# Design and Research on Human-Computer Interactive Interface of Navigation Robot in the IOT Mode

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**Abstract.** The display design methods in the background of media convergence is improving gradually, and the navigation robot is applied to the public environment as a new kind of display assistant method, which can better meet visitors' needs and enhance their emotional experience to the exhibition. However, the existing exhibition displaying methods were passive by practical researches, it has blank areas in path planning, which includes the period from visitors generating visiting consciousness to enter the pavilion, visiting process and the time people are out of visiting state but still in the exhibition hall. Based on the problem and existing human-computer interactive interfaces, conduct design and research from the perspective of audience experience. Using the theories of human eye cone cells biological characters and experience design, Internet of thing and the basic design principles of human-computer interactive interface, to complete the human-computer interactive interface design schemes of navigation robot, test the prototypes and by scheme optimization to reach the final result, based on the research and analysis of existing problems. To design an easy to use and user-friendly human-computer interactive interface, and achieve the result which shortened unnecessary time and optimize the visiting path ways of the audience. It solves the problems include unbalanced visitors flow rate, special individual visiting path needs of the visitors and improve people' satisfaction of visiting experience. And hoping it can provide a basic design paradigm and an effective reference for the solution to user navigation problem.

**Keywords:** Art with new technology · Interaction design
Service design · Navigation robot · IOT

## 1 Introduction

As one of the display design approaches for public, the navigation robot can effectively enhance the visitors' exhibition experience. And many scholars have studied it, which mainly focus on four aspects: (a) Development trend, which is more intelligence, network and modularization [1, 2]. (b) The problems in path planning of navigation robot, including how to detect and avoiding obstacles, identifying objects, and achieving a better path effectively with the lowest cost, etc [3–6]. (c) Special design of navigation


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robot for the disabled [7, 8]. (d) Improvement in human-machine interaction, including the trend on man-machine collaboration, more attention to the sense of immediacy on interaction methods, accuracy improving, evaluations and so on [9–12]. But those are all about the intrinsic function from the navigation robot aspect, ignoring the connection between visitors and their environment, human factor and special individual needs, and the practical application hasn't met the original design goal as well. Additionally, the visiting process is segmented and the whole navigation process is incomplete, which results in one-way human-computer interaction and asymmetric information exchange process.

This paper is mainly to solve the path planning problem in the period from visitors generating visiting consciousness to the pavilion, visiting process and the time people are out of visiting state but still in the exhibition hall, transforming the original robot oriented navigation behavior into visitor oriented, conducting data capture and analysis to the entire display area with IOT tool, and presenting the information which visitors needs on the human-computer interactive interface. We also did field surveys to several museums and exhibition halls in Shanghai, Hefei, and Nanjing, and finding that the relations in human, exhibits and environment are determined by the result of information exchange in practical visiting process. The fluency of the information exchange is related to effective and real-time data capture of the visitor flow, which is consistent with the IOT concept. For improving the original interactive approach, realizing effective information exchange, enhancing visiting experience and a better navigation effect, the IOT concept is introduced to the design of the navigation robot' human-computer interactive interface.

The remainder of the article is organized as follows. Solutions and four schemes design to the path planning problem in the form of human-computer interactive interface is discussed in section two. In section three, the brief analysis of internal technical system in human-computer interaction is displayed, and proper presentation carrier is filtrated considering the actual situation. And in section four, the schemes in section two are simulated and we conduct prototypes tests with 20 invited samples to simulate interactive experience in real environment, and have schemes optimization based on the tests. Section five concludes the paper.

## 2 Design and Research on Human-Computer Interactive Interface

Human-computer interaction is an important medium for navigation robot to realize its function, and the visual way is more direct for information dissemination. For the visitor oriented path planning problem of navigation robot, we codify the visitors' real needs to form the function modules for problem solution, and integrate the function modules with IOT to exchange the navigation space information with visitors in the most direct and effective visual interaction way, that is the human-computer interactive interface.

## 2.1 Research on Path Planning

The navigation behaviors between visitors and navigation robot is actually an information interactive process among people, things and environment, which is lasting and dynamic as well. However, from the preliminary survey data, we found that the visitors are guided only by the set navigation route, and the human-computer interaction is one-way, which is limited to exhibits introduction to visitors by navigation robots. Visitors' unsatisfied navigation needs exist in three periods which is from visitors generating visiting consciousness to enter the pavilion, visiting process and the time people are out of visiting state but still in the exhibition hall. And it appeared to be the visitor oriented path planning problem in the process.

Based on the preliminary investigation, visitors' navigation states of the three periods can be divided into two categories. One is visitors generating visiting consciousness before their entrance and visiting process, their actual psychological need is seeking no repeated routes on their move for visiting purpose. And the other is out of visiting state but still in the hall, their actual psychological need is the exploration and understanding to the surroundings. The influence factor of the two states is exhibition area ambience which concrete expression to visitors flow. And the factor causes visitors' original exhibition route change and negative emotion generating, thus the visitors' needs can be subdivided into three types based on their behavior model and psychological states (the influence factor is the attendance of each viewing area):

(a) Visitor with specific visit purposes, manifest as preference to certain kinds of exhibits;
(b) Without specific visit purposes, manifest as some degree of sequenced itinerary;
(c) Location needs for the exhibition surrounding facilities, such as washrooms, restaurants and so on.

    Then we propose corresponding function modules to meet various demands, which are as follows:

(d) Optimal path, corresponding (a), providing visitors' exhibition path planning in the shortest time based on the actual human flow and surroundings;
(e) Interest path, corresponding (b), on the basis of visitors' interest, prioritizing the areas and providing the best path planning;
(f) For surroundings, corresponding (c), providing nearest and shortest queuing time route planning.

These three function modules shorten and qualify the information exchange between human and surroundings based on the visitor flow of the display area. The key point is realizing information interaction and the settlement of interconnection between objects and objects, people and objects, and people. And the point is consistent with the concept of IOT [13, 14], so we propose it here and conduct research and design based on it.

Compared with traditional ones, the navigation robot in IOT mode will transform from single workstation to whole area collaboration. Here the entire area is divided and numbered, the real-time data of visitor flow of the corresponding area are captured by each on-line navigation robot, then sent back to each robot after processing by service desk. When visitors have navigation demand, classify which function module it belongs to, and then conduct path planning based on the real-time information feedback and stored exhibition hall map. Thus forming a continuous navigation process, extending the navigation range and creating a good visiting experience for visitors.

## 2.2 Interface Framework Design

Existing interaction modes of traditional navigation robot, including voice and easy visual interaction, are simple, slow and the effect is not obvious. Compared with the modes, the human-computer interactive interface can carry more information and is more intuitive. Using it could better exchange information with visitors, their demands could be received more quickly and the feedback is direct. After introducing the IOT mode, information exchange process is realized by the real-time data capture function of IOT between visitors and surroundings based on the advantages of the original interfaces. Thus visitors could obtain information they need, shorten unnecessary visiting time and get good visiting experience. In this state, the entire exhibition space will be in a dynamic balance, realizing optimal resource allocation to some extent.

The human-computer interactive interface design is based on the function modules for problem solution in 2.1part. Based on the depth of information exchange between users and navigation robots, here we divide the interactive behavior into two levels. The first level is visitors don't have any instructions to the navigation robot, we called shallow interaction mode. In this mode, the human-computer interactive interface is on standby state, and shows color-coded real-time visitor flow of corresponding areas at regular intervals according to the flow size, so the visitors could know flow size at any time; The second level is visitors have deep information exchange with navigation robot, at this point, visitors have strong navigation demand, we called deep interaction mode. Visitors do touch, click and other behaviors to the interactive interface to exchange information with navigation robot and surroundings by function modules. The second level is visitor oriented path planning based on the first, we correspond the function modules to real exhibition and plot function prototype wireframe of the human-computer interactive interface, the function modules are divided or combined to more specific function set (see Fig. 1). Module one and two belong to different directions of route planning, module three is for the surroundings navigation and crystallized into washroom, restaurant and shopping area (here refer to stores like adjacent boutique). Moreover, considering visitors' other needs and helping them learn more about the exhibition, we add emergency call and exhibition features function. Because the solution is realized via interactive interface, the other methods are not detailed here.

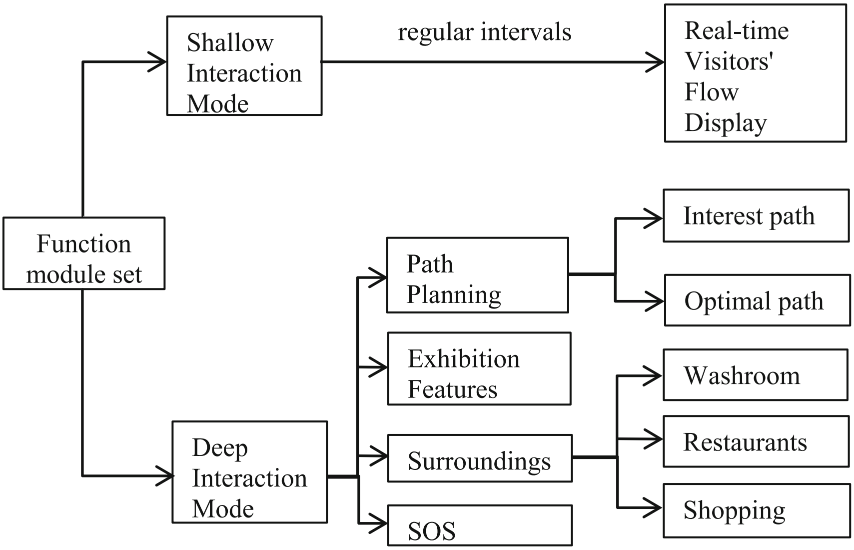


**Fig. 1.** Function module set of human-computer interactive interface.

### 2.3 Interface Design and Research on Vision Scheme

Human-computer interactive interface is a medium that people could "see" and exchange information with the outside, its usability, which is determined by two parts, operating system (this one will be showed in section three) and interface visual design, effecting the fluency of information exchange process and then the visitors' navigation experience. Interface visual design includes prototype framework building which is showed in 2.2, and UI design which includes interface layout and visual elements. We do scheme design of human-computer interactive interface based on 2.1part and function module set in 2.2part.

**Interface Layout Design.** The human-computer interactive interface design system has been completed generally and is advancing to more natural. More natural reflects in layout matching users' operating habits and providing good psychological and physical experience to them. When operating behaviors happen in the human-computer interactive interface, eyes and hands play a leading role. Eyes receive information and then hands do feedback to it, which is related to the eye' attention mechanism. The features of uneven distributed receptor cells in retina lead to attention priority in order when people are watching thing besides factors of the objects themselves [15]. Zeev [16] has proposed the generalized Gabor scheme of image representation in biological and machine vision. The Gabor function is usually used in image processing for edge extraction as a liner filter. And biological experiments have proved it can approximate receptive field function of single cell which can also be called the transfer function of light intensity stimulation as a bionic mathematical model. The Gabor function provided a theory for the layout design of human-computer interactive interface, and Li [17] proposed an optimization method for the layout design of human-computer interactive interface based on it. In this method, human-computer interactive interface is divided into several parts corresponding to the distribution of light-sensitive cells in retina, and then building a partition model to solve the model. It is proved that the optimized interface is better and more natural in practical interaction. Here we adopt the method to the layout design based on the functional solution modules in 2.1 and 2.2 parts.

The screen resolution we choose is 1920 × 1080 and the division chart is divided into five areas by five concentric circles based on the quantity of the function modules. The radiuses are 8.73 mm, 43.75 mm, 79.19 mm, 115.45 mm and 152.87 mm from the centre, and more close to the centre, the visual perception is stronger. Thus we get rough distribution range of the function module set in the interface. And then for more accurate result, we do a complete plan from Fig. 1, getting and numbering the specific function modules (see Fig. 2). The back button is included in the HOME button for the interface frame structure.

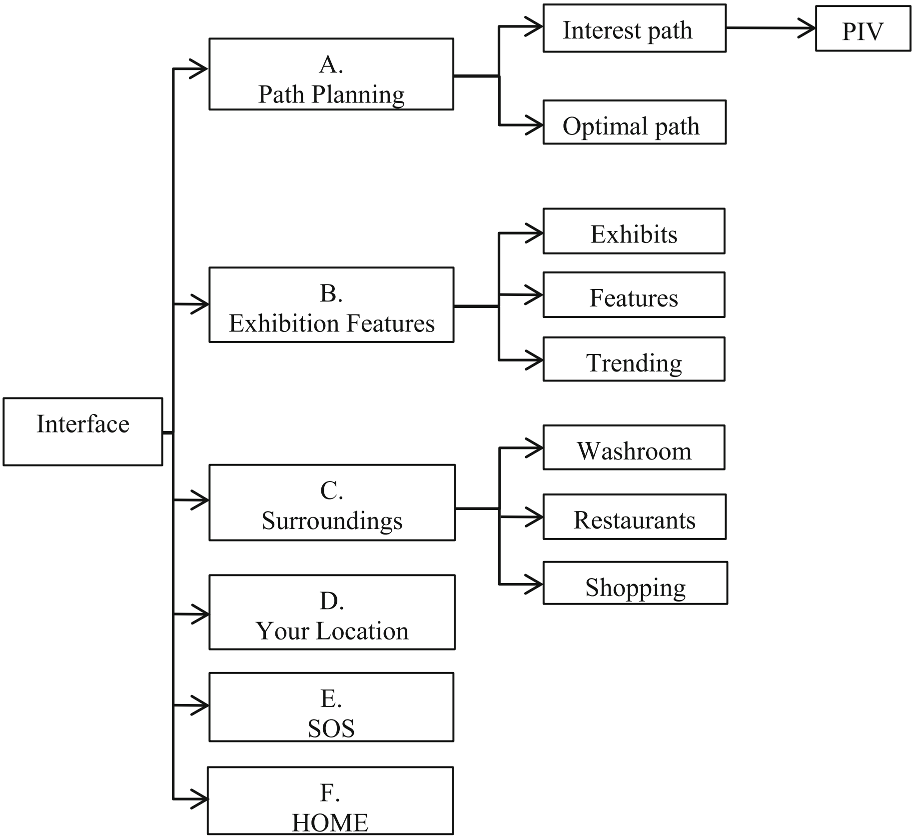


**Fig. 2.** Specific number function modules of human-computer interaction interface.

The sequence of the specific function modules on priority is based on the importance of the modules by ordering method, details are as follows: after numbering, comparing their importance between every two modules, more important we plus 1 and the less one plus 0, the same plus 0.5, then getting Table 1.

**Table 1.** The priority numbers of specific function modules.

| Intensity (from weak to strong) | Numbers of the modules | Importance |
|---|---|---|
| 6 | D | 5 |
| 5 | A | 4.5 |
| 4 | B | 2.5 |
| 3 | C | 2.5 |
| 2 | E | 0.5 |
| 1 | F | 0.5 |

From Table 1, the sequence of the specific function modules on priority is DABCEF. But the optimized interface layout we got above is still not accurate, so we do a refinement to it based on the sequence for a more accurate result.

We investigate, synthesize and analyze existing layout forms of interaction interface, conclude main kinds of human-computer interactive interface layouts. The existing interfaces could be divided into three categories, including web, software and mobile phone, and what we design and research is belongs to the software category. There are no any interfaces in the same direction we do, so we do comparative research with similar interaction interfaces, and the similar frame structure layouts are put as one kind for later easier refinement of the interface design. The details are as follows:

(a) Layout likes a frame, such as T-type, L-type, etc. This kind has many variants, and is usually applied to the interface with more information and functional sites because of its large coverage. It has clear structure and priorities. But meanwhile, the interface may become crowded visually, which makes visitors' information finding process more difficult. And its background is often darker, so the interface will be easily tedious without good detail treatment. Except for enterprise and forum, it seldom appears in other areas due to compatibility and aesthetic problem;

(b) Full-page. The entire screen is a frame with pictures as design centre likes a poster, and has some text and web links in it as well. Its direct and strong visual effects often lead to comfortable and interface atmosphere impressions. However, it is often used in the website homepage and some enterprise web with special requirements due to its slow loading speed and little contents only. Additionally, one special branch of it has the same simplified frame but belongs to responsive interaction. Its all content included in one screen without scrolling, perfect screen fitting, highly focused and clear levels are the differences from the full-page one.

(c) Header text and classic F-type. This kind is mainly for content display and applied for blogs and login interface.

Classic F-type is based on human's reading habits, its layout is from up to down, the wide left is for left-aligned information, and the right is related links.

(d) Layout likes Roman numeral III or similar. Simple, clear and with interface atmosphere, which can use more interface space.
(e) Layout with lattice structure. This style is minimalistic and clear with easily controlled breakpoint and good responsive interaction, which not only can display vast content without crowded feeling but also has many details. And different division methods lead to different effects, its popular form is clear large image with clean and logical flowcharts. But we should pay more attention to the distance and size between each part, otherwise, the interface balance will be broke.

Rhee [18] has proposed and tested a theory about efficient digital signage-based online store layout. They found the signage-based online store layout can be divided into three kinds: Tree, pipeline and guiding pathway, and verified the tree kind is better than the others. We find the tree kind is similar to the layout kinds (b), (d) and (e), what we proposed above. Based on 2.1 and 2.2 part, function modules of visitors' demands are not too much and its relatively large vertical extension and visitors aim at getting information they need as quickly as possible in the surroundings, adopting clear layout can attain the design propose better. Thus we apply the layout kinds (b), (d) and (e) for the scheme design.

We superimpose the preliminary layout partition result and the three layout methods respectively from effect, and then choose their intersection parts for twice interface layout refinement of the navigation robot.

**Interface Visual Element Design.** After getting refined human-computer interactive interface layout in the part of interface layout design, for the preliminary interface scheme design, we will discuss the interface visual element design next. Take the museum as an example, for the existing application area of navigation robot is museum. From user experience perspective, we conduct scheme design on icon and color with aesthetic theories and application features. Details are as follows.

*Icon.* Icon is one of the most direct and effective information interactive medium in human-computer interactive interface. A good icon should have usability, helping visitors acquire information quickly and decreasing the malfunctions.

According to 2.1 and 2.2 parts, clear and bright style, easy to response is the direction for the design requirements. Here we introduce the concept of quasi flat design which is more nature. Comparing with flat design, it adds the concept of depth and design language of usability and high efficiency, which increases visitors' comprehension to human-computer interactive interface and highlights important information without ruining the whole design atmosphere. This is consistent with our goals.

Additionally, icon shape is also an important factor for interaction experience. The visual attention mechanism of human demonstrates that larger areas, more obvious contour changes and graphics with a certain threshold around the corner are easier to notice. Here we use large icon for main functional modules and simplify other elements on the premise of usability for visitors' good navigation experience. As for the icons with stereotype, keep identity without any changes.

*Color.* Rational color use can coordinate and even fill the gaps in interface design. In color psychology, light color is soft, dark color is tough, warm color is forward and the cool one is backward. Generally, in case of visual fatigue, interface should use high purity and light color and no more than five categories. In large area of interface, gray hue is better. And for the vital function modules, colors like red, blue and green is suggested, but the area shouldn't be too large in case of visual mess. In our scheme design, the application is museum, thus we choose blue and green with little gray for visitors' impression to it.

### 2.4 Scheme Design of Human-Computer Interactive Interface

As mentioned earlier, we solve the path planning problem of the periods from visitors generating visiting consciousness to the pavilion, visiting process and the time people are out of visiting state but still in the exhibition hall in the IOT mode, and then for the solution presentation, do quadratic sieve from physiology and user experience perspective and analysis of the visual elements to the human-computer interactive interface layout. The following will propose four concrete schemes based on the research results above.

**Scheme One.** Different size means the function keys' importance, which with larger area will has more attention. The function keys can be moved left or right in a dynamic and interesting interactive approach (see Fig. 3).

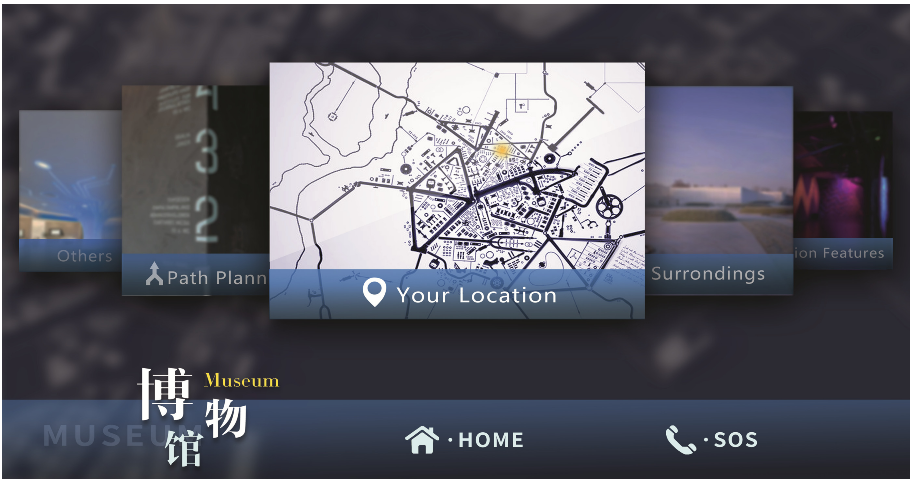


**Fig. 3.** Scheme one of the human-computer interactive interface design.

**Scheme Two.** Combining layout (b) and (d), having more use of the interface space. Clear and clean design style makes people feel comfortable and broad in visual, the main function keys are designed on the graphic designing principles (see Fig. 4).

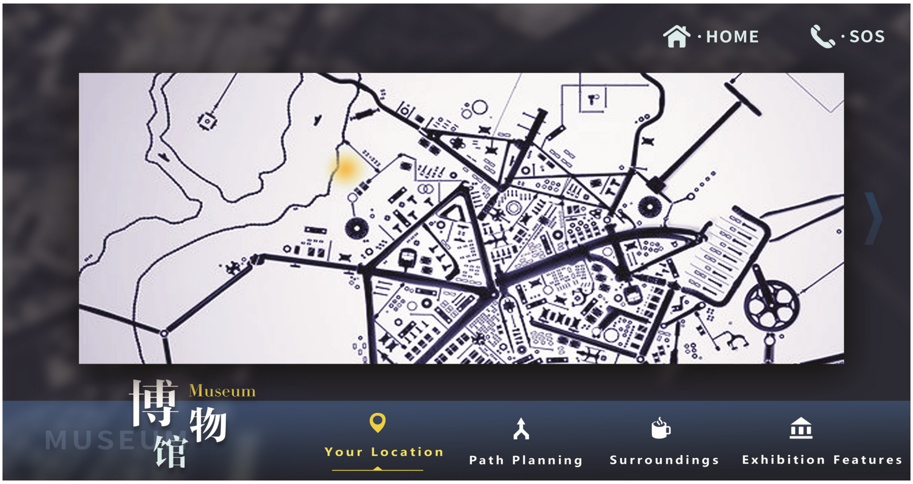


**Fig. 4.** Scheme two of the human-computer interactive interface design.

**Scheme Three and Four.** Combining layout (d) and (e), scheme three is free but ordered. Unique shapes could attract visitors while the switching command process may cause uncomfortable feeling (see Fig. 5); Combining layout (b) and (e), direct and strong pictures in visual make people feel comfortable for scheme four. Highly focused interface and clear structures make information finding process more easily (see Fig. 6).

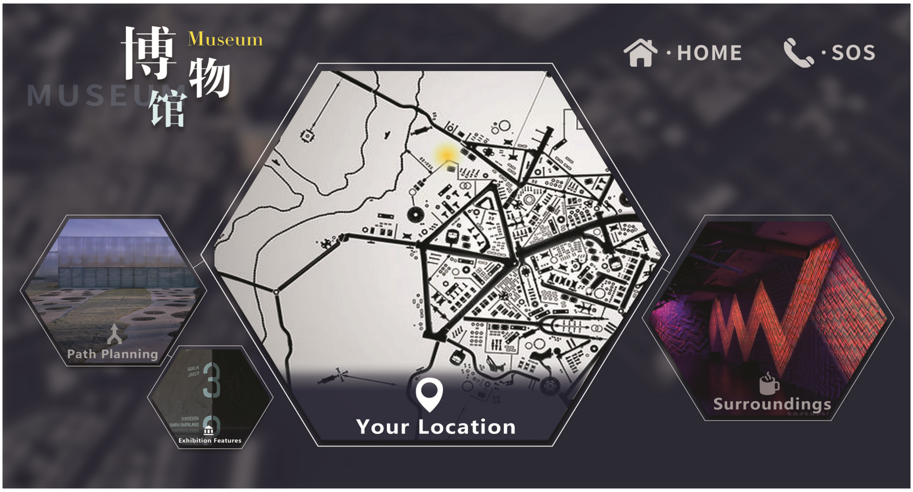


**Fig. 5.** Scheme three of the human-computer interactive interface design.

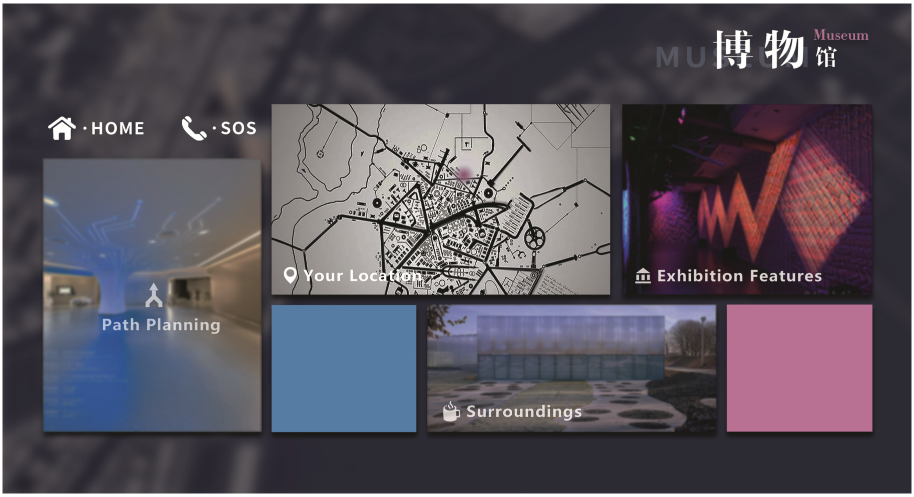


**Fig. 6.** Scheme four of the human-computer interactive interface design.

## 3 Operating System of Human-Computer Interactive Interface

We mentioned that operating system can influence visitors' exhibition experience by directly influencing the usability of human-computer interactive interface, and section three will conduct contrast analysis of the existing operating systems and touch screens to conclude a better one for the human-computer interactive interface. We propose corresponding responsive process design and measures for possible system problems as well.

### 3.1 Control System

WinLOL, Android, Linux and SCM are the existing four easy operating systems. According to the scheme design in section two, the design goals require strong compatibility of controls. SCM cannot satisfy the goals for its simple structure. WinLOL is excluded for its complicated implementing process. Linux has advantages of simple configuration process, less applications and easy submitting procedures of app store, but its development system is closed, with low adaptability of cross-platform and complicated field tests methods. For Android, though the functions are opposite to the Linux and the technology is maturing, its version and applications have mess, which cannot satisfy customers without loyalty. Therefore, considering the design goals, cost and other related factors, we choose Android as the operating system and suggest a control system frame (see Fig. 7).

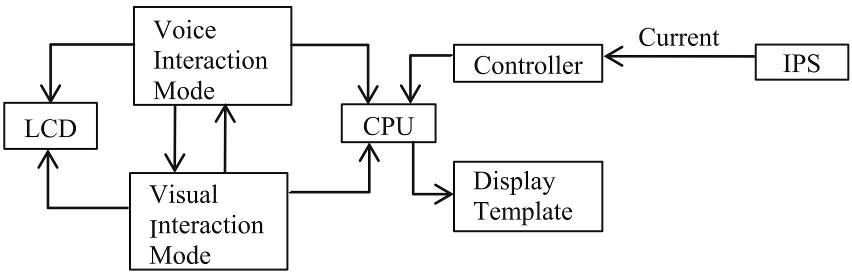


**Fig. 7.** Control system frame.

In software design, Du [19] has proposed a modularize method for control system which can shorten the reaction time of robots greatly. Thus for enhancing visitors' exhibition experience, we adopt modularize method to divide the whole system into several modules based on Android system, and add feedback and monitoring system as well. When an error occurs, the error module will be monitored, sent and managed quickly, which can reduce the workload of maintenance, shorten the troubleshooting time and is more manageable. And we also propose several solutions to the defects of Android system which are the sluggish phenomenon due to repetitive operations. Details are as follows.

(a) Enhancing system property, using latest Android 7.0 to improve the capacity of data processing.
(b) Clearing cache, which is major causes of sluggish phenomenon. Storing data in cloud regularly and extracting when needed on IOT mode to improve the operating speed.
(c) Frequency reduction in physical way. Besides installing ventilation fan inside the navigation robot, thermal conductivity glue is used to connect the components. The environmental non-toxic thermal conductivity glue has good bond strength, excellent thermal conductivity and superior temperature resistance, which benefits for the performance and service of products.
(d) Setting command orders. For sluggish reduction, execution sequence bases on orders when there are multiple valid commands.

### 3.2 Touch Screen

As an absolute positioning system and a kind of computer output equipment, touch screen is the simplest and most natural human-computer interactive medium. It has advantages of quick reaction, space saving, easy accessibility and so on. Here we use the touch screen in the scheme design.

The existing touch screens can be classified into six categories [20] as follows:

(a) Vector pressure sensing touch screen technology. For tech hysteresis it is rarely in use now.
(b) Resistive touch screen technology. It is accurate but with high cost and physical limitations, and its surface is easy to scratch.

(c) Capacitive touch screen technology. Its structures and design are rational but with the defects of serious image distortion, PEAD and low accuracy.
(d) Piezoelectric touch screen technology. Low cost and its performance is between capacitive and resistive ones. The power consumption is similar to the capacitive one and no touching no power consumption.
(e) Infrared touch screen technology. Low cost, but with surface distortion problem due to fragile outer frame which can lead to light interference.
(f) Surface acoustic wave touch screen technology. Clear and solid, but water droplets can easily slow the operating speed and even stop it.

We finally adopt IPS based on the analysis to these six touch screens and consideration of the applications for its low cost, relatively high accuracy and linear characteristic.

Based on Sect. 2 and visitors' interactive behavior pattern, we do flow chart of the operating process with IPS (see Fig. 8). The process of operating is as follows: CPU runs, the interface shows visitor flow of the exhibiting area at regular intervals without any touching behaviors. When there is a touching, judge its validity, if it is, then to the navigation process, otherwise, come to the end. Additionally, it only executive one valid command at a time with orders.

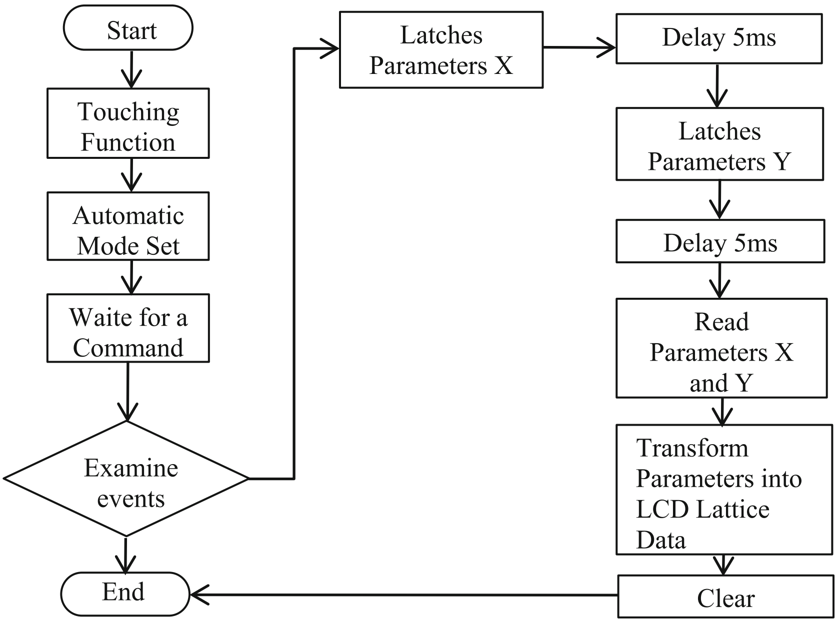


**Fig. 8.** Flow chart of the operating process.

## 4 Scheme Optimization and Evaluation

For the optimum scheme and rationality, we conduct simulation to the four preliminary interface schemes in 2.4part for quadratic sieve, and then filtrate with questionnaire. Visitors' experience of the operating process is dynamic, their psychological states cannot be monitored directly, thus here dividing the optimization process into two parts for more practical. In the first part, we simulate the schemes with MockingBot software which is easy and fast for interaction design. And the second part is a questionnaire survey to visitor samples for an optimum.

In July 2017, we choose twenty five samples randomly in Shanghai museum and do questionnaire to the simulation models got in the first part. The samples are required to do online simulation tests to the four schemes and fill the questionnaire. Finally, we get the optimal design scheme from visitors' perspective by the analysis of the questionnaire's results. The questionnaire includes basic information of the samples in anonymous way and their evaluations to the four schemes. Through the analysis to visitors' preference rank of the schemes we can get the final result. There are two influence factors, layout and shape. And the color factor is neglected due to the same color application. The sample selecting method is random, after deviation excluding, the effective sample is twenty, half men and half women, eight students, five enterprise staff and seven professional technicians. For accuracy, here some subjects are multiple choices or unnecessary to select if visitors don't have the will. The specific statistical results are as followed tables from four aspects:

The Table 2 shows people prefer scheme four, and for men, scheme four is better, for women, is the scheme one.

**Table 2.** Preferences of schemes.

| Schemes | Number of man | Number of women |
|---|---|---|
| 1 | 1 | 5 |
| 2 | 0 | 1 |
| 3 | 3 | 1 |
| 4 | 6 | 4 |

The Table 3 shows that the layout of scheme four is better, both men and women.

**Table 3.** Analysis of layout factor.

| Schemes | Number of man | Number of women |
|---|---|---|
| 1 | 4 | 6 |
| 2 | 0 | 2 |
| 3 | 3 | 2 |
| 4 | 6 | 7 |

We can conclude that the icon shape of scheme three is more popular. Women don't have special preference to the icon shape of the schemes. Although more men like the icon shape of scheme three and four, the figures is close without any reference. Thus for the shape factor, there is no any effect on the design (Table 4).

**Table 4.** Analysis of shape factor.

| Schemes | Number of man | Number of women |
|---|---|---|
| 1 | 1 | 3 |
| 2 | 1 | 3 |
| 3 | 2 | 3 |
| 4 | 2 | 2 |

And as for the ranks of the schemes preference, scheme four is the first and scheme one follows, here we only select the first one.

We analyze the questionnaire results from four aspects above and get the optimal one. People prefer the Scheme four which is with lattice structure and quasi flat design style, their preference is related to layout greatly compared with other factors. Here the human-computer interaction interface design is for the special application, color is certain, thus is out of the consideration.

## 5 Conclusion

A visitor oriented solution based on the IOT mode is proposed and presented in human-computer interactive interface form through research and design on the path planning problem. It realized the resource optimization allocation in exhibition hall, made the visitors get path planning before and after their visit, optimized visitors' visiting experience, improved the efficiency and effectiveness of information exchange among human, machine and environment. This paper firstly proposes the concept of visitors oriented path planning in navigation robot based on IOT mode, thus filling the space of this field, and providing research ideas for the user navigation problem in public as well. But for the interesting navigation aspect, visitors' information identification still needs further research.

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