Design of Medical Robot Control System Based on Single-Chip Micro Computer

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Abstract: In this study, a medical robot based on a single-chip computer is proposed and designed to reduce the need for human resources, enhance the management of COVID-19 prevention, and stop the epidemic from spreading. The primary control core is the STC89C52 single-chip. Infrared sensors pick up on obstructions. And to find the path, the robot makes use of the tracking module. From there, the IO-port control L298N drive template modifies the two DC motors' operating states, which in turn modifies the robot's motion state by adjusting the differential in speed between the two motors. The robot enters the ward by using an intelligent tracking module to determine the optimal path for inspection, after which it applies a genetic algorithm. Following cleaning, the robot employs the Yolo5s algorithm to detect the mask by driving the OV2640 camera with an STM32F4 processor. Ultimately, it transmits the data it has gathered to the computer in order to enable real-time patient condition monitoring. The simulation findings demonstrate that path planning, facial mask identification, and wireless communication needs may be realized by the medical robot in an accurate and efficient manner. The effectiveness and security of medical personnel will be greatly enhancedbythis.

Key words: facial recognition, wireless connection, medical robot, one-chip computer, and path planning.

I. Introduction

According to the National Health Commission and provincial health commissions, until 24:00 on February 10, there were still 1424 confirmed cases of COVID-19 (including five severe cases). In total, there have been 100704 cured and discharged cases, 4636 dead cases, 106764 confirmed cases, and 38682 close contacts still under medical observation[1]. At the same time, as a hot area of robot research, service robot hasmade great progress in recent years. The functions of robot such as perception, decision-making, planning and control are more perfect and can apply in more and more complex environments. Therefore, under the current severe epidemic situation, if robots are used instead of manual work to complete much traditional work, it will effectively reduce the time that medical workers are exposed to high-risk environments, reduce the spread of disease and improve the epidemic prevention efficiency. Therefore, it is necessary to design an intelligent epidemic prevention robot with the functions of body temperature monitoring, environmental disinfection and a wearing-mask reminder to reduce the exposure of medical workers[2]. Not only respiratory isolation, contact isolation, personnel control, but also body temperature monitoring and environmental disinfection should be executed strictly. To reduce workforce requirement, Wang Xing's[3] team from Taiyuan University of Science and Technology designed a door control system. Facial recognition and identity card authentication are applied to enhance security. Liang Ziyi[4] of the University of Electronic Science and Technology of China designed an analysis system for automatic detection and reporting of individual body temperature. Although the former has comprehensive functions, it can only detect people entering and leaving the gate, which is challenging to monitor the personnel in the ward and other areas. Although the latter has a little restriction on space, it has high manufacturing cost, highly depends on user consciousness, and it does not have other functions. Both of them cannot disinfect the environment and cannot replace medical workers to complete simple tasks such as food delivery and medicine delivery. In addition, with the development of the deep learning algorithm, the target detection algorithm based on it become a good option.

To solve the problems above, we designed a medical robot. The robot can plan the path, disinfect the environment, deliver objects, monitor whether people wear masks and track their body temperatures. It can also execute other commands in certain areas. These robots are capable of taking the place of some nurses, reducing human input, and decreasing infection. In addition, the data transmission to the computer can be realized through the wireless module, which is convenient for monitoring the working condition of the robot and mastering the data of each person. It greatly improves efficiency and has great practical value.

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II. Control system of medical robot

A. Structure of control system

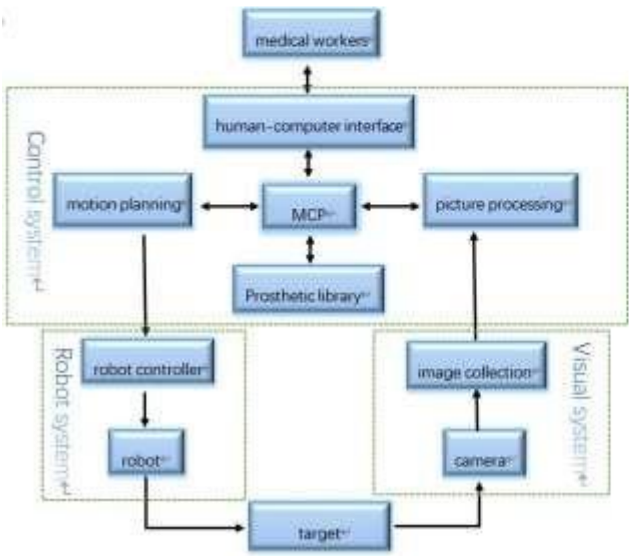


Figure 1. Structure of control system

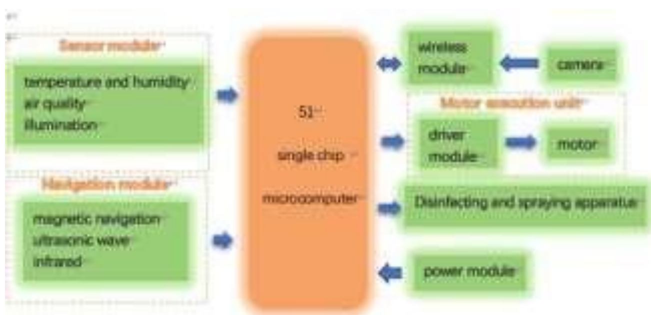


Figure 2. Hardware frame diagram

Figure 1 is the control system of the medical robot, which mainly includes the functions of robot tracking and navigation, path planning, human facial image acquisition, upper and lower computer interactive information, etc. Other auxiliary functions, such as food and medicine delivery or mask monitoring, are realized based on the above functions. The medical staff can setthe working environment and functions of the robot through the operation interface. The robot carries out corresponding motion planning through the main control program, and carries out image acquisition at the corresponding target location and personnel through the infrared camera. The image acquisition information will be uploaded to the image acquisition card and finally fed back to the medical staff. For example, mask monitoring identification and other corresponding statistical work. The robot controller can control the movement of the medical robot, and complete the transportation of food and medicine, spraying medicine along the way for disinfection, tracking and navigation, etc. The hardware design block diagram is shown in Figure 2.

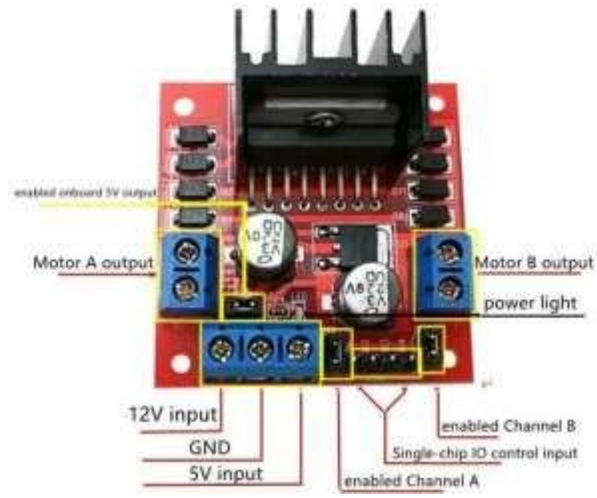


Figure 3. L298N Physical wiring diagram

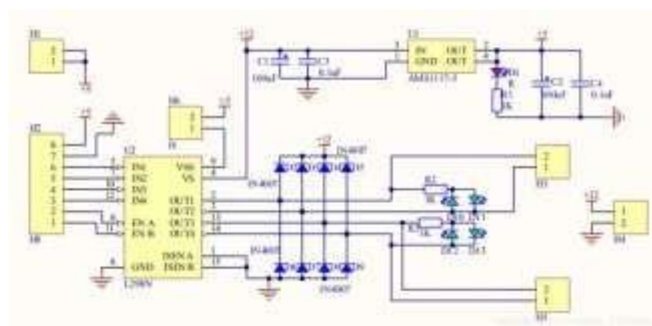


Figure 4. Driving schematic diagram

Figure 3 is the physical wiring diagram of L298N, and Figure 4 is the driving schematic diagram. L298N is a driving chip that has two H-bridges internally, so the motor's operationonly requires three signal controls: two direction signals and anenable signal. (The input voltage cannot exceed its rated voltage). The working voltage of the L298N chip requires two ways, which is to output the power supply and input logic control loop power supply for the motor circuit. Power 5V (power supply / into). The port of the L298N access DC motor is mainly IN1、IN2、IN3、IN4, which also requires enabled Aand enabled B to control the Speed Control PWM Signal to change the Rotation Mode (FWD, REV, STOP) of DC motor M1 and M2.

B. Theory of path planning

In order to improve the efficiency and safety of distribution, the path planning problem of medical robots is studied. Using the path planning method combining grid method modeling and genetic algorithm, the shortest path of medical robot distribution is planned. Based on this, taking minimum snap [5]-[6] as the optimization goal, the path is optimized by polynomial curve fitting through the method of hard constraint [7]. The safe flight corridor [8] can effectively prevent the possible collision of robots on the way.

Firstly, we need Matlab to carry out a genetic algorithm to build a grid map. After the grid map is constructed, we need toinitialize the population. The flow chart is shown in Figure 3:

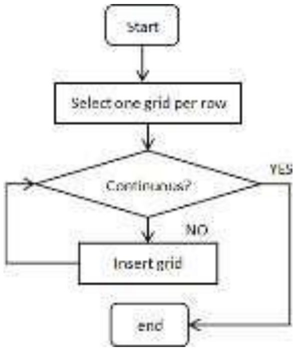


Figure 5. Flow chart of Population initialization

On the premise of population initialization, the selection is made. The theoretical formula is as follows:

$$d=\sum_{i}^{end-1} \sqrt{(x^{i+1}-x^{i})^2+(y^{i+1}-y^{i})^2}; \quad (1)$$

$$fit_1 = 1/d; \quad fit_2=\cos^{-1}((b^2+c^2-a^2)/2bc); \quad (2)$$

$$fit = a\,fit_1 + b\,fit_2; \quad P_i = fit_i \Big/ \sum_{i=1}^{end} fit_i \quad (3)$$

Generating a new path is equivalent to generating other individuals in the population, and selecting the best one. The evaluation index is shown in the above formula, represented by fitness *fit1* and *fit2*. *Fit1* represents the reciprocal of the length of the path. The shorter the path, the larger *fit1* is, the better thepath is. The method is expressed by the Angle of an inflection point and calculated by inverse trigonometric function. On the basis of *fit1* and *fit2*, parameters *a* and *b* in the total fitness formula were obtained through experiments. P_i stands for the probability of an individual being selected in a population. Thehigher the fit is, the higher the probability of the route being selected is, namely, the idea of "natural selection, survival of the fittest". Some individuals that look bad have a low chance of being selected, but not none. The idea is that these individuals might get better through later crossover and mutation, and keeping them in can keep the diversity of the population.

Then crossover and mutation are carried out, that is, two grids in the path are randomly selected, and then a new path is generated between the two grids by using the method in the above population initialization.

Based on completing the path planning based on genetic algorithm, the method of trajectory optimization is to divide the tortuous trajectory into several parts, each part is represented by different polynomials, so as to achieve the effect of fitting, make the route smoothly connected at the inflection point, andavoid the sudden and large turning at a certain point during theoperation of the robot. Figure 4 shows the pyramid model for achieving the target requirements required for trajectory optimization.

The function of the trajectory is recorded as *P(T)*, the first and second derivatives are velocity *V(T)* and acceleration *a(T)*, respectively, and the third and fourth derivatives are recorded as *jerk(T)* and *snap(T)*.

The n-segment polynomial trajectory *P(T)* can be expressed as:

$$p(t)=\begin{cases}[1, t, t^2, \cdots, t^n]\cdot p1 & t0 \le t < t1 \\ [1, t, t^2, \cdots, t^n]\cdot p2 & t1 \le t < t2 \\ [1, t, t^2, \cdots, t^n]\cdot pk & tk-1 \le t < tk\end{cases} \quad (4)$$

The time t is allocated according to the path length and average speed. The next step is to solve the parameter *P* and determine the trajectory.

Furthermore, in order to avoid the problem that the curve optimized by polynomial may collide with obstacles, the safe flight corridor is used for constraint. Its principle is to scatter many points equidistantly on the broken line segment of hard constraint and create a region centered on these points. When we select enough points, It can form a closed area like a corridor [7]. As long as the optimization curve is constrained in the area of the safety corridor, the problem of collision between the optimized route of the robot and obstacles can be prevented. Inequality constraints are as follows:

$$xmin \le p_t x \le xmax, \quad ymin \le p_t y \le ymax, \quad (5)$$

$$[1, t_i, t_i^2, \cdots, t_i^n]\,p \le p(t_i)+r, \quad (6)$$

$$[-1, -t_i, -t_i^2, \cdots, -t_i^n]\,p \le -(p(t_i)-r). \quad (7)$$

C. Facial mask detection

The module is implemented by yolov5 algorithm based on deep learning.[11] Convolutional Neural Networks (CNN) represent the deep learning model, which is composed of multi- layer Neural connections. An initial hierarchical structure is constructed by convolution and pooling between neurons. Then, the whole connection layer was designed to adapt to different visual tasks, and the response of output neurons was obtained by using activation function. Finally, the whole network structure was optimized according to different objectivefunctions.

Yolov5 model is adopted for intelligent face recognition [10]. The yolov5 target detection algorithm continues the overall layout of the previous Yolo algorithm, and its network structure is composed of four parts: input, backbone, neck and prediction.

The components are described as follows: Input: adopt mosaic data enhancement method, adaptive anchor frame and adaptive picture scaling to reduce black edges and redundant information; Backbone: focus structure, CSP networks (cross- phase local area network);

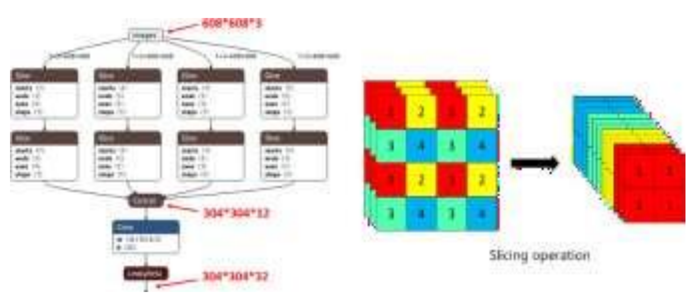
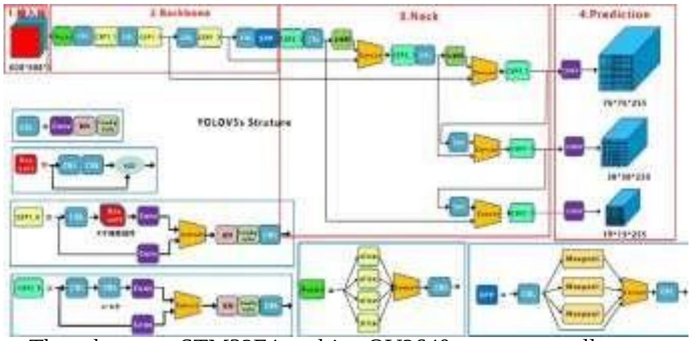


Figure 6. Focus structure

There are four kinds of yolov5 algorithms: yolov5s, yolov5m, yolov5 and yolov5x. Their network structure is deepening and widening. Although the detection accuracy is improved significantly, the detection speed is decreasing.

Because the detection algorithm studied in this paper needs to quickly detect whether patients wear masks, the yolov5s network structure is used to train the model.



The robot uses STM32F4 to drive OV2640 camera to collect video data. It then uses algorithms to verify the video data read by Python. The algorithm will automatically mark the position of the face or mask in the video data, and then output the detection results. If the test result shows that the mask is not worn, a reminder will be sent to urge the patient to wear the mask until the test result shows that the mask is worn. The process is shown in Figure 7.

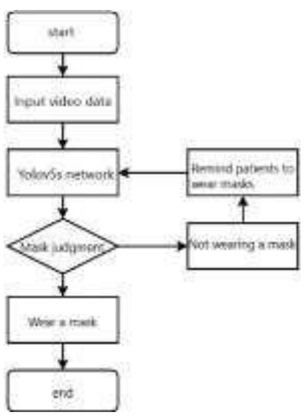


Figure 8. Mask detection flow chart

D. Theory of wireless communication and interactive interface

ESP8266, is selected as the bridge to connect the upper computer (the computer used to control the robot) and the lower computer (medical robot) in the wireless communication system. The upper computer, used to control the robot, is equipped with the medical console program to send commands. The user's commands sent are sent by the computer, transmitted through the wireless network and received by the esp8266 chip.

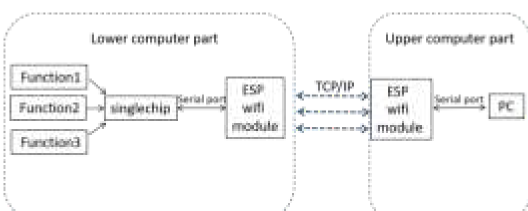


Figure 9. Communication of upper and lower computers

The chip uploads it to the computer through the wireless network and an interactive process is done.

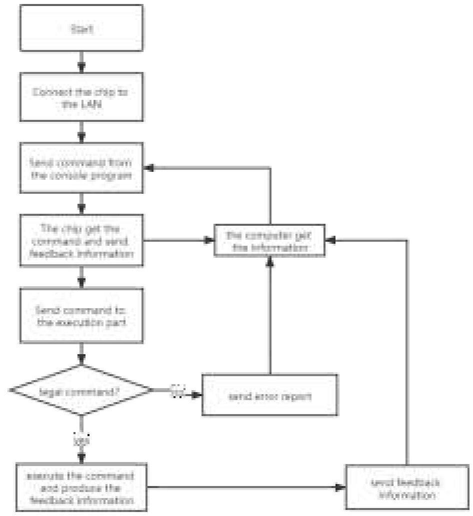


Figure 10. Wireless communication control logic diagram

The upper computer's medical robot console includes several modules: area selection, function selection, other commands, execution monitor, data of body temperatures and position monitor, as well as three keys of "confirm", "recall" and "emergency stop". All functions can be selected based on need, which greatly improves the robot's efficiency, shortens the time of a working cycle, and makes it work longer between charges.

The area selection function allows users to choose the areasthey need to focus on. Fewer duty areas will make the robot staylonger in the more important areas.

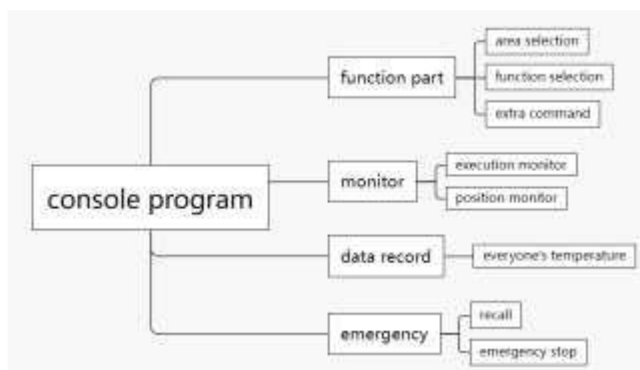
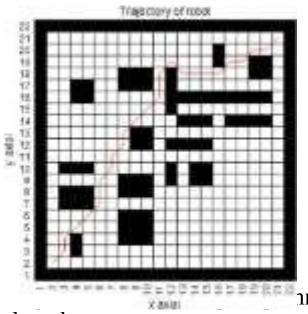


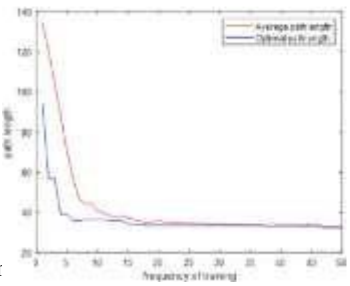
Figure 11 Upper computer control

III. Experimental results and analysis

A. Path planning experiment



length



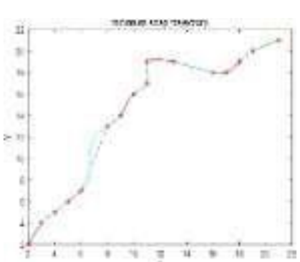
with training times

When using MATLAB for the path planning problem basedon the genetic algorithm, we need to set some parameters on thebasis of constructing the grid map [3], such as the starting position ‘p_start’ = 23 and the end position ‘p_end’ = 460, the population number NP setting is 200, the maximum evolutionary generation ‘max_gen’ is recorded as 50, the crossover probability pc=0.8, and the mutation probability pm=0.2. According to the above principle, initialize the population first, find the must-pass nodes, start from the row where the starting point is located, and select a free grid in each row to form the must-pass nodes. There is no discontinuous path, and then the loop iteration operations of selection, crossover, mutation and update are carried out [9]. By comparing the path length, path smoothness and fitness, the optimal route is continuously updated in a loop, and finally, the optimal route is found. Finally, the plot function is plotted, andthe path planning result shown in Figure 11 is obtained. From Figure 11, we can see that the average path length and the optimal path length are asymptotically optimized with the increase of the number of iterations until they tend to a stable value.

After the path planning route is obtained, to make the curve smoother, the path optimization is more conducive to the continuous and stable movement of the robot in practice. Path optimization using high-order polynomials.

First, way points need to be designed: the starting point, the destination point, and the key nodes passed on the way. These

nodes will be stored in a 2*16 matrix, the acceleration of the start and end points are set to 0, ie: v0=[0,0], a0=[0,0], v1=[0,0], a1=[0,0], the total time T is set to 5 seconds, the time of each segment is allocated according to the path length of each segment, and the polynomial order is set to 5.



optimization results

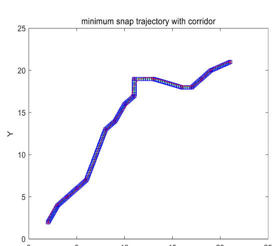


Figure 15. The route after buildinga corridor

The resulting graph of path optimization is shown in Figure 13. The "*" in the graph is the selected way point, and the curve represents the polynomial fitting result of each segment on the ‘xoy’ plane. Figure 14 shows the optimization curve for building a safe flight corridor.

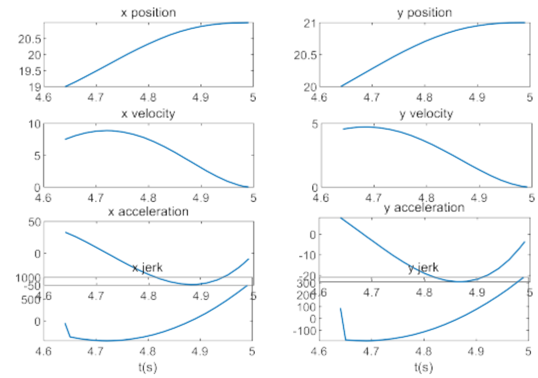


Fig 16. Variation curves of position, velocity, acceleration and jerk with time t(s) in x and y directions

In addition to the safe flight corridor, we can also fundamentally solve the problem of a possible collision. We can avoid collision by selecting more way points, especially some inflection points or points close to obstacles , as shown in Fig. 15.

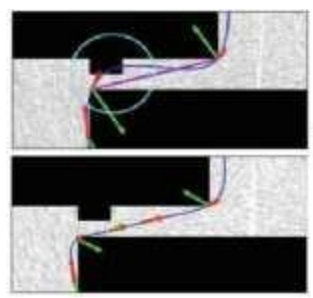


Figure 17. Avoid collision by selecting more points

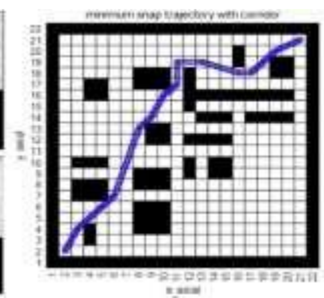


Figure 18. Final optimized route

The final optimized route is shown in Figure 17. It can be seen from Figure 17 that the final optimized route can effectively avoid collisions, and it is a nearly optimal route.

B. Face mask recognition experiment

This paper extracts 2000 images from the face detection dataset WIDER Face as the dataset for the model. Labeled with Labellmg software to make it meet the data requirements of the YOLOv5s model. Among them, 1600 images are used formodel training, and 400 images are used for model validation.

Table 1. Test environment and configuration

name	Specific parameters
processor	Intel i7-9750H CPU @ 2.60GHz
graphics card	NVIDIA GeForce GTX 1660Tioperating system
Development language	python 3.8, pytorch 1.8.0 framework
software library file	opencv 4.5.1 cuda 11.0. tensorboard 2.5.0

Experimental parameter settings and the training phase of the model:

The algorithm in this paper uses 80% of the 2000 images as the training set, the epoch number is set to 100, the batch size is4, the input image size is 640*640, and the optimization method adopts stochastic gradient descent (SGD).

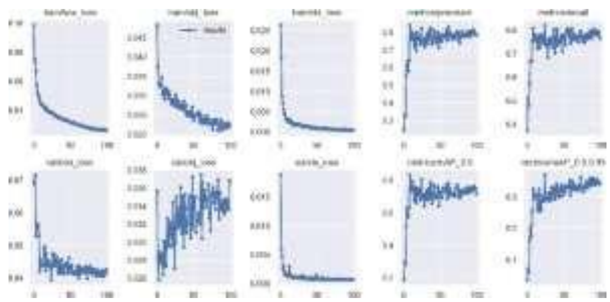


Figure 19. Graph of parameters with the number of iteration

Accuracy, that is, the number of correct targets marked divided by the total number of targets marked, the closer to 1, the higher the accuracy will to be.

Recall rate, the number of correct targets marked divided by the total number of targets to be marked. The closer it is to 1, the higher the accuracy.m AP-0.5 and m AP-0.5:0.95: AP is the area enclosed by Precision and Recall as the two coordinate axes. The closer this value is to 1, the higher the accuracy. As the number of iterations increases, the values tend to be stable.Results show:

Figure 20. The effect of mask detection in different situations

C. Communication Interactive interface experiment

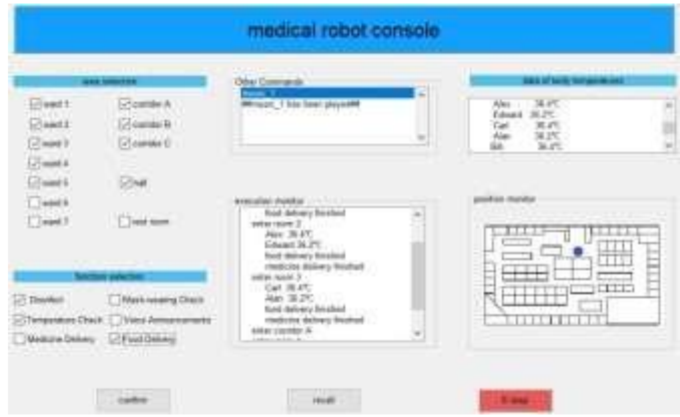


Figure 21. Rendering of the host computer interface

The corresponding operation speed is fast, and the robot position is displayed clearly.

IV. Summary

The results of this research will be beneficial to the epidemic prevention and control work around the world, reducing the risk of infection caused by human-to-human contacts to a certain extent. This type of medical robot meets people's urgent needs for epidemic prevention and control, and uses artificial intelligence to solve in view of practical problems. The focus of future research in this field focuses on how to put this type of medical robots into practical life to better meet social needs. In the system simulation part, the functions of some medical robots are shown, and in the future, the whole will be designedand displayed in more detail through physical objects.

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