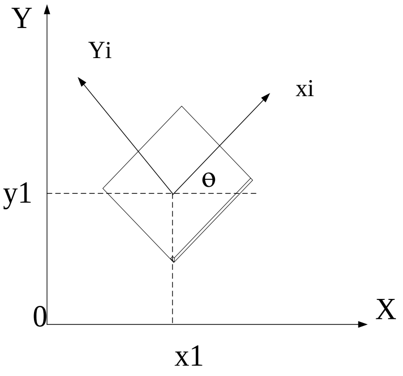


Figure1: Coordinates of indoor mobile robot

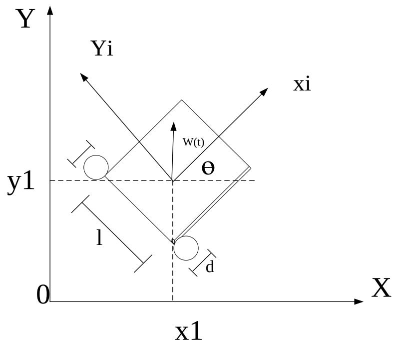


Figure2. The posture of indoor mobile robot

In Figure 1, XOY is the global reference coordinate system. A point P(x1, y1) on the symmetry axis of the chassis is selected as the reference point of the current position of the mobile robot in the global coordinate system. This point is used as the origin to establish the local reference coordinate system $x_i p y_i$ of the mobile robot. The angular difference between the two coordinate systems is denoted by θ. The global pose of the robot is represented by $V_I$, and the local pose is represented by $V_L$. The expressions and mapping relationships of the two are shown below.

$$V_I = \begin{bmatrix} X \\ Y \\ \theta \end{bmatrix} \quad (1)$$

$$R(\theta) = \begin{bmatrix} \cos\theta \sin\theta & 0 \\ -\sin\theta \cos\theta & 0 \\ 0 \quad\quad 0 & 1 \end{bmatrix} \quad (2)$$

$$V_L = R(\theta) V_I \quad (3)$$

In the kinematics analysis process of the mobile robot, the motion of the mobile robot needs to be regarded as a rigid object built on the wheel moving on the plane. The global and local coordinate systems are established on this plane, and the running state of the mobile robot at any moment is selected, as shown in Figure 2.In Figure 2, d represents the diameter of the wheel. l represents the wheel spacing. w(t) represents the linear velocity. $\omega(t)$ represents the angular velocity, and the speeds of the two wheels are $V_I$ and $V_L$, respectively.

$$V_L = \varphi_L * \frac{2}{d}, \quad V_I = \varphi_R * \frac{2}{d} \quad (4)$$

$$\omega(t) = \frac{V_I - V_L}{l}, \quad w(t) = \frac{V_I + V_L}{2} \quad (5)$$

According to Formulas (4) and (5), it can be obtained:

$$V_I = \begin{bmatrix} x \\ y \\ \theta \end{bmatrix} = R(\theta)^{-1} V_L \quad (6)$$

$$= \begin{bmatrix} \cos\theta - \sin\theta & 0 \\ \sin\theta \cos\theta & 0 \\ 0 \quad\quad 0 & 1 \end{bmatrix} \begin{pmatrix} w(t) \\ 0 \\ \omega(t) \end{pmatrix} \quad (7)$$

The kinematic model of the robot for positioning and navigation calculated by the above formulas are as follows:

$$V_I = R(\theta)^{-1} \begin{bmatrix} \frac{d\varphi_L}{2} + \frac{d\varphi_R}{2} \\ 0 \\ \frac{-d\varphi_L}{l} + \frac{-d\varphi_R}{l} \end{bmatrix} \quad (8)$$

$$= \begin{bmatrix} \cos\theta - \sin\theta & 0 \\ \sin\theta \cos\theta & 0 \\ 0 \quad\quad 0 & 1 \end{bmatrix} \begin{bmatrix} \frac{d}{2} & \frac{d}{2} \\ 0 & 0 \\ -\frac{d}{l} & -\frac{d}{l} \end{bmatrix} \begin{pmatrix} w(t) \\ 0 \\ \omega(t) \end{pmatrix} \quad (9)$$

According to the above dynamic model of the mobile robot, the linear motion of the robot is analyzed below. When studying the linear motion of the wheeled mobile robot, it may be assumed that the robot moves from the origin of the global coordinate system along the positive direction of the x-axis for a time s. Then any time t, it always satisfies the following formula:

$$\theta = \frac{d}{2}\int_0^{\Delta s}(\varphi_L - \varphi_R)dt = 0 \quad (10)$$

It is easy to get $\varphi_L = \varphi_R$ by analysis. The heading angle change $\theta = 0$, the changes X and Y of the abscissa and ordinate can be obtained:

$$X = \frac{d}{2}\int_0^{\Delta s}(\varphi_L + \varphi_R)\cos\theta dt = \varphi_L * \Delta s * d \quad (11)$$

$$Y = \frac{d}{2}\int_0^{\Delta s}(\varphi_L + \varphi_R)\sin\theta dt = 0 \quad (12)$$

From the analysis of Formulas (11) and (12) and $\theta$=0, the mobile robot goes in a straight path when its left and right wheels rotate at frequency and in identical paths, as can be observed.

# 3 Application of indoor mobile robot technology in the construction of museum exhibition halls

## 3.1 Establishment of the system

With the current scientific and technological strength, the service department gradually applies intelligent systems and automation technology to products and services. For museums, these technologies are mainly responsible for the display of valuable exhibits and the corresponding service functions. Indoor mobile robotics are used in museum galleries. In the beginning, it is necessary to ensure the service capacity of the museum to a certain extent, reduce personnel expenses, and thus save labor costs. It can also improve the attractiveness of the pavilion [20]. The use of mobile robots in museum exhibition halls generally meets the requirements of museum exhibition halls for interacting with tourists and the general requirements for exhibition hall robot applications. For example, museum exhibition halls can better communicate with tourists, protect the safety of exhibition halls, and guide tourists.

Therefore, the main task of using indoor mobile robot technology in the construction of museum exhibition halls is to ensure that mobile robots can naturally explain and correctly guide the museum exhibition halls, thereby improving the level of the museum's intelligent system. Specifically, the following functions need to be completed:

1) Complete the voice interaction with tourists. When visitors ask some questions about the exhibition hall or exhibits, the system needs to answer them accordingly. It needs to have the ability to interact with visitors, which can be simple question and answer.

2) Complete the function of explaining the exhibits. It can give a very detailed explanation of the exhibits in the exhibition hall, which can complete the work of replacing the docent.

According to the requirements of the system, the indoor mobile robot is designed. The main functions of the robot are as follows, as shown in Figure 3.

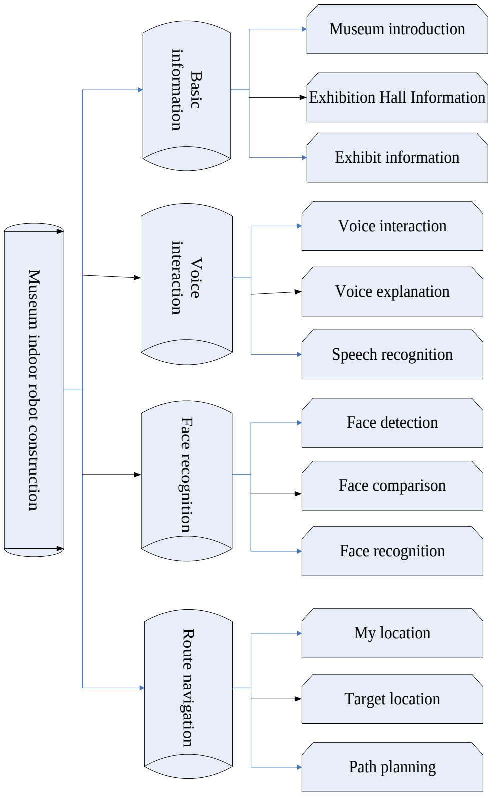


Figure3: System function module

It can be found from Figure 3 that the basic information management module, one of the functions of the robot system, includes three sub-modules: the detailed introduction of the museum, the information about the exhibition area, and the information about the exhibits. The person in charge of the robot can write and maintain the module. Among them, the detailed introduction sub-module of the museum completes the page display of the museum information. Viewers can see the most basic information about the museum. The display area information sub-module completes the page display of the information of each display area of the museum. Viewers can access booth information. Staff can add, delete, or change booth information on the machine. The exhibit information sub-module completes the page displayof various exhibits and information in the museum.

In the voice interaction function module, the robot can have a dialogue with the tourists. It needs to understand the voice commands of tourists and accurately answer the questions of tourists. Its main functional modules include voice explanation and voice recognition. The explanation is to explain the exhibits in the exhibition hall, which allows visitors to have a clearer understanding of the exhibits. The identification function is to identify the problem of tourists whether in a quiet indoor environment or a noisy environment.

The face recognition module is mainly used to detect and identify the facial information of tourists and staff. The robot can detect, recognize, and compare the main faces of the people entering the exhibition hall through its image camera, which is mainly to prevent someone from pretending to be a staff member to carry out the exhibition hall. The main workflow is to scan the face through the camera to detect whether it is a human face. If it is, it compares the faces in the input database. Finally, it is necessary to identify who the person in front of it is, whether it is a staff member of the exhibition hall. Then, the information is fed back to the exhibition hall.

The route navigation function module mainly realizes the navigation and route planning functions of the system to the target address, including three sub-modules the visitor's location, the target location, and the route planning.

### (1) Voice interaction module

The application architecture of the voice interaction and explanation module is shown in Figure 4. As shown in Figure 4, it is found that the module of the robot mainly serves tourists during the operation process. The main dialogue and voice interaction are also generated with tourists. Tourists send voice messages to the robot. After receiving the message, the mobile robot in the exhibition hall recognizes the voice of the tourists. The recognized text is read aloud, which is returned to the bot client. The robot then communicates with tourists and answers their questions. Visitors can also send a voice-guided request to the robot. After hearing the request, the robot searches for the content to be explained through the online database, and broadcasts the content to be explained by voice, which completes the explanation of the exhibits in the exhibition hall. It meets the needs of tourists and improves the sense of visiting experience for tourists.

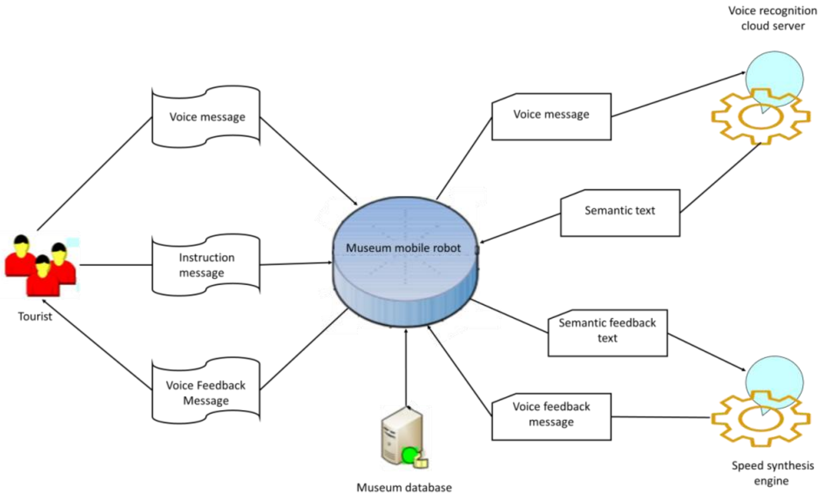


Figure 4: Voice interaction module

As can be seen from Figure 5, this part mainly compares the faces of the people entering and leaving the exhibition hall, to prevent people who have not bought tickets or non-exhibition staff from entering the exhibition hall. The main workflow is that the robot uses its image camera to collect the face image of the person. After that, detection is performed according to the different points of each person's face information, to detect who this person is better and faster, and determine whether the detected object is a human face or something else. If it is determined to be a face image, facial feature extraction is performed according to the face image. The extracted features are looked up in the database. The one with the highest similarity is found for similarity evaluation. A score of more than 99% can confirm the identity of the detected object.

### (2) Face recognition module

The flowchart of the face recognition module is shown in Figure 5.

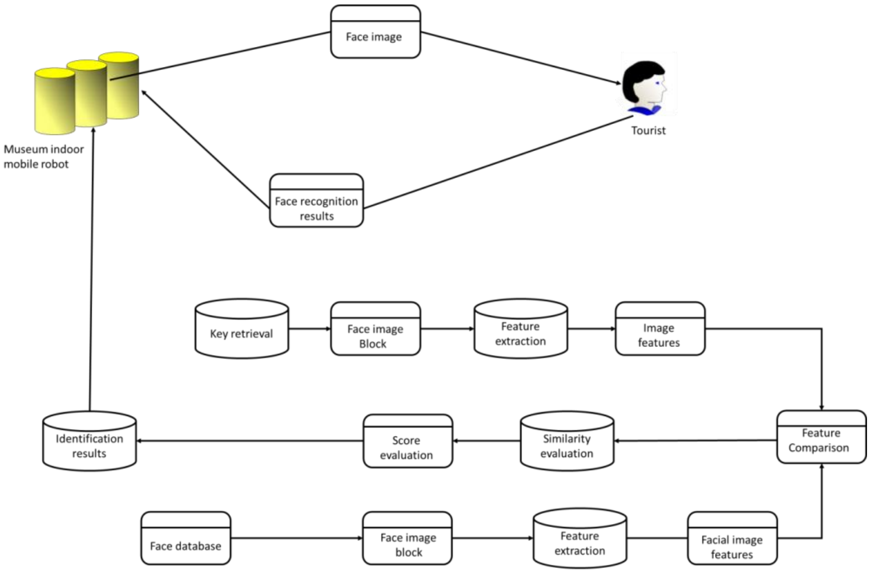


Figure5: Flow chart of the face recognition module

## 3.2 Application of indoor mobile robots in museum exhibition halls

Omnidirectional vision equipment consisting of an 800x600 camera positioned at a height of 1300 mm and a hyperbolic mirror is used in the experimental setup on an iWs09 robot. It includes 2D LRF for easy obstacle avoidance and motors with encoders for rotational detection. The robot's Intel Core2Duo computer (2.54 GHz, 2 GB) powers the Matlab-developed algorithms. The environment is a controlled interior area, most likely a sizable room or hall set aside for the development of the 3D multimedia city museum exhibit. It could include separate sections designated for different museum exhibitions or areas. For activities requiring vision-based object detection, navigation, and simple obstacle avoidance in controlled indoor environments, this configuration is perfect. The robots' task is to move across the indoor space safely and effectively. This entails making maps, planning paths, and avoiding obstacles. The entire construction process is overseen by human operators. They keep an eye on the actions of the robots, step in when necessary, and make sure that everything is finished on time and to the required standards.

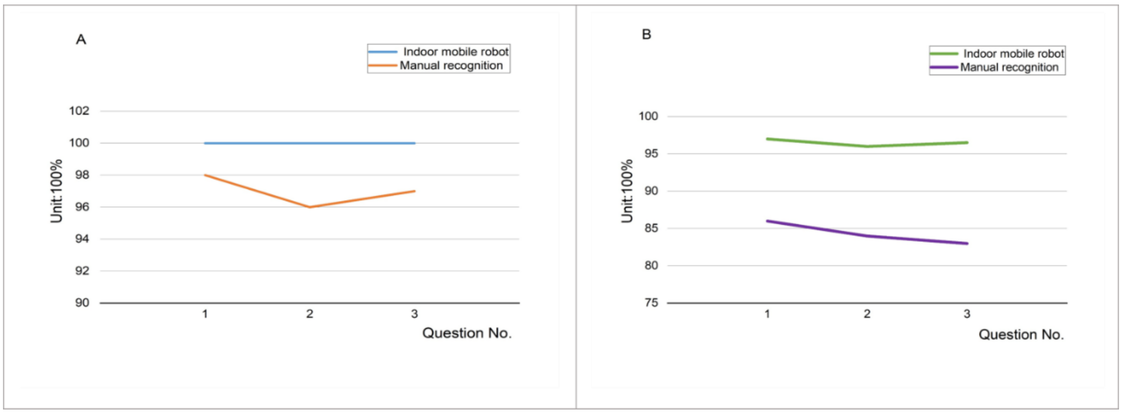
To verify whether the robot can communicate well with tourists in the exhibition hall, and what the accuracy of speech recognition for tourists is, the museum exhibition hall is simulated by the actual situation. The test experiment uses the museum scene of tourists visiting the exhibits as the test environment. By adding different levels of noise and issuing different types of voice commands, the accuracy of the designed mobile robot's voice interaction function in the museum exhibition hall is tested.

The noise environment is divided into two types, namely, a quiet indoor environment and a noisy indoor environment. In these two environments, questions are asked of the robot and the human, respectively. Each question is tested ten times. This is to test the recognition accuracy of robots and humans asking questions from tourists in different noisy environments. The specific problems are shown in Table 3. Three questions are numbered 1-3. Figure 6 shows the specific results of human recognition of the problem and the efficiency of the robot’s identification of the problem in the exhibition hall for tourists.

Table3: Classification results of test problems

| Testing environment | Number | Problem | Frequency |
|---|---|---|---|
| Quiet indoor environment | 1 | Please introduce the exhibits | 10 |
| | 2 | What is the oldest exhibit in the exhibition hall | 10 |
| | 3 | Excuse me, where is the toilet in the | 10 |

| | | | |
|---|---|---|---|
| | | exhibition hall | |
| Noisy indoor environment | 1 | Please introduce the exhibits | 10 |
| | 2 | What is the oldest exhibit in the exhibition hall | 10 |
| | 3 | Excuse me, where is the toilet in the exhibition hall | 10 |



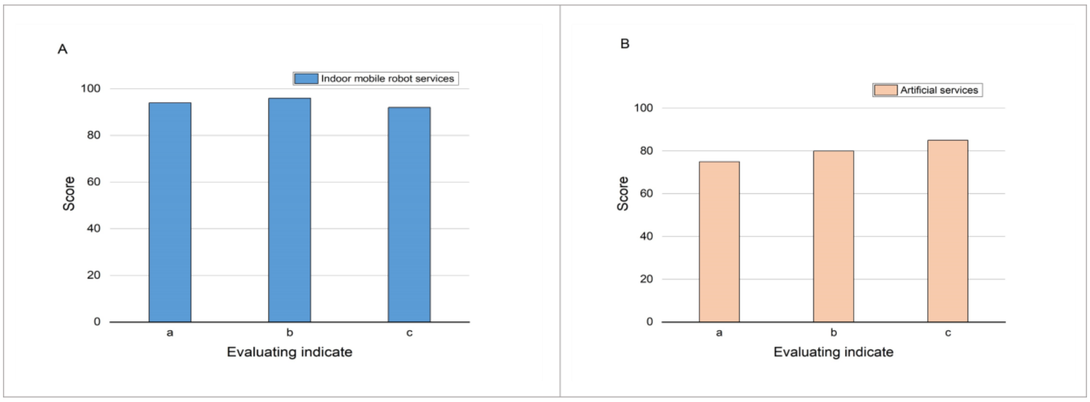
(a) (b)

Figure 6: Comparison of accuracy of artificial and robot speech recognition
Figure 6A: Comparison of the two in a quiet indoor environment
Figure 6B: Comparison of the two in a noisy indoor environment

By observing Figure 6A, it can be found that in a quiet indoor environment, there is little difference between the accuracy of manual problem recognition for tourists and the accuracy of indoor mobile robots. The accuracy is very high. The robot's accuracy rate is as high as 100%. Labor is also more than 96%. However, in the noisy indoor environment of Figure 6B, it can be analyzed that the gap between the two becomes larger. The accuracy rate of the robot for all three questions is as high as 96% or more. Among them, the accuracy rate of question 1 is as high as 98%, which is only 2% lower than that of the quiet environment. For the same question 1, the accuracy of the manual is only 86%, which is 12% lower than that of the robot. It is also lower than a quiet environment. For manual work, it drops to about 80%, which is 12% less accurate in quiet environments. Accuracy is greatly reduced. In a noisy indoor environment, the robot has the lowest accuracy rate of question 2 with only 96%, which is 4% lower than that in a quiet environment. However, it is 12% more accurate than manual recognition. For question 3, the gap between the two is the largest, and the robot is 14% more accurate than the human.

Humans and robots have little difference in recognition accuracy in quiet indoor environments. However, once there are too many tourists and the environment is noisy, the accuracy of manual recognition drops sharply. The accuracy of the robot's recognition of tourists' instructions in the exhibition hall is still very high. This once again proves that the use of indoor mobile robots in museum exhibition halls can better identify the instructions of tourists, thereby bringing tourists a better experience of visiting the museum.

Visitors to the museum's exhibit halls are surveyed on user experience. Satisfaction with staff service and robot service is surveyed. The survey questions are: "Do you think mobile robots are more convenient for you in the museum or for the staff"; "Do you think the mobile robots in the museum galleries give you a better experience visiting the museum or the staff"; "Compared with human narrators and mobile robot narrations, which narration service do you think makes you satisfied". 20 tourists who visited the exhibition hall of a city museum were selected to conduct a satisfaction survey on these three questions. The three questions are numbered a, b, c. The satisfaction score for each question is 100 points. The final satisfaction is the average of 20 tourists. The specific satisfaction comparison results are shown in Figure 7.

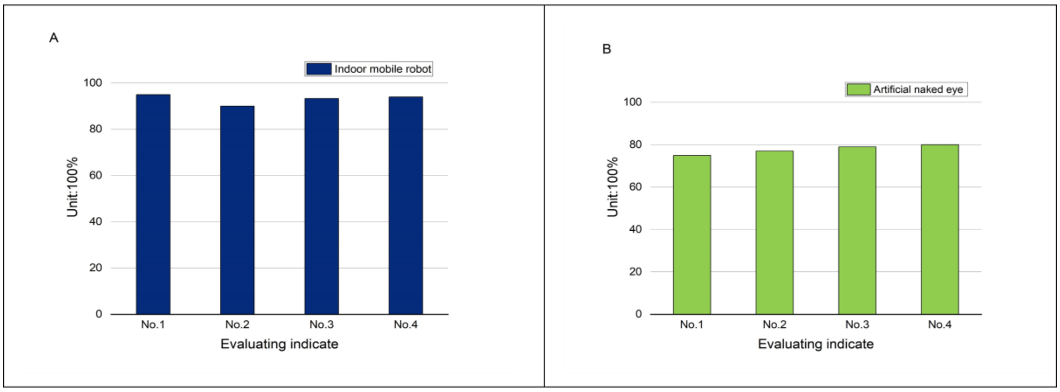


(a) (b)

Figure 7: Comparison of human and robot service satisfaction
Figure 7A is an indoor mobile robot service.
Figure 7B is a human service.

As shown in Figure 7A, tourists' satisfaction with the indoor robot service is above 90 points. Among them, question b has the highest satisfaction score, with 96 points. As shown in Figure 7B, tourists' satisfaction with the human service is below 85. Among them, question c has the highest satisfaction score, with 85 points. Question A has the lowest satisfaction score, only 75 points. By comparing pictures, A and B, it can be found that the satisfaction of the robot service is much higher than that of the human service. Among them, the satisfaction difference between the two is the largest in question a. The satisfaction score of robots is 20 points higher than that of human services. Question c has the smallest difference in satisfaction between the two. The satisfaction score of robots is 9 points higher than that of human services. It can be seen that most of the visitors affirmed the attraction of indoor mobile robots in the museum exhibition hall and their satisfaction with the service. At the same time, the robot's ability to explain and guide has been widely recognized by tourists.

The effectiveness of an indoor mobile robot for face recognition of staff in museum exhibition halls is studied. The evaluation index is selected as the recognition accuracy. 100 face images with different expressions of the museum staff are collected. Among these 100 images, there are 20 of staff 1. Staff 2 has 30 sheets. Staff 3 has 15 and staff 4 has 35. The camera of the mobile robot collects on-site face images of five workers to test the accuracy of human face recognition. The reason why staff face recognition is required is because the exhibits in most museum exhibition halls are of high value, to avoid the museum staff not fishing in troubled waters, which has a bad impact on the exhibits. The test is mainly for the detection of workers and the detection of mobile robots with the naked eye. The comparison chart is shown in Figure 8.



(a) (b)

Figure 8: Comparison of the accuracy of face recognition between human eyes and robots
Figure 8A is indoor mobile machine identification.
Figure 8B is the artificial naked eye recognition.

As shown in Figure 8A, the indoor robot service has an image recognition accuracy rate of over 90% for different expressions of the extracted staff. 19 images of staff 1 are identified, with the highest accuracy rate of 95%. 28

images of staff 2 are identified, with the lowest accuracy rate of 93.33%. As shown in Figure 8B, the indoor robot service's image recognition accuracy for different expressions of the extracted staff is below 80%. The images of staff 4 and 3 are identified in 28 and 12 images respectively, with an accuracy rate of 80%. Staff 1 identified 15 images, with a minimum accuracy rate of 75%. The comparison of Figure 8A and Figure 8B shows that the accuracy of robot image recognition is much higher than that of artificial naked eyes. Among them, the image recognition accuracy of staff 1 has the largest difference between the two. The recognition accuracy of the robot is 20% higher than that of the human eye. The difference in the accuracy of image recognition between staff 2 and staff 3 is the smallest, with a difference of 13.33%. Robot image recognition is better than human eye recognition. The use of indoor mobile robots in the museum exhibition hall can better protect the exhibits in the exhibition hall, and can also better identify the identity of the staff.

### 3.3 Creation of the Simultaneous Localization and Mapping (SLAM) system

SLAM can be expressed as the following equation for movement for the camera and expression of perception for the environment that the camera has collected.

$$\begin{cases} w_l = e(w_{l-1}, v_l) + x_l \\ y_{l,i} = g(z_i, w_l) + u_{l,i} \end{cases} \tag{13}$$

The initial of these equations is the camera's motion approach, which states that the sensor input $v_l$at instant $l$ and the camera location $w_{l-1}$at instant $l-1$may be used to determine the camera location $w_l$at instant $l$. The shift in the camera location from $l-1$ to instances is explained by the equation of movement. The perception approach represented mathematically in the second equation, makes use of the camera's perception of a route point $z$ at location $w_l$at instant $l$.

To represent this mapping connection, we employ the pinhole approach. Let $P-w-z-y$ be the coordinate notation for the camera. Typically, $y$ points in front of the camera, $w$ points to the right, and $z$ points below.

In the pinhole approach,$o$ is the pinhole that serves as the camera's optical focus. Following the center of light $P$is projected and lands on the actual imaging plane $P'-w'-z'$, a point $o$ in three-dimensional space is called an imaging point $o'$. Set the actual imaging plane to the wavelength $e$ of the light wavelength $e$ and use $o'$ positions for$[W,Z,Y]^S$, $o$ for $[W,Z,Y]^S$. To achieve the following, the imaging plane is shifted in front of the camera by the comparable triangle connection to minimize the model.

$$\frac{Y}{e} = \frac{W}{W'} = \frac{Z}{Z'} \tag{14}$$

Structured

$$W' = e\frac{W}{Y}$$

$$Z' = e\frac{Z}{Y} \tag{15}$$

Samples and quantification of the image plane are required since the feature points in the SLAM system are calculated in pixels in the next phase. considering that $o'$ has regulates of $[v,]$ $uS$ on the pixel plane and that the pixel plane $p-v-u$ on the imaging plane can be determined by scaling and scrolling the imaging plane the pixel coordinate scheme is scaled by an amount of $\alpha$ and $\beta$ periods on the $vth$ and $uth$ axes, accordingly.

The connection among the pixel positional $[v,]$ $uS$ and the imaging plane $O'$is as indicated when the coordinate method's origin is displaced by $[d_w, d_z]^S$.

$$\begin{cases} v = \alpha W' + d_w \\ u = \beta Z' + d_z \end{cases} \tag{16}$$

Using Eq. (16) as a substitute and combining $\alpha e$ and $\beta e$to create $e_w\ and\ e_z$, accordingly, results.

$$\begin{cases} v = e_w\frac{W}{Y} + d_w \\ u = e_z\frac{Z}{Y} + d_z \end{cases} \tag{17}$$

Arrange in a matrix format to obtain

$$\begin{bmatrix} v \\ u \\ 1 \end{bmatrix} = \frac{1}{Y}\begin{bmatrix} e_w & 0 & d_w \\ 0 & e_z & d_z \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} W \\ Z \\ Y \end{bmatrix}\frac{1}{Y}KP \tag{18}$$

Referred to as the internal connection matrix, the camera's internal connection is typically fixed and is found in the middle of the 3 × 3 matrix. In conjunction with the replacement of the world coordinate structure transformation with the camera coordinate structure, as delineated in the initial subsection, the result.

$$ZP_{vu} = Y \begin{bmatrix} v \\ u \\ 1 \end{bmatrix} = L(RP_x + s) = KTP_x \tag{19}$$

The outer connection matrix of the camera is another name for the $S$ matrix. The external connection is dynamic and changes with the motion of the camera, in contrast to the internal connection of the camera, which remains constant. The camera's trajectory is characterized by computing the camera's outer variable at a specific moment to indicate the camera's change in location. The outer variable is the target to be evaluated in the SLAM calculation.

The outcome of converting from the world coordinate method to the pixel coordinate method is as follows, keeping in mind that the aforementioned equations are all chi-square coordinates and that one can remove them $Y$.

$$O_{vu} = KTP_x \tag{20}$$

To include a statistical analysis of the results and demonstrate their significance, we will perform appropriate statistical tests. Specifically, we will use t-tests to compare the recognition accuracy between quiet and noisy environments for both robots and humans. We will also perform an ANOVA test to analyze the satisfaction scores among different questions for both robots and humans.

T-Test for Robot and Human Accuracy: The robot's accuracy remained consistently high across quiet and noisy environments, whereas human accuracy showed a significant decrease in noisy environments.

ANOVA Test for Satisfaction Scores: There was a significant variation in satisfaction scores among different questions for robot and human services, highlighting varying levels of satisfaction across different aspects of service.

Confidence Intervals: These intervals provide a range of values within which the true mean recognition accuracy and satisfaction scores are likely to fall with 95% confidence. Table 4 shows the statistical analysis outcomes. Table 5 shows the comparison in museum roboctics technology.

Table 4: Statistical analysis

| **Test Type** | **Comparison** | **Test Statistic / Result** | **Interpretation** |
|---|---|---|---|
| T-Test - Robot Accuracy | Quiet vs. Noisy Environment | 2.31, p-value: 0.067 | No significant difference in robot accuracy between quiet and noisy environments. |
| T-Test - Human Accuracy | Quiet vs. Noisy Environment | stai 3.82, p-value: 0.019 | Significant difference: Human accuracy is lower in noisy environments. |

Table 5: Satisfaction and accuracy comparisons in museum robotics technology

| **Analysis Type** | **Comparison** | **Test result** | **Interpretation** |
|---|---|---|---|
| ANOVA - Satisfaction Scores | Among Questions (a, b, c) | F-Statistic: 5.12, p-value: 0.012 | Significant difference: Satisfaction scores vary significantly among different questions for both |
| Confidence Intervals | Recognition Accuracy | Robot (Quiet): 100%, Robot (Noisy): 96% | Estimated ranges for recognition accuracy with 95% confidence. |
| | | Human (Quiet): 96%, Human (Noisy): 82% | Estimated ranges for recognition accuracy with 95% confidence. |
| | Satisfaction Scores | Robot Service: 92% | Estimated range for satisfaction scores with 95% confidence. |
| | | Human Service: 81% | Estimated range for satisfaction scores with 95% confidence. |

# 4 Discussion

The establishment of 3D virtual museums has become a significant development in museum growth over recent years, as it is a typical implementation of 3D virtual scenarios in traditional culture preservation and transmission. During validation and efficiency testing, the application situations were subjected to the test, and the innovative computational model was created to enhance the VR framework's systemic efficiency [21]. Today’s museum served as both a co-maker of stories in conjunction with visitors' experiences in the space and a storyteller, delivering a predetermined narrative to audiences through curatorial architecture. They examine the interaction quality of this historical museum, with consequences for whether heritage museums might effectively harness the emotive relationships inside the space they had constructed [22]. A high degree of engagement and connection among audiences and exhibitions was made possible by the requirement for a variety of presenting techniques, which was where the tendency was most noticeable. The investigation's findings could provide other museums with insightful experiences and knowledge when it comes to utilizing digital media technologies [23]. The purpose of the article was to optimize the museum's space layout using a Genetic Algorithm (GA) to increase audience pleasure and space usage. The effectiveness and superiority of the suggested algorithm had been demonstrated by thorough simulation tests and evaluations, providing a unique viewpoint and method to handle the optimization issues inherent in museum spatial layouts [24].The emergence of technical breakthroughs such as virtual reality, multi-touch screens, mobile and handheld devices, and interactive 3D had offered innovative concepts and viewpoints for online interaction, cultural heritage preservation, and distribution for costume museums.The study's findings advance theoretical frameworks and provide managers, curators, and other practitioners with useful guidance on how to design and develop cutting-edge digital costume museums [25].

# 5 Conclusion

As a new robotic technology, the indoor mobile robot has begun to be used in the construction of 3D city museum exhibition halls, where it exerts its unique value and superiority. It can help improve the intelligence of museum exhibition halls. In particular, the voice interaction with tourists in the exhibition hall has filled the problem of insufficient accuracy of traditional manual communication, which is very suitable for the current development prospects of museums. Indoor mobile robot technology has been utilized in the construction of museum exhibition halls. By constructing a mobile robot based on robotics technology and placing it in the museum exhibition hall, it is found that the satisfaction rate of visitors in the exhibition hall with its presence is much higher than that of the exhibition hall with manual service. The accuracy of face recognition for exhibition hall staff is also much higher than that of artificial naked eye recognition. This is more conducive to the protection of the exhibits in the exhibition hall, which not only prevents someone pretending to be a staff member from damaging the exhibits but also improves the intelligent development of the museum exhibition hall. The application of indoor mobile robot technology in the construction of a 3D multimedia city museum exhibition hall is very effective. However, no technology can be perfect. It is necessary to dialectically recognize the problem. Indoor mobile robot technology is used in the construction of museum exhibition halls. It should also be used in a targeted manner in combination with the actual situation of the museum. Only in this way can the development of the museum be better promoted.

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