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Application of Laser Ranging in Path Planning of Mobile Medical Robot

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Abstract. Compared with traditional industrial robots, mobile robots with autonomous sensing, decision-making and execution functions have broad application prospects. With the continuous development of computer science and sensor technology, the research of mobile medical robot is also developing in the direction of intelligence and autonomy. The mobile medical robot senses the environmental information and its own state through sensors, and realizes the autonomous movement facing the target in the environment with obstacles, thus completing the medical functions specified by the designer. When applied to some practical scenes, the environment faced by mobile medical robots is often full of complexity and unknowns. Accurate 3D scene model is beneficial for robots to obtain accurate pose estimation by data matching and other methods, and can generate collision-free navigation paths based on environmental information. The mobile medical robot can move autonomously safely and effectively only if it can accurately and automatically position itself, the obstacle information in its working environment and its movement state.

Keywords: Mobile medical robot; Path planning; Three-dimensional scene.

1. Introduction

Mobile robot is an important research field of robot technology and an important branch of robotics. Robot is a kind of automatic machine. The difference is that this machine has some intelligence abilities similar to human or biology, such as perception ability, planning ability, action ability and cooperation ability. It is an automatic machine with high flexibility [1]. In the case of given robots, autonomous operations are required to be faster and to be able to perform faster tasks [2]. The mobile robot perceives the surrounding environment and its own state through the relevant sensors carried by itself, and can move towards the target position autonomously in the environment with obstacles, and achieve certain functions [3]. For the mobile medical robot, it is an important embodiment of robot autonomous behavior to be able to plan its own motion path and execute the motion path well [4]. In the complex and unknown environment, the existing knowledge of mobile robot is arranged and provided by the designer, and the knowledge is generally very small [5]. Then the robot real-time navigation will need to combine the cognition of environmental information with the optimization of navigation decision-making, acquire environmental knowledge in the process and express it in a reasonable and efficient way in real-time [6].

The navigation of mobile medical robot refers to the perception of the surrounding environment and its own state through the relevant sensors carried by the chemist, so that the robot can move autonomously in the environment with obstacles [7]. Based on the working environment information detected by the related sensors carried by the robot, the environment modeling is carried out. The environment model away from the precision can effectively improve the positioning accuracy of the robot. The more accurate the positioning is, the higher the accuracy of constructing the environment model is [8]. Firstly, the mobile robot senses the surrounding environment and its own state through the sensor, and through identifying the surrounding obstacle environment, the mobile robot can move autonomously with the given target as the destination, so as to complete certain operation tasks [9]. When the working area of mobile robot is moderate, the effect of regional planning may have reached the global requirements to some extent [10]. In order to realize the environment modeling, the mobile robot needs to analyze the sensor data to obtain the current accurate pose of the robot, so as to realize the map construction. Through the three-dimensional construction of the scene, the surrounding environment of the mobile robot can be displayed more intuitively, which is convenient for the robot

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to carry out path planning in this scene [11]. Only when the mobile medical robot has accurate automatic position, obstacle information and motion state in the working environment, can the mobile medical robot safely and effectively move autonomously.

2. Establishment of global path planning model for mobile robot

It is one of the most important capabilities of mobile robots and the basis of other functional applications of mobile robots that mobile robots can move autonomously towards the target point in an unknown and complex environment, and at the same time, can avoid obstacles existing in the traveling path. In the process of autonomous navigation in indoor scenes, mobile robots often need the map of the current scene, locate according to the sensor data returned in real time, and then adopt a certain path planning method to guide the robot's autonomous movement. Indoor scenes are generally structured, but there are many objects in some scenes, and there may be people walking in the scenes. The two-dimensional raw data directly obtained from laser sensors may be messy and contain many invalid points [12]. If such two-dimensional laser data is converted into three-dimensional laser data in spatial coordinate system, it will increase the difficulty of subsequent data matching, which may cause matching failure, so invalid points need to be removed. There is little prior knowledge in unknown environment. Of course, there is no known target to track. In this case, if we only rely on the odometer to obtain the current pose information of the robot, there is great uncertainty, and the accumulated error is large.

The mobile robot detects the current working environment in real time according to the known environmental map information or the relevant sensors carried by itself, and plans a traveling path of the mobile robot according to these environmental information, so that it can advance along this path towards the target position without external interference. The actual driving process of robot motion system is obtained through visual behavior analysis, and a unified visual and behavioral model is formed, as shown in Figure 1.

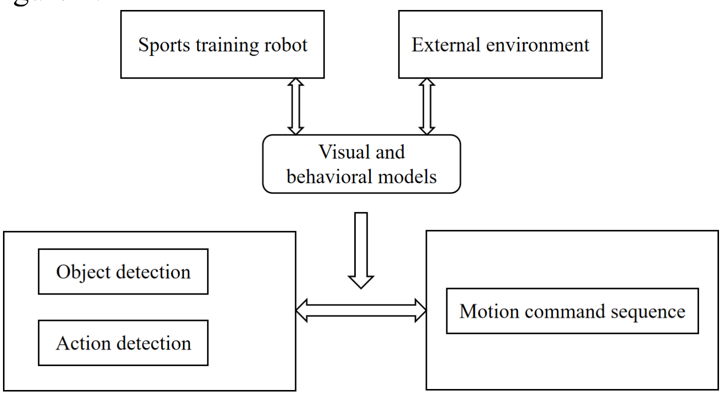

Figure 1 Vision and behavior model

In the complex unknown environment, the mobile robot can observe part of the surrounding environment information as fully as possible, only through the limited sensing equipment it carries. The function of the robot control system is to operate and control the mechanism body according to the user's instructions, and complete various actions of the operation. The basic structure of robot network is shown in Figure 2.

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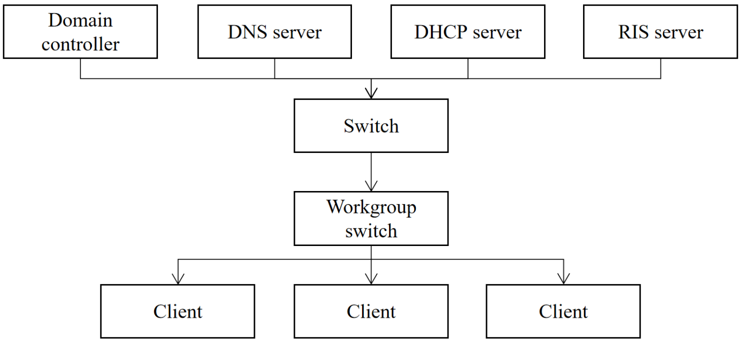

Figure 2 Network infrastructure

The function of path planning is to find an optimal path without collision avoidance from the initial state to the target state according to certain standards in the working environment with various obstacles. In multi-sensor system, the positioning information provided by each information source is uncertain to a certain extent, and the fusion of these information is essentially an uncertain reasoning process. Global path planning means that all the environmental information in the environmental map is known, while local path planning means that the environmental information is unknown or part of the environmental information is known. During the moving process, the mobile robot detects the surrounding environmental information according to the relevant sensors carried by itself, thus determining the current position of the mobile robot and the distribution information of surrounding obstacles. Because the basis of local planning is based on the obstacle detection module based on multi-sensor fusion, the fusion module has already dealt with the terrain with large fluctuation. Therefore, the significance of considering terrain undulation in the stage of local route planning lies in comprehensively considering the factors that hinder the passage of vehicles, and making an overall assessment of the passability according to these factors.

3. Robot motion control and trajectory tracking

Detect the closed loop enclosed by each free link line and obstacle boundary or working area boundary in free space graph, and the closed loop of each free area is called free convex polygon area. When all conditions are the same, when the target point is near obstacles, the robot can't reach the target point based on the traditional artificial potential field method, but the robot can reach the target point smoothly based on the improved artificial potential field method. The reason is whether the distance factor is introduced into the potential field function. When the target point is in the range of obstacles, the repulsive force will be far greater than the gravitational force, so that the robot can't reach the target point at last. When the robot moves towards the target point, the attraction is getting smaller and smaller, but the repulsive force is getting bigger and bigger, which will cause the attraction to be smaller than the repulsive force, so that the mobile robot can't reach the target point finally, and the path planning fails. Mobile medical robot is a kind of robot system that sends samples. They sense the environmental information and their own state through sensors, so as to realize the target-oriented autonomous movement in the environment with obstacles. In the environment, there are some factors which have similar frequency to the laser rangefinder, such as light source [13]. These interferences cause some noise in the ranging data of laser rangefinder.

In a complex unknown environment, the existing knowledge of mobile robots is collated and provided by designers, and this knowledge is generally very small. Then the robot's real-time navigation needs to combine the cognition of environmental information with the optimization of navigation decision, and acquire environmental knowledge in the process and express it in a reasonable and efficient way in real time. Fig. 3 is an artificial intelligence tracking diagram of a mobile medical robot.

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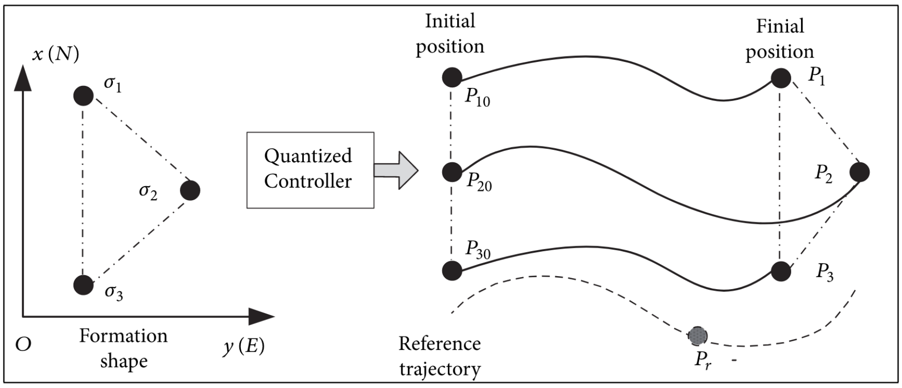

Figure 3 Artificial intelligence tracking diagram of mobile medical robot

Suppose that the mobile robot takes a sequence of three consecutive images $f_{k-1}(x,y), f_k(x,y), f_{k+1}(x,y)$ at a certain position. By adjusting the sensitivity coefficients of the image hue H, saturation S and brightness I attributes, each frame of the resulting sequence of images is converted into an improved HSI image $f_i(x,y)$ that can highlight the moving target, as follows:

$$(\ f_i(x,y)=\{W_H H_i(x,y), W_S S_i(X,Y), W_I I_i(X,Y)\}=\{H'(x,y), S'(x,y), I'(x,y)\} \quad (1)$$

Among them: W_H, W_S, W_I are the sensitivity coefficients of the set hue, saturation and brightness respectively. The image difference between the kth frame and the k-1th frame converted by formula (1), and the image difference between the k+th frame and the kth frame. The frame difference image calculation model is as follows:

$$f_{d1}(x,y)=\{|H'_k(x,y)-H'_{k-1}(x,y)|, |S'_k-S'_{k-1}(x,y)|, |I'_k-I'_{k-1}(x,y)|\} \quad (2)$$

$$f_{d2}(x,y)=\{|H'_{k+1}(x,y)-H'_k(x,y)|, |S'_{k+1}-S'_k(x,y)|, |I'_{k+1}-I'_k(x,y)|\} \quad (3)$$

Among them: $f_{d1}(x,y), f_{d2}(x,y)$ is the result of frame difference of three consecutive image sequences.

Wheeled robot is a typical nonholonomic system, and there are various wheeled robot systems, among which the following two-drive wheeled mobile robots, automobile mobile robots and wheeled mobile robots with trailers are widely studied. If the laser sensor rotates at a certain position, because the internal dynamic model of the laser sensor is known, the registration of laser point cloud data can be easily obtained. However, if the robot with laser data acquisition platform starts to move, the registration of laser point cloud is related to the internal dynamic model of laser sensor and the external movement. The forms of map construction mainly include geometric representation, grid representation and topological representation. The external sensors of mobile robot include camera, ultrasonic, infrared and laser rangefinder. With the development of robot technology, mobile robot has become an effective tool, which can be used for rescue, exploration and monitoring. In order to accomplish the above tasks, the mobile robot needs to navigate autonomously in unknown environment. In this process, the mobile robot needs to perform pose estimation, environment map construction and path planning simultaneously.

On the basis of laser rangefinder as an environmental sensor, the hierarchical control is designed in the robot control layer by combining local planning with dynamic careful planning. Single navigation strategy can hardly meet the real-time needs of unknown environment, so dynamic environment modeling is combined with local planning and dynamic careful planning. Figure 4 shows the structure of agent nodes.

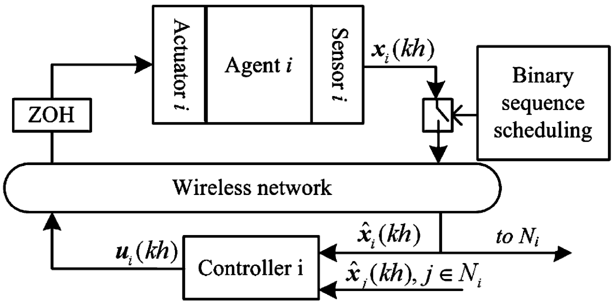

Figure 4 The structure of the agent node

Intelligent control combines the control theory with the flexible framework of various intelligent computing methods, and changes the control strategy to adapt to the complexity and uncertainty of the controlled object, so it has better stability and robustness. Each data of the two-dimensional laser sensor is a laser line composed of many laser points. Because the distance values reflected by the laser points hitting objects in the scene are different, the laser line presents a certain shape. In actual planning and control, the reflective behavior, reactive behavior and thoughtful behavior of mobile robot are combined. This composite navigation mode is more conducive to dealing with complex and changing unknown environments. Figure 5 shows the framework of medical service detection and tracking system using image error technology.

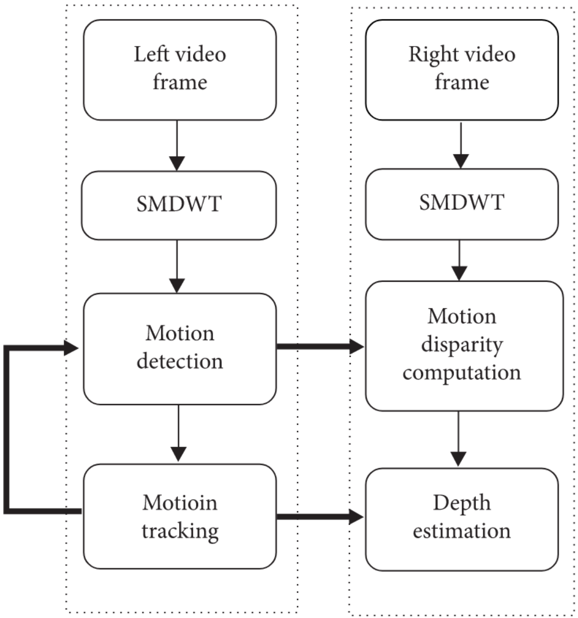

Figure 5 Medical service detection and tracking system framework using image error technology

The second frame difference image operation is:

$$Y(x,y)=f_{d2}(x,y)\cdot f_{d1}(x,y)=\{Y_H(x,y)Y_S(x,y)Y_I(x,y)\} \tag{4}$$

The algorithm is defined as:

$$Y_H(x,y)=\min\{|H'_k(x,y)-H'_{k-1}(x,y)|,|H'_{k+1}(x,y)-H'_k(x,y)|\} \tag{5}$$

$$Y_S(x,y)=\min\{|S'_k(x,y)-S'_{k-1}(x,y)|,|S'_{k+1}(x,y)-S'_k(x,y)|\} \tag{6}$$

$$Y_I(x,y)=\min\{|I'_k(x,y)-I'_{k-1}(x,y)|,|I'_{k+1}(x,y)-I'_k(x,y)|\} \tag{7}$$

Among them: Y (x, y) is the result of the phase AND operation, and the phase AND operation is the minimum operation of the chroma H, saturation S and brightness I of the two frame difference images $f_{d1}(x,y)$ and $f_{d2}(x,y)$. In order to determine the results of the two frame difference images, $f_{d1}(x,y)$ $f_{d2}(x,y)$ is the area obtained from the phase and operation results, and the ratio of the cluster spacing to the cluster spacing is used as the objective function of the best segmentation.

Single navigation strategy is difficult to meet the real-time needs of unknown environment, so the dynamic environment modeling is combined with local planning and dynamic careful planning. In

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the actual planning and control, the reflective behavior, reactive behavior and deliberative behavior of mobile robot are combined. Due to the consumption of battery power in the process of robot movement, the actual voltage will be less than the rated voltage of battery, resulting in the actual movement speed of robot will be smaller than the theoretical value [14]. According to the sensing area, the laser rangefinder selects the angle range that should be set, and selects the corresponding sector rolling planning window. Local planning can be applied to the situation of unknown environment and shows high intelligence. However, its complex and intelligent search algorithm limits its response speed, which requires that the planning system adopted has high quality. The length of the path obtained by the robot and the movement time of the smooth path are less than those of the other two methods, making the average speed of the robot faster than the other two algorithms [15]. In real-time control, each control variable is the sum of the reasoning time of a group of forward rule bases to parameters and the operation time of the controller. Compared with the fixed parameters, a group of forward rule base reasoning time is increased, but the fuzzy parameter generator can adjust the parameters in real time according to the real-time system feedback information, which makes the system achieve good performance.

4. Conclusions

With more and more robots being used in various fields, robots are required to have higher intelligence, more agile motion function and more anthropomorphic behavior. For the mobile robot with fixed obstacles, environment modeling, path planning and trajectory tracking are the key research links of robot autonomous navigation. For multi robot path planning, it is necessary to introduce the communication mechanism between robots. The motion space modeling before path planning becomes more complex, which may cost more computing time or require higher processor. The map is processed without distortion by projection transformation, and then filtered by Gaussian kernel filter. In this way, the information in the map can be identified correctly, which helps the mobile robot to navigate better. In the experiment of moving map construction, the environment is constructed in the virtual interface according to the data measured by sensors. In the path planning experiment, we can clearly see in the virtual interface how the robot can bypass the obstacles in the process of moving towards the target point, and can successfully reach the target point, and successfully complete the path planning task.

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