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Design of Intelligent Medical Guidance Robot

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Abstract. The contactless service has become an important measure to avoid the spread of COVID-19 since its outbreak in 2020. Combining with the current epidemic situation and the epidemic prevention problems exposed by the present situation of outpatient service in hospitals and the analysis of their causes, this study applied the thinking and method of product design, and put forward an intelligent medical guide service robot design. By analyzing the user's actual outpatient demand, the functional modules of the robot are planned, and the corresponding hospital scene is established by using the open source simulation software Webots, which simulates the navigation function of the robot. The purpose of this study is to reduce the labor burden of medical staff, alleviate the contradiction of medical resources shortage, improve the quality of hospital outpatient service and build a new intelligent medical service platform. Meanwhile, it also provides relevant reference for the design of intelligent medical products.

Keywords. Intelligent navigation, functional structure, awareness of environment, simulation system

1. Introduction

For accelerating the transformation and upgrading of Chinese manufacturing, China has successively issued a series of important policy documents such as "Manufacturing in China 2025", and pointed out the research and development direction of intelligent medical robot industry [1, 2]. This is of great significance to promote the rapid development of China's medical system from traditional mode to modern intelligent medical mode. The proposal of "triple pregnancy policy" reflects the aging population, the shortage of medical resources and the increasing cost of social services in our society. This has brought huge development space for intelligent medical service robots. The application environment of intelligent medical service robot is not limited to hospitals, but also includes communities, nursing homes and other environments. Intelligent medical service robot helps to improve the diagnosis and treatment technology of medical system and the working efficiency of hospital. The first medical service robot was born in the 1980s, after 20 or 30 years of continuous development, it has been widely used in many fields such as patient care, medical surgery, transportation of medical materials, rehabilitation, medical teaching, disinfection and epidemic prevention [3].

The official data of China National Bureau of Statistics shows that the number of existing medical and health institutions in China and the number of visits per year are

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increasing year by year, as shown in Figure 1. The research on medical service robot is of great significance in alleviating the shortage of medical resources, reducing the working pressure of medical staff and improving the quality of medical services. Particularly in the special period when some infectious diseases are rampant, robots can even take the place of manpower to deal with some simple and tedious tasks that cannot be neglected [4, 5].

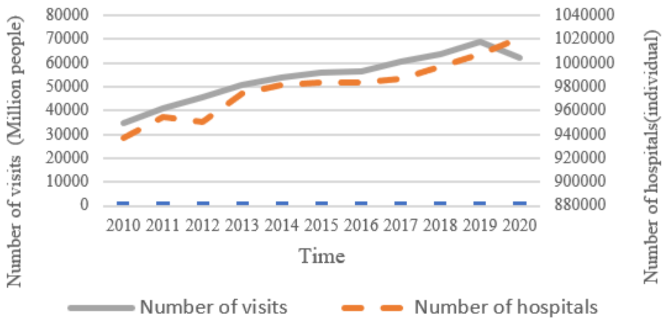


Figure 1. Trends of hospital number and visits in China from 2010 to 2020.

The COVID-19 outbreak suddenly broke out in 2019, with the quick spreading and strong infectivity, the number of infected people at home and abroad surged in a short time. Many patients' treatment has caused a great test to the existing medical resources, and the medical staff have even borne the extreme work intensity. As a public place for consultation, the hospital hall is the only place for medical workers, patients and outsiders. It's not only the place for communication between various departments but also the main place for hospital registration, charging and patient waiting. The condition that the large number of people gathered in a short time makes it a high-risk and susceptible occasion. With high population mobility, the virus can spread and spread quickly, which easily leads to serious cross-infection.

This paper made a survey on the guiding service of the existing outpatient department in the hospital. We analyzed and summarized the main problems and causes of the patients' treatment in the outpatient clinic at present (Table 1).

Table 1. Analysis of the main problems and causes of outpatient service.

Existing Problem	Cause Analysis
During the consultation, the professional knowledge of the medical guide was insufficient, and the answer was vague.	Medical professionals are in short supply, and hospitals employ other personnel to engage in outpatient affairs.
Poor attitude and low efficiency of medical guidance, patients are ignored.	Most out-patient departments have a large flow of people, a large workload of medical guidance, a high repetition rate, and are prone to emotional slack and lax attitude.
Vulnerable groups and patients themselves were helpless in consultation and didn't give special care.	The outpatient departments and departments in the hospital are numerous, the positions of each department are not easy to distinguish, the role of guiding slogans is not obvious, and the service manpower is limited.
The backward service mode of hospital outpatient department and the complicated medical treatment process have brought many inconveniences to patients.	The hospital lacks the concept of service management, and has insufficient understanding of the patient-centered service mode.

The analysis above shows that the main problems and contradictions existing in the outpatient department are mainly the problems existing between doctors and patients in the process of consultation. Medical guidance has a high repetition rate, strong mechanics, tedious work, but low difficulty coefficient. It needs patience, stable mood and professional knowledge to be patient-centered. Compared with human resources, intelligent medical guided robot can quickly respond to the demand of people for consultation [6-8]. It has the advantages of high consistency, saving manpower and improving service speed and quality, and is of great significance to improve the medical environment of outpatient department. At the time of epidemic situation, intelligent medical guide robot in hospital hall was used instead of manpower [9]. It can reduce the direct contact between people and reduce the risk of cross infection, which is particularly important to prevent the epidemic situation in the outpatient hall of the hospital.

2. Scheme Planning of Intelligent Epidemic Prevention Medical Guide Service Robot

According to the above demand analysis, the functional modules of the intelligent medical navigation robot are planned [10-11]. At first, the robot should have the basic voice recognition function. After the user gives the consultation instruction, the instruction information will be transmitted to the internal control system, and the robot can recognize the user instruction by voice. Next, the robot needs to give feedback to the outside after recognizing the instruction. Since the robot is designed and positioned in the navigation module, it needs to guide people’s behavior and lead them to the corresponding destination. In the process of guidance, it is necessary to be able to perceive the environmental conditions, detect the existence of obstacles and avoid them in time. The robot needs to plan the path of its destination to ensure that it can lead the user to get there in the shortest path and the fastest time [12]. The robot should be equipped with a motor control system to ensure the realization of the motion function and the human-computer interaction interface to assist the user in simple consultation and display the current and destination environment [13]. Above all, the main functional modules of the robot include speech recognition module, autonomous obstacle avoidance module, path planning module, motor control module, visual operation interface module, etc. These modules are interdependent and inseparable.

3. Design Practice of Intelligent Epidemic Prevention Medical Guide Robot

3.1. Modeling Sketch Design of Robot

By analyzing the robot scheme, the functional requirements of each part of the robot are determined. On the basis of the modeling of the existing guided robot, the modeling of this intelligent guided robot is sketched (Figure 2). It has a streamlined overall appearance, which gives people a feeling of safety and comfort, and can emotionally ease the anxious atmosphere in the hospital hall. In addition, the robot arm is printed with a red “cross” typical hospital symbol, which means that the hospital will do its best to serve every patient.

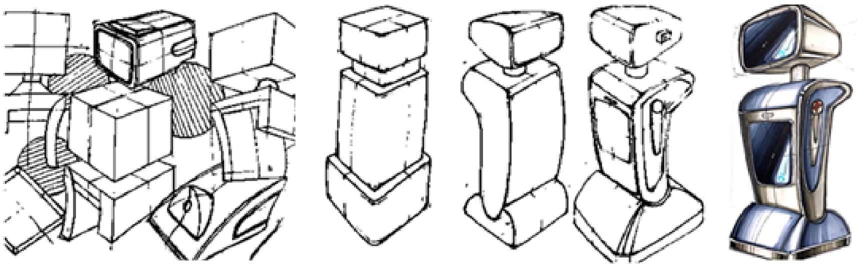


Figure 2. Design sketch.

3.2. Robot Model and Render

Based on the design sketch, the 3D model was built using 3D software. The height of the model is about 1.6 m, and the width is about 0.5 m. The 3D model was imported into Keyshot software to be rendered, and the result of rendering is shown in Figure 3.

Figure 3. The 3D model (left) and the rendering of the model (right).

Detailed structural diagram of each part of the robot is shown in Figure 4. It needs to be equipped with speaker device and man-machine interface. The speaker device is the channel of man-machine communication, mainly being used as the "ear" and "mouth" of the robot, which can recognize all kinds of voice information and convey voice information to the users [14]. The interactive interface displays the current environment information in the working process and standby state. At the bottom of the robot, there are charging ports and radar scanning devices. Radar scanning device is mainly used to scan and perceive the current environmental information, and assist the robot to avoid pedestrians and obstacles autonomously, which acts as the “eyes” of the robot. The middle part of the fuselage is equipped with a robot arm and a navigation display screen. The arm can rotate freely, which can point out the direction for the user. According to the experience of patients, the robot system constantly improves its own service algorithm, the comprehensiveness and quality to bring a better medical service experience [15]. The final rendering effect is shown in Figure 5.

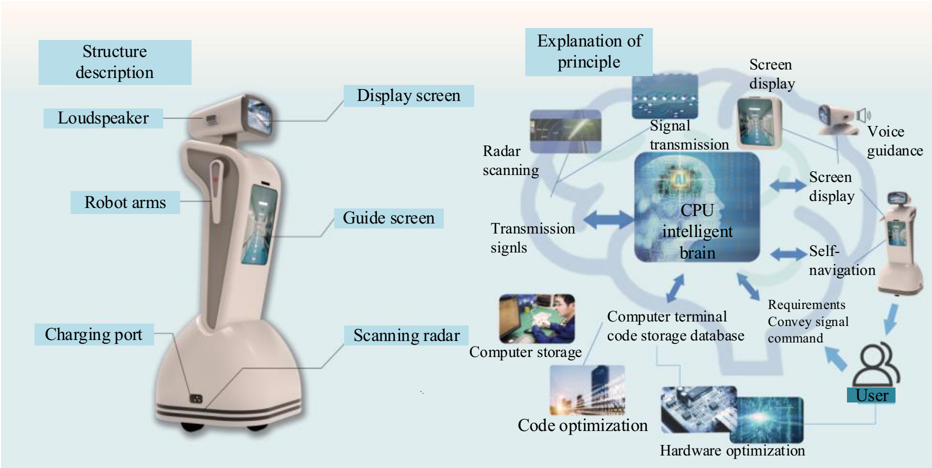
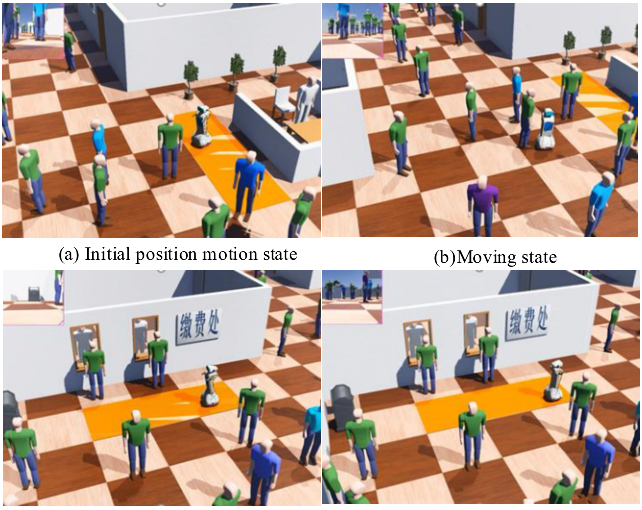


Figure 4. Illustration of structural principle.

Figure 5. Display of product hospital scene rendering.

4. Construction of Simulation Scene of Intelligent Medical Navigation Robot for Epidemic Prevention

The model was imported into Webots, and the control motors and sensors were added to the robot. The hospital environment was constructed with a total area of 300 square meters, including the information desk, toll collection office, registration office, CT room, medicine collection office and other places. Among them, the orange highlighted areas were the position of the robot initial point and (Figure 6a) the position of the corresponding target point (Figure 6d), respectively. Figure 6 shows the process of the robot arriving at the destination and then returning to the initial position after receiving the instruction. In the case, the stationary and moving dummies were used as obstacles in the journey, and the driving route of the robot was planned and designed to ensure that the robot could avoid the fixed and mobile obstacles independently in the process of moving.



(a) Initial position motion state

(b)Moving state

(c) Reaching the destination movement state

(d) Return status

Figure 6. Robot moving line display diagram.

4.1. General Technical Route

The database of hospital environment was established through Webots, and it was stored in the "brain" of robot. Using the A* algorithm, the paths between the target points in the hospital were planned statically, and then the coordinates of each path were imported into the robot control system. After receiving the information of the target position to be reached through the visual operation interface or voice, the robot called out the planned shortest path in the control system through corresponding instructions. And then the robot's own navigation and positioning module was used for positioning, and then the robot moved along the planned path coordinates through the control program.

The ultrasonic distance sensors were used to detect obstacles in the process of guidance, so that different guidance decisions could be made according to different obstacles. Once an obstacle is encountered, it will temporarily deviate from the planned path due to the need to adjust the path. When the robot detects that the distance of the surrounding obstacles is greater than the safe distance, it will automatically return to the original planned path guidance. When the robot reaches the target point, it will pause for a moment, waiting for whether there are people in need nearby. When someone uses it, the robot will take this place as the starting point again, re-plan the new path to the new destination, and carry out the guidance process. When no one is using it, the robot will automatically return to its initial position, so that other people in need can continue to use it. At the same time, during the guidance process, the mechanical arm rises to remind pedestrians to travel in a certain direction. By feedback from users, the algorithm and related hardware are continuously optimized to improve the service quality of the robot.

4.2. Driving System

By controlling the rotation speed of four driving wheels in the left and right rows, the robot can realize fast steering, as shown in Figure 7. According to the obstacle information of different distances and angles detected by the sensors on the robot, the angle that the robot needs to turn is accurately calculated, and then the different motor speeds of the corresponding two rows of wheels are calculated to control the robot's steering.

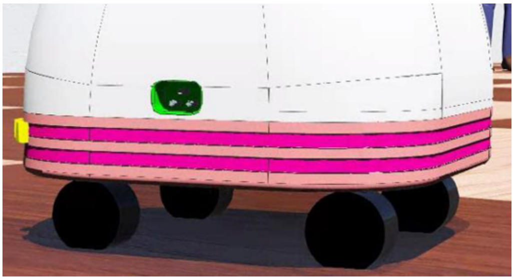


Figure 7. Four-wheel drive system.

4.3. Environment Sensing Module

The hospital is crowded and the environment is complex. In order to detect all kinds of obstacles, four ultrasonic ranging sensors are used in this study. The measurement accuracy of ultrasonic distance measurement can reach centimeter level, the blind area is small, and the distance information of obstacles can be accurately fed back in real time. Ultrasonic ranging sensor is a suitable choice for obstacle detection of low-speed robot [16, 17]. Install four ultrasonic ranging sensors in front of the chassis of the service robot, named as left corner sensor, left middle sensor, right middle sensor and right corner sensor, and the installation positions are shown in Figure 8.

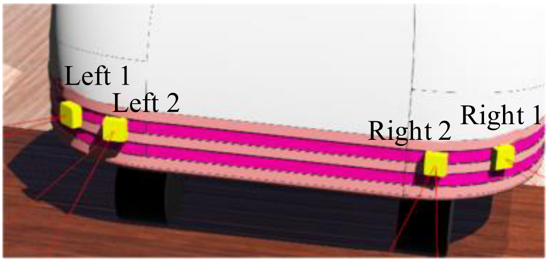


Figure 8. Sensor installation diagram.

The ultrasonic ranging sensor will emit ultrasonic waves in a certain direction when it works, and start timing at the same time. The ultrasonic waves will spread in the air, and will immediately return when encountering obstacles on the way. When the ultrasonic receiver receives the reflected wave, it immediately stops timing, and then calculates the actual distance from the transmitting point to the obstacle according to the time difference between transmitting and receiving [18]. The decision scheme in the figure includes all combinations of whether the detection distance of four sensors is greater than the safe distance, which is safe and reliable. In the process of robot steering, according to the distance of obstacles detected, the corresponding steering coefficient and steering of front and rear wheels are also different, which makes the steering process safer. In the simulation environment, all obstacles with different heights are tested.

The lower part of the hospital seat is empty, which may cause the sensor on the chassis to fail to detect the presence of the seat. Four sensors are installed on the chest of the robot, and the upper and lower sensors can be regarded as a group of sensors. In case the distance of obstacles detected by any sensor in a group is less than the safe distance, it can be regarded that the distance of obstacles detected by this group of sensors is less than the safe distance, and the decision-making method remains unchanged.

4.4. Navigation Module

Positioning module is composed of GPS and integrated inertial navigation system, which provides the robot's position information in real time. By comparing the control platform with the high-precision map, the pose of the robot is formed, and the autonomous navigation is realized through path planning.

The GPS is installed at the top of the robot to obtain the real-time position information of the robot. The basic idea of sensor and algorithm control is shown in Figure 9.

The integrated inertial navigation system (INS) is installed at the top of the robot, which is used to obtain the information of the robot's speed and acceleration. When GPS positioning is adopted, it is easy to be disturbed. In closed places of hospitals, high-rise buildings and trees block out, which can easily cause multipath effect, resulting in the accuracy of positioning results being reduced or even lost. Integrated inertial navigation generally includes accelerometer, gyroscope, magnetometer, barometer inertial measurement unit and calculation unit for reasoning. It can not only temporarily fill the gap left by differential GPS when the GPS signal is lost or weak, but also obtain the closest three-dimensional high-precision positioning by integral method, and can independently obtain the robot's speed and attitude information.

In the navigation and positioning module, the integrated inertial navigation system can obtain both absolute position and relative position independently. In the data processing of the navigation and positioning module, the integrated inertial navigation system is the main system, and the difference between the attitude, position and speed of the integrated inertial navigation system and GPS is taken as the state quantity, and the combined data is output to the control platform once every GPS epoch to make decision instructions.

4.5. Route Planning Module

A* search algorithm is an algorithm used to calculate the shortest path. Because of its high efficiency, it is widely used in artificial intelligence and other aspects. The map space can be divided into grids of equal size, and then the cost map can be formed by generating the cost value of each grid according to the obstacle information of the map. Algorithm A * combines heuristic algorithm with formal method. It estimates the distance from the current point to the end point on the way through an evaluation function, and thus determines its search direction. When this path fails, it will try other paths, check the adjacent squares, and expand outward until it finds the target.

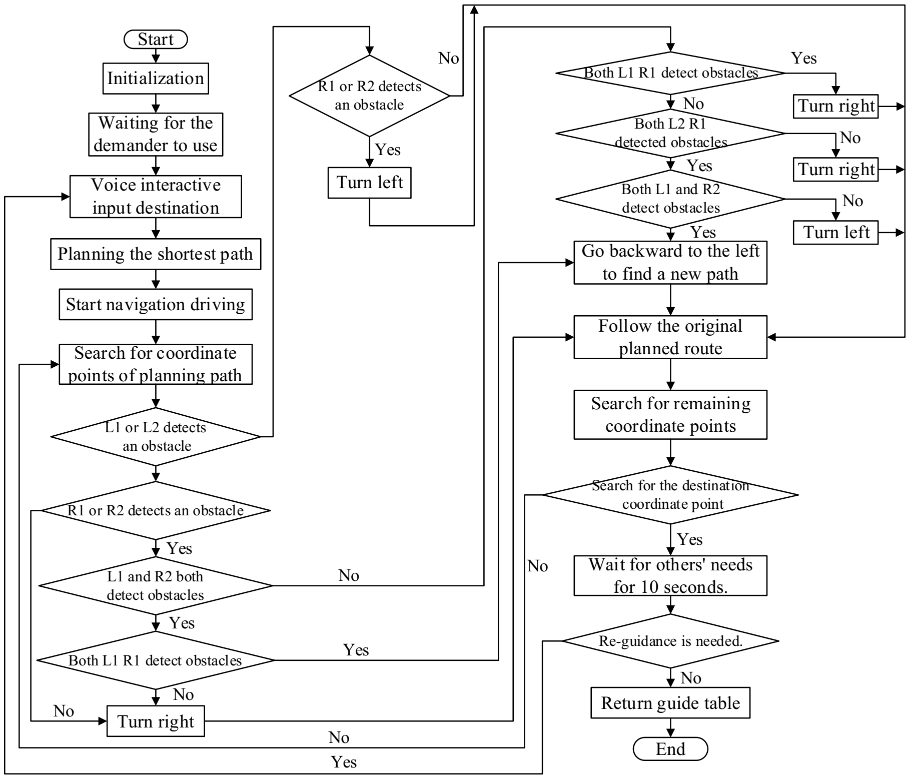


Figure 9. Controlling flow chart.

In the simulation environment, in order to plan the route between each target point, we input the fixed obstacles in the hospital scene into the grid map of A* search algorithm according to the actual size. Then the path coordinates between the target points are generated, and the path coordinates are imported into the control system. It is the shortest path when the robot moves along this path coordinate, which also saves the time of demanders.

5. Summary and Prospect

This research designed an intelligent medical guide service robot, and simulated its autonomous navigation ability in the hospital hall using Webots. Through the establishment of hospital scene database, we could effectively and accurately provide intelligent guide service for the patients. The robot can interact with users by voice, and after receiving instructions, it can directly lead patients to the corresponding departments, providing convenient consultation services for medical staff. The guide method uses A* search algorithm to plan the shortest path between the target points and obtain each coordinate point that the robot has to pass through. Robot GPS and integrated inertial navigation positioning technology are adopted to detect the surrounding obstacle information by using ultrasonic ranging sensors at every coordinate point, and it can avoid obstacles autonomously when encountering obstacles. Compared with the traditional tracking method, the above guidance method does not need to lay navigation devices such as tapes, color bars, reflectors, etc., which ensures the beauty and cleanliness of the hospital ground.

The design of the medical guide robot can effectively relieve the working pressure of medical staff, and its extensive application can reduce the labor service cost of medical guidance in hospitals. At the same time, it can improve the consultation efficiency of patients, improve the medical service quality of existing hospitals, and make more patients feel the high-quality and efficient consultation service. Improvement of life quality has increased people's attention to the field of medical health, and the development of intelligent technology has improved the intelligence of medical services. Deep integration of "artificial intelligence + medical service" confirms the profound change of traditional medical service mode. On this basis, combined with the "internet plus" technology, the problem of people's medical difficulties can be effectively solved in the future. Based on this, combined with "internet plus" technology, it can effectively solve the problem of people's medical difficulties in the future.

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