An Epidemic Prevention Robot System Based on RoboMaster Technology

Tao Li, Lei Cheng, Huanlin Li, Yanjie Wu, and Guang Li

Abstract Based on the RoboMaster AI Challenge, a solution is proposed to use robots to replace epidemic prevention personnel to perform tasks. The epidemic prevention robots are designed for schools, office buildings and other public places to complete the monitoring of the body temperature of the entering personnel and disinfect the environment, etc. The robot designed in this study can go through deep learning to allow the body temperature of the entering person to be more accurately measured. The study introduces the working principle of the intelligent anti-epidemic disinfection robot and mainly explains the control of the gimbal to spray disinfectant and the autonomous path planning of the robot. The simulation experiment results show that these anti-epidemic robots can effectively complete their tasks. This has laid a good foundation for the next step of research on the epidemic prevention robot system.

Keywords Epidemic prevention robot · COVID-19 · TensorFlow · ROS · MATLAB

1 Introduction

The history of the epidemic is a terrible disasters history. Three thousand years ago, the smallpox virus brought huge disasters to Indians and even the world. The spanish flu that originated in the United States in 1918 spread globally, causing more than 21 million deaths [1]. Covid-19 is currently raging globally. At the time of writing, 16,000,000 people worldwide have been infected with Covid-19, and 600,000 people have died. The epidemic will also hit the global economy. During the H1N1 outbreak, the US GDP growth rate was negative; during the SARS outbreak, China's GDP growth rate declined; during the Covid-19 outbreak, the epidemic

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hit small- and medium-sized enterprises a lot, and the contribution of small- and medium-sized enterprises to China's GDP was approximately 60%, and about 80% in terms of employment, which almost affects China's economic and financial stability [2]. Therefore, how to prevent and control the epidemic is a matter of great concern to governments.

In recent decades, with the development of science and technology, robots have been widely used in many fields. However, after the outbreak of Covid-19, there are very few robots that can participate in the prevention and control of the epidemic, so people are basically fighting the epidemic in person. On the battlefield, this also caused many policemen, delivery workers and couriers to contract the epidemic. Fortunately, shortly after the outbreak, researchers actively developed various anti-epidemic robots and put them into the battlefield. All kinds of robots appeared. A 5G-powered patrol robot manufactured by Guangzhou Gosuncn Robot Company is used for temperature monitoring and mask detection in airports and shopping malls [3]. In another example, the mobile Aimbot robot [4] and humanoid Cruzr robot from Shenzhen-based UBTECH Robotics is being used in school and hospital. They can measure temperature and confirm whether the masks are worn correctly. About robots for disinfection, in Danish, using high intensity UV-C light with a wavelength of 254 nm, the UVD Robots manufactured by Blue Ocean Robotics are used to kill bacteria and viruses [5]. In Singapore, PBA Group which is a local company has produced a disinfection robot called Sunburst UV Bots [6]. They use lider to complete autonomous navigation and use UV lamp to disinfect. In addition to the UV disinfection, there is also the method of spraying disinfectant. In March 2020, the VHP Robots were deployed in Hong Kong's railway station, using hydrogen peroxide to disinfect the compartments and stations [7]. In Shanghai, the Keenon Robotics can disinfect by using UV lamp and hydrogen peroxide, but they need remote-controlled from a phone or tablet. The use of robots has not only reduced the direct contact between staff, but also greatly reduced the work burden of the epidemic fighting personnel, making great contributions to the fight against the epidemic. The development and application of intelligent technology will play an increasingly important role in epidemic prevention and control. Based on RoboMaster technology, this article proposes a design scheme of an epidemic prevention robot, which completes functions such as body temperature monitoring, spraying disinfection and autonomous navigation.

The paper consists of the following parts. The second section gives the design ideas of the robot system. The third section describes the various robots and what we do simulation work. The fourth section presents the conclusions of our research and the outlook for the future anti-epidemic robots.

2 System Structure

Based on the current situation of the epidemic situation, we propose a design scheme for an epidemic prevention robot system based on the RoboMaster AI robot. Two types of robots are planned to be designed. The first type is a temperature detection

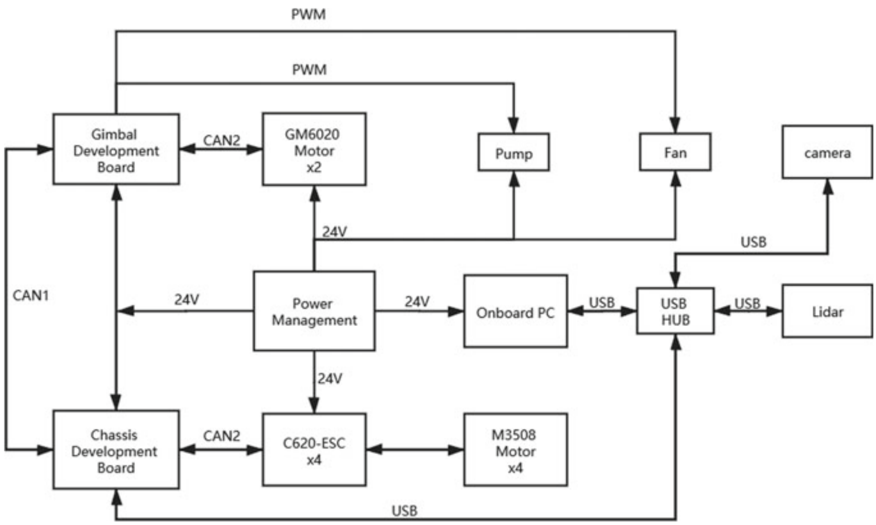


Fig. 1 Structure of the system design

robot, which is mainly responsible for monitoring the temperature of moving personnel at designated locations, finding people with abnormal body temperature in time and controlling the further spread of the epidemic; the second type is a disinfection robot, which is mainly responsible for disinfecting the area to reduce the risk of cross-infection.

For the design of a single robot, the robot can use a unified model to save costs. Temperature detection robots mainly use robot vision technology, so they are equipped with infrared cameras and RGB cameras. The disinfection robot will not be equipped with a camera and will only use lidar for composition and positioning. The structure of the system design is shown in Fig. 1.

3 Function Design and Practice

The following of this section describes the basic parts of the system. The first part uses an infrared camera and an RGB camera, adopts the KCF tracking algorithm and trains a recognition model through TensorFlow to realize the functions of pedestrian tracking and body temperature detection. In the second part, the spraying model is established according to the automatic disinfection function of the robot, which lays the foundation for the intelligent disinfection of the robot. In the third part, it introduces the research of robot autonomously determining the motion trajectory on ROS [8] by using AMCL algorithm and A* algorithm.

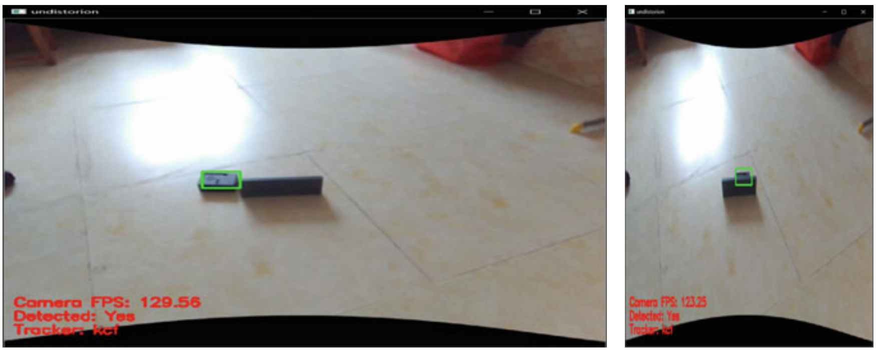
3.1 Thermal Imaging Visual Tracking

The hardware of the vision solution consists of an infrared imaging sensor and an RGB monocular camera. The infrared imaging sensor is used to obtain the thermal radiation video stream. From it, the approximate object contour boundary can be obtained. It can be used to track the moving objects when the environment is not much complex, but it is quite difficult to track and recognize an object when the light is bright or the environment changes greatly. About this question, the RGB camera can improve it. The infrared image and the RGB image can be complemented to get temperature and light texture information at the same time.

Tracking objects can be divided into two situations: bright light with the environment complicate and dim light with the environment ordinary. In the first case, tracking people with abnormal body temperature is best achieved through RGB vision. For the second case, when the light is insufficient and the environment changes little, it is better to use infrared images for analysis, identification and tracking.

Implementation methods of identification and tracking. Recognition function is to train offline .pb models by TensorFlow, including face recognition model and pedestrian recognition model. The main function is to identify people with abnormal body temperature. The edge information, texture information, color information and centroid inflection point information can all be extracted in the acquired image. In addition, other features of the face and body area can also be obtained. Using this method can make tracking relatively simple, and the system has good robustness. In order to improve the tracking ability under high-speed motion and ensure that the target is not easily lost, the commonly used and mature KCF tracking algorithm is adopted. The tracking effect is shown in Fig. 2.

For temperature detection, firstly, pedestrians and their faces are detected in RGB images. In the infrared image, choose the area corresponding to the RGB image of the detected pedestrians forehead. And then obtain the temperature information from



(a) (b)

Fig. 2 KCF tracking algorithm renderings. **a** shows the start of tracking with KCF, and **b** shows the tracking after a few frames

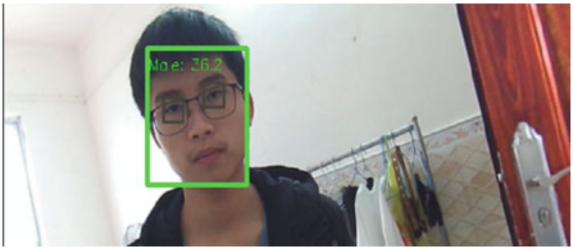


Fig. 3 Tracking test under infrared image and RGB image

intercepted infrared image, and average the local value as the body temperature of the detected person. If the body temperature is found to be greater than 37.3 °C, the person will be added to the key tracking target, the KCF algorithm will be used for tracking and real-time feedback of position information, and the pedestrian's position information will be read when the pedestrian needs to be further checked. Using this information enables the robot to conduct autonomous navigation and tracking. The tracking test effect with the infrared image and the RGB image is shown[1] in Fig. 3.

Disadvantages and improvements: Due to the instability of the infrared image, the measured temperature will jump at ±0.2 °C. Therefore, the critical point of 37.3 °C should be suspicious. For this situation, a more effective treatment should be used method. For the same person under test, taking 10 times as the detection cycle, if the temperature measured more than 6 times is the same value, then this value is taken as the measured temperature value. In the subsequent cycles, when the error between the measured temperature value and the current value exceeds 0.3 °C, the currently confirmed temperature value will be updated, otherwise it will remain unchanged.

3.2 Automatic Disinfection Function Design

The automatic disinfection function is one of the most important functions that a disinfection robot needs to have. According to the recommendations of WHO experts, 70% medical ethanol can be used repeatedly special equipment for disinfection, such as a thermometer. 0.5% of sodium hypochlorite to disinfect the surfaces of objects frequently touched at home or in medical institutions [9]. Sodium hypochlorite is the main component of 84 disinfectant. Therefore, 84 disinfectant is used as a disinfection weapon for epidemic prevention robots.

This section will introduce the realization of automatic disinfection tasks in two parts. The first part will introduce the hardware design, and the second part will introduce the spraying model design based on MATLAB.

Hardware Design The RoboMaster development board type C (STM32f407IG) designed by DJI is used as the gimbal control board and chassis control board. The M3508 motors are used to drive the robots to move, and the GM6020 motors are used

[1]Informed consent was obtained from the participant included in the study.

to control the rotation of the gimbal and the spraying direction of the disinfectant. The disinfectant is pumped up from the medicine box by a pump and atomized into small droplets by a fan and a nozzle.

Simulated Disinfectant Spraying Model After the sprayer atomizes, the disinfectant will form a group of small droplets. We assume that each small droplet is spherical, and the small droplets can form a cone-shaped droplet group. Based on this, we carry out modeling analysis (Figs. 4 and 5).

The movement of droplets in the air should consider the influence of air resistance. According to the knowledge of aerodynamics and Newton's second law [10], some differential equations can be listed:

$$\begin{cases} m\ddot{x} = -k\dot{x}^2 \\ m\ddot{y} = -k\dot{y}^2 \\ m\ddot{z} = -mg - k\dot{z}^2 \ (t > t_1) \\ m\ddot{z} = -mg + k\dot{z}^2 \ (t \le t_1) \end{cases} \tag{1}$$

where t represents the movement time of the droplet; t_1 represents the rise time.

The simulation result Fig. 6 is obtained by solving Eq. (1) and performing MATLAB simulation. When the spray speed is constant, the greater the angle of the spray, the larger the disinfection range. When the angle of the spray is constant, the greater the spray speed, the farther the range. And ejecting droplets of the initial velocity

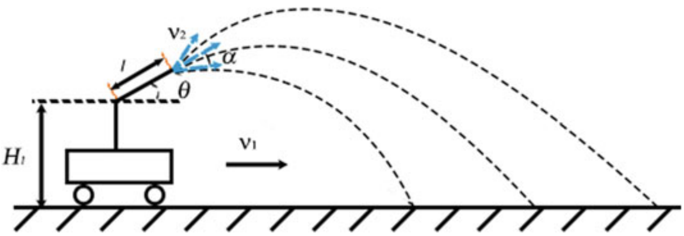


Fig. 4 Schematic diagram of spraying disinfectant

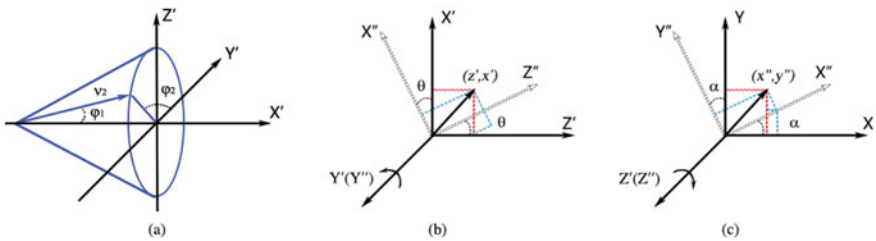
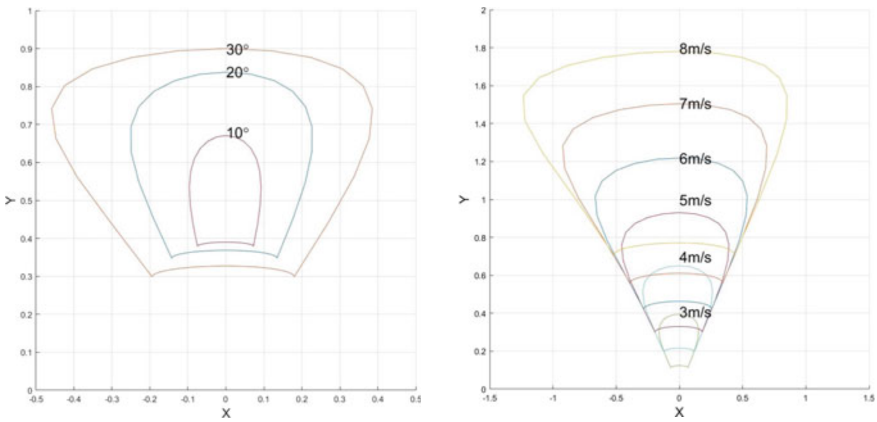


Fig. 5 Coordinate establishment and transformation. In **a** φ_1 represents the spray opening angle; φ_2 represents the radial angle of injection. In **b** represents the relative coordinate system; In **c** represents the absolute coordinate system



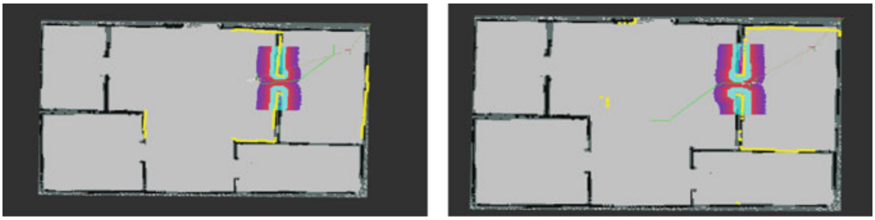
(a) (b)

Fig. 6 Relationship between the spray range of the disinfectant and the spray opening angle and the initial spray velocity. In **a**, the initial spray velocity is 5m/s, and the spray opening angle is 10°, 20°, 30°. In **b**, the spray opening angle is 30°, and the initial spray velocity changes in 3–8m/s

is determined by the speed of the fan, the spray opening angle is determined by the pump power. Therefore, according to the relationship between simulation and calculation, the robot can choose the power of the pump and the speed of the fan according to the width and depth of the terrain of the disinfection area to achieve the optimal disinfection efficiency.

3.3 AMCL Is a Probabilistic Localization System for 2D Mobile Robots

Adaptive Monte Carlo Localization(AMCL) is used in the localization section. AMCL is a probabilistic localization system for 2D mobile robots. It achieves adaptive (or KLD sampling) Monte Carlo localization. Based on the known map, particle filters are used to track the robot's attitude. The basic idea of traditional Monte Carlo localization refers to particle filtering and Bayesian filtering. From the viewpoint of Bayesian theory, state estimation problem is to calculate the credibility of the current state according to the previous series of existing data recursively, which is mainly divided into two steps: prediction and update. The particles are sampled from the motion model, and the current confidence is used as the start point. The measure model is selected to determine the particle weight distribution. The initial confidence is obtained from those particles which are randomly generated by the prior distribution (set the sampling points), and the same weight factor is assigned to each particle. KLD is introduced by AMCL method, KLD method takes the sample collection after being weighted not the re-sampling as input. AMCL method produces the sample set until reaches its approximation error of statistics. ROS has prepared the relevant



(a) (b)

Fig. 7 Localization simulation results. **a** shows the motion planning of the robot from the starting point, and **b** shows the simulation when the robot returns

function package which can easily running by subscribing to the relevant topics and setting some parameters.

In the planning section, A* algorithm [11] is quoted to get the effective routine which is also the shortest. The whole area would be simplified to the area contained with square grids, turning the map to the two-dimensional array. The number of the grids, which is calculated by the program, is the routine needed. The shortest routine would be searched from the start point to the surrounding area. Each start point is determined by the grid which has the minimum sum of the distances from A and B. In the ROS platform, a virtual scene is constructed and motion planning is carried out (Fig. 7).

4 Conclusions and Future Work

This article introduced a body temperature monitoring robot that could perform deep learning and a disinfection robot that could navigate autonomously. Most of the robots on the market now complete the epidemic prevention work independently. If the robot fails, the entire anti-epidemic system may be paralyzed. In the future work, we plan to group multiple robots into a robot system. Divide the task to be completed into multiple parts, arrange specific tasks for the robots in the system, and cooperate to complete the tasks through a collaborative method, so that the anti-epidemic work can run stably.

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