

Research based on open space collaborative intelligent fire system

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Abstract. The open space collaborative intelligent fire protection system studied in this article uses STM32F407 as the main control chip of the drone, and the STM32F103 is used as the main control chip of the fire truck. ZigBee wireless communication and other modules. The main innovation of this article is to use OpenMV's ground black line recognition positioning, the attitude fusion algorithm of the main controller module, and the PID control algorithm for real-time positioning of drones and fire trucks in the testing area of the test. After actual testing and verification, this system can complete the full coverage of the patrol area in different environments, fire identification in the patrol area, and fire extinguishing tasks. Through the ZigBee wireless communication module Essence.

Keywords: Drone, Unmanned Fire Truck, Gesture Fusion Algorithm, PID Control Algorithm.

1. Introduction

Avacal collaborative intelligent fire protection system is a fire system that combines air drones, ground robots, visual recognition^[1] and artificial intelligence deep learning technology, which aims to improve fire response capabilities and fire extinguishing efficiency. This system uses advanced sensors, communication and artificial intelligence technology to enable air drones and ground robots to achieve real-time collaborative operations and information exchange.

In recent years, the research and application of open space collaborative smart fire systems has gradually emerged at home and abroad. The fire departments and research institutions of some large cities have begun to explore and develop open space collaborative intelligent fire protection systems. Researchers are committed to developing efficient task allocation algorithms to ensure that drones and robots can work together and conduct information collection in the fire scene⁰ and a series of fire extinguishing operations^{[3][4]}. In addition, some key research directions also include independent navigation and path planning of fire robots, fire detection and monitoring technology of drones, and intelligent management systems of the Fire Command Center. However, in general, the research of open space collaborative intelligent fire systems is still in a relatively early stage, facing many difficulties, such as the positioning error of the quadrilateral drone^[5], the anti-interference capacity of the open space collaborative real-time and the system^[6]. Generally, in the face of the real-time path planning and response measures of complex ground fire trucks, etc. The open space collaborative intelligent fire protection system studied in this article has the innovation of path planning algorithm^[7] and other more in-depth research. It is expected that it will become an important tool in the fire extinguishing operation in the future, improve the efficiency of fire extinguishing, protect the safety of firefighters while reducing the fire caused by fires.

2. System solutions

The open space collaborative intelligent fire protection system studied in this article is mainly composed of the main controller module, image recognition module, wireless communication, optical current positioning module, and motor module. The choices of these modules are demonstrated below.

2.1. Research and selection of the main controller module

The MSP430 series single -chip microcomputer using Texas instruments is used as the main controller. This series of single -chip machine resources are rich, easy to control, and low power consumption. However, this series of single -chip microcomputer itself is low and the processing speed is slow.

The STC51 single -chip microcomputer is used as the main controller. This series of single -chip microcomputer resources are rich, easy to program, and complete. However, the chip has a slower operation process, lack of self -protection ability, and inadequate burning.

The STM32F4 series single chip machine is used as the main controller. The STM32F4 series is based on ARM Cortex-M4 as the core, and the highest frequency is 32-bit single-chip machine with 168MHz. It has the characteristics of fast speed, good performance, small power consumption, internal timer, IIC, SPI and other resources. Can meet the requirements of various embedded development. And this series of single -chip microcomputer has rich development resources, especially the STM32F4 series single -chip microcomputer has more communication interfaces, which has a higher number of main frequency and serial ports than other series of single -chip microcomputers.

In summary, on the main controller module, the system designed in this article uses uses STM32F407.

2.2. Research and selection of image processing module

Select CMOS camera such as OV7620 as an image processing module. The resolution of OV7620 can reach 640×480, and the maximum image collection rate is 60 frames per second. It can be configured to output RGB565 color graphs or gray graphics, which comes with FIF, but the read image format is complicated and the development cost is not high.

Select K210 as an image processing module. K210 is a camera that adopts the RISC-V processor architecture with a visual and hearing, independent IP kernel and programmable capabilities. It supports a camera for machine vision and machine hearing multi-modal recognition, and has a good computing power And better power consumption performance, stability and reliability. However, the K210 camera resolution is low, resulting in the vague shooting images. In addition, K210 supports less video formats.

Select OpenMV as an image processing module. OpenMV contains 216MHz ARM Cortex-M7 microprocessor and OV7625 camera is an open source, small, low-power, low-cost programmable camera, which can support a series of extensive image processing functions and neural networks support machine vision and machine auditory audiovisual. Multi -mode recognition, with high image clarity, supports more video formats.

In summary, in the image recognition module, t the system designed in this article uses uses OpenMV.

2.3. Research and selection of motor module

Select DC motor as a motor module. DC motors are large, wide range of speed, good dynamic characteristics, simple transmission functions, and fast speed. However, this type of motor can only control the speed, poor controllability, and it is difficult to control the position of the motor.

Select the step motor as a motor module. Step motor can realize the opening of the ring, no feedback signals, suitable for high -precision control, and the effect of frequent action control of short distances. However, this type of motor is complicated, with high delay value, slow speed, small torque, and poor dynamic characteristics, which are not suitable for real -time control.

Choose a brushless motor as a motor module. Brushless motor has high speed and strong controllability. It adopts external rotor structure and large torque, and is convenient for control. From a mechanical perspective, brushless motors are almost a maintenance -free motor with the advantages of low interference, low noise, smooth operation, long life, low maintenance costs, and easy real -time control.

On the motor module, the system designed in this article uses a brushless motor.

3. System theoretical analysis and calculation

3.1. System performance analysis

The open space collaborative intelligent fire protection system studied in this article uses STM32F407 and STM32F103 as the main control module, which has the advantages of good performance, fast operation processing speed, short response time. The image recognition module adopts the OpenMV module, which is compatible with a variety of image resolution and has good image processing capabilities. The communication signals between the overall circuit of this design are relatively stable, ensuring that they have good real-time security adjustment capabilities during the flight^[8], and can efficiently process and analyze real-time data.

3.2. Theoretical calculation of system function implementation

3.2.1 High suspension algorithm

The data of the laser-fixed high module and SPL06 air pressure meter is read at 50MS. The main control module will integrate the data obtained by the main control module, and the high control of the output of the drone will be exported to the flying high. As shown in Fig 1.

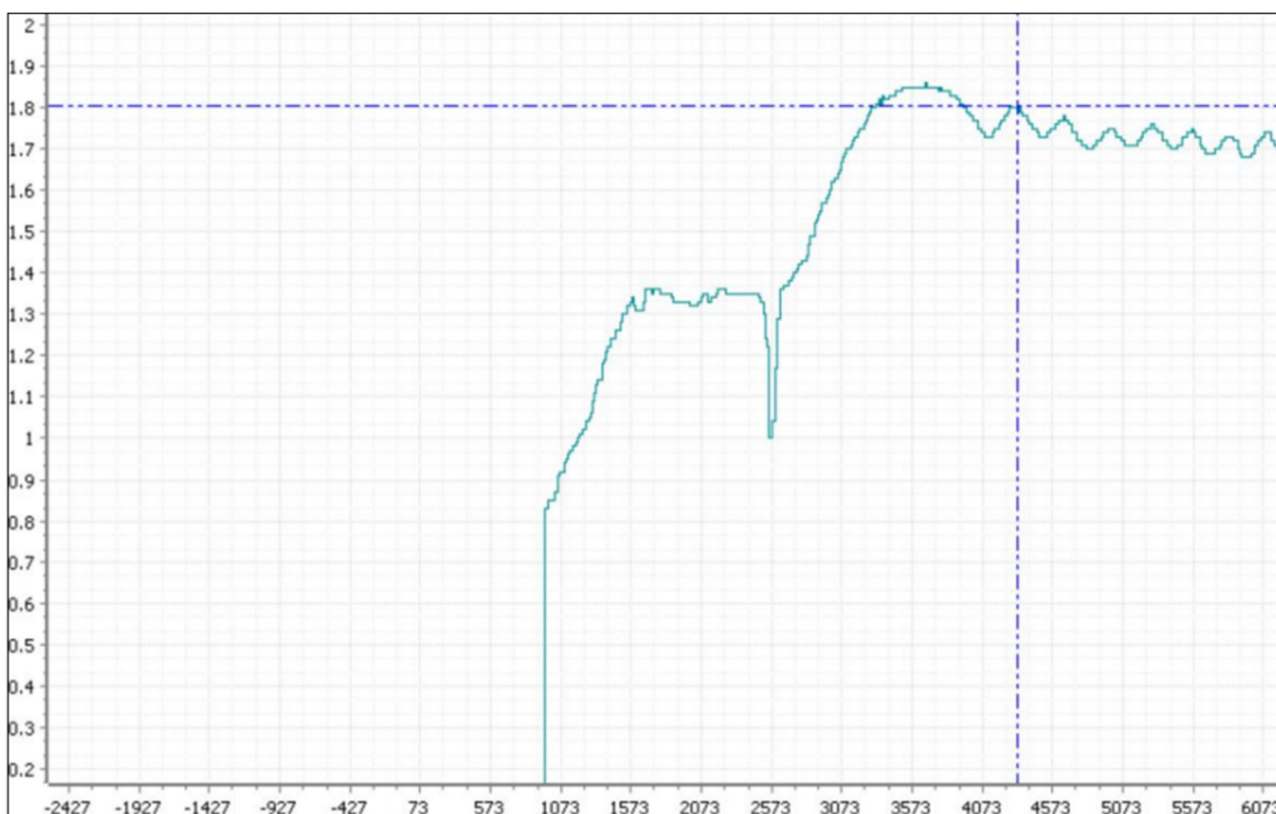


Fig 1. Air fixed high suspension algorithm test waveform

3.2.2 Image processing algorithm

Divide OpenMV images into five interests (ROI) areas to find the maximum color block in the five interested areas with the goal of finding black lines, and then find the central point coordinates of the center of the black line; All the black lines in the image, then find the straight line in the qualifying group, and find the coordinates of the intersection. OpenMV sends the coordinates of the black line center and the intersecting black line to the flight control process to achieve real-time positioning and the full-scale coverage of the patrol area.

3.2.3 PID control algorithm

The PID control algorithm is a classic algorithm in the principle of automatic control. It is widely used in industrial control and consists of proportions, points, and differential links. Its application principle on drones. As shown in Fig 2.

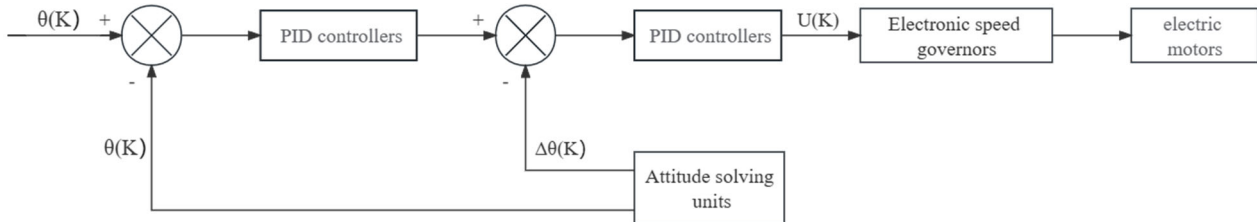


Fig 2. Principles of serial PID controller

The proportional control is the basis of the PID control algorithm, which determines the strength of the control; integral control can eliminate the static error of the system; in addition to hoping to eliminate static errors, the system also requires to accelerate the adjustment process. At the moment when the deviation occurs, a immediately respond to the deviation, and at the same time, it is necessary to pre -give appropriate corrections based on the changing trend of the deviation. To complete the requirements of the system, you need to add micro -control control. In this system, the PID control algorithm is mainly used for the position control of the drone.

The core of the drone to complete the full range of the patrol area is the position control of the drone. As shown in Fig 3, the main control module uses the acquired black line center and the coordinate OPMV_MEA of the fire source, and the expected coordinates calculated in the program OPMV_EXP is reduced to obtain deviation ERR:

$$err = opmv_exp - opmv_mea \tag{1}$$

Cumulate the deviation value ERR to get ERR_i:

$$err_i = err_i' + err \tag{2}$$

Err_i 'in the formula (2) represents the accumulated deviation before the accumulation of ERR accumulation. Use the deviation value again ERR_D can output PID_OUT of the position control of the drone through the proportions, points and differential links of the serial PID controller, so as to correct the response of the system location information⁷⁶, as shown in the following formula (3):

$$pid_out = k_p \times err + k_i \times err_i + k_d \times err_d \tag{3}$$

In the formula (3), KP, KI, and KD respectively represent the proportional item coefficient, integral item coefficient and differential project coefficients.

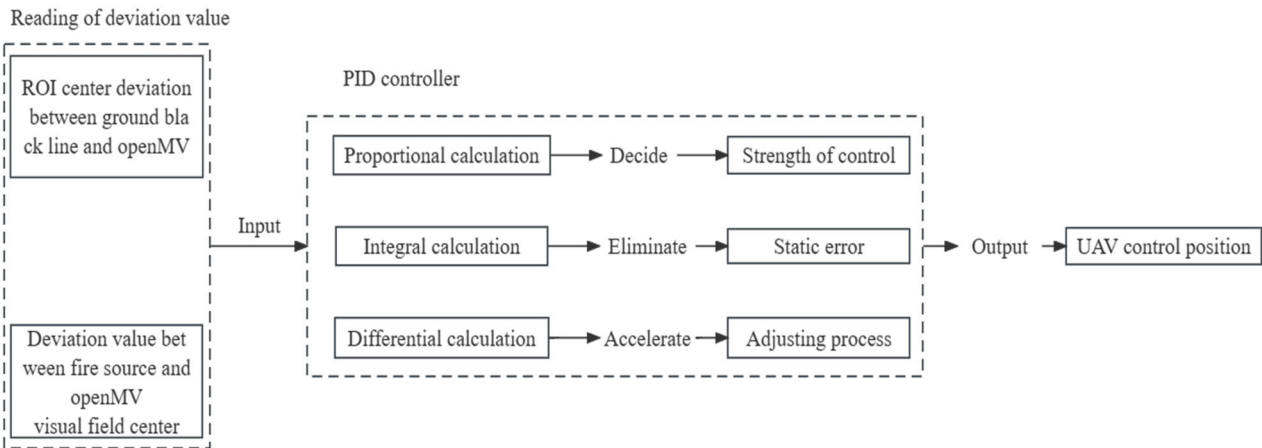


Fig 3. UAV position PID control schematic diagram

4. Circuit and program design

4.1. Circuit design

The open space collaborative intelligent fire protection system studied in this article is mainly composed of the drone system and the fire truck system. The overall box diagram of the system circuit is shown in Fig 4. The circuit of the drone system consists of the main controller module, image recognition module, wireless communication module, light current positioning module, motor module, posture acquisition and solution module, and indicator light module. The circuit of the fire truck system consists of the main controller module, image recognition module, wireless communication module, key module and display module. The main control chip STM32F407 and STM32F103 are used to perform wireless communication through the wireless communication module ZigBee.

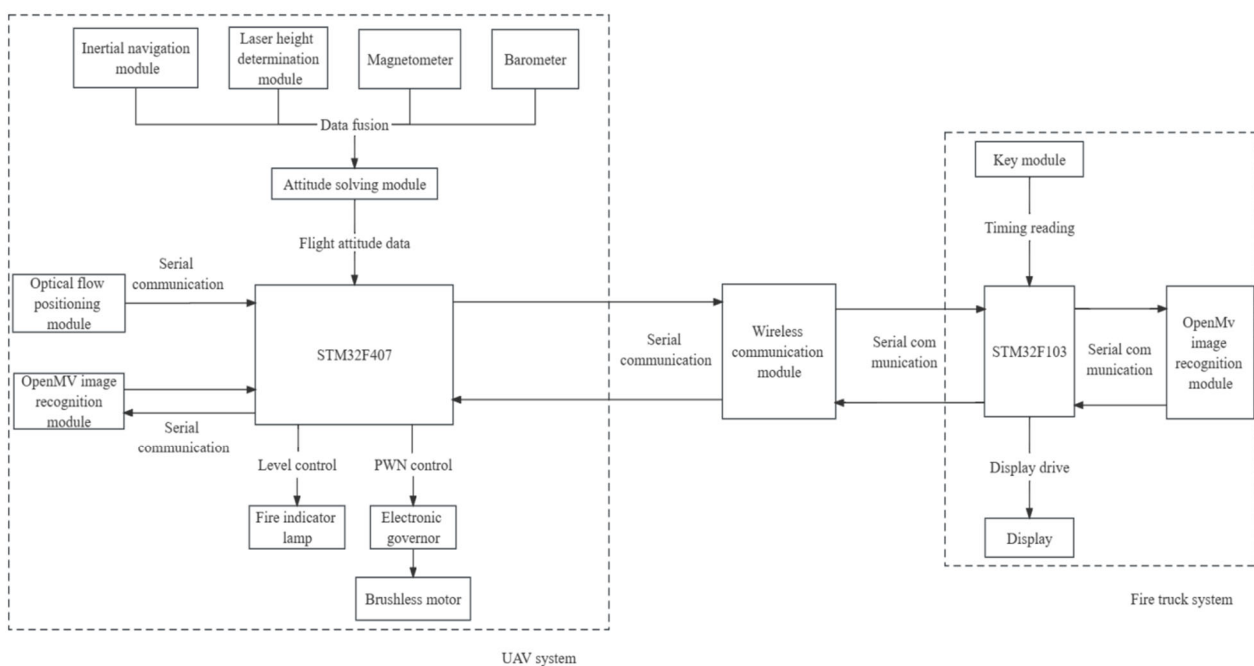


Fig 4. System circuit overall box diagram

4.2. Programming

4.2.1 Program function description and design ideas

The software part of the open space collaboration in this article implements the image processing of OpenMV, control of drone motion trajectories, control of the motion trajectory of electric cars, and display functions of display screens.

(1) OPENMV image processing:

Movement control of drones.

On the fire truck system, OPENMV is responsible for conducting fire source detection of fire sources of fire [10] after completing the fire extinguishing task. Control modules perform fire truck control.

(2) Control of drone motion trajectory: STM32F407 processes the data sent by OpenMV through the serial port, controls the motion status on the horizontal plain direction of the drone, and completes the control of the drone motion trajectory.

(3) Control of the fire truck motion trajectory and display function: STM32F407 will send the processed valid data to STM32F103 in real time through wireless communication. It will process the data received with the data read by its own OpenMV and pass it through it and pass it through it. OLED and LCD display display.

4.2.2 Program flow chart

The main programs of the open space collaborative intelligent fire protection system studied in this article are divided into programs for STM32F407, which are controlled by drones in the main control module and STM32F103 of the fire truck.

This system needs to complete the key control drone take-off on the fire truck, the drone is fully covered in the cruise area, and the coordinate information, fire source coordinates and fire information of the drone are updated in real time through wireless communication Perform a series of tasks such as fire extinguishing tasks and returning starting areas.

- (1) Fire truck program flow chart is shown in Fig 5.
- (2) The main program flow diagram of the drone is shown in Fig 6.

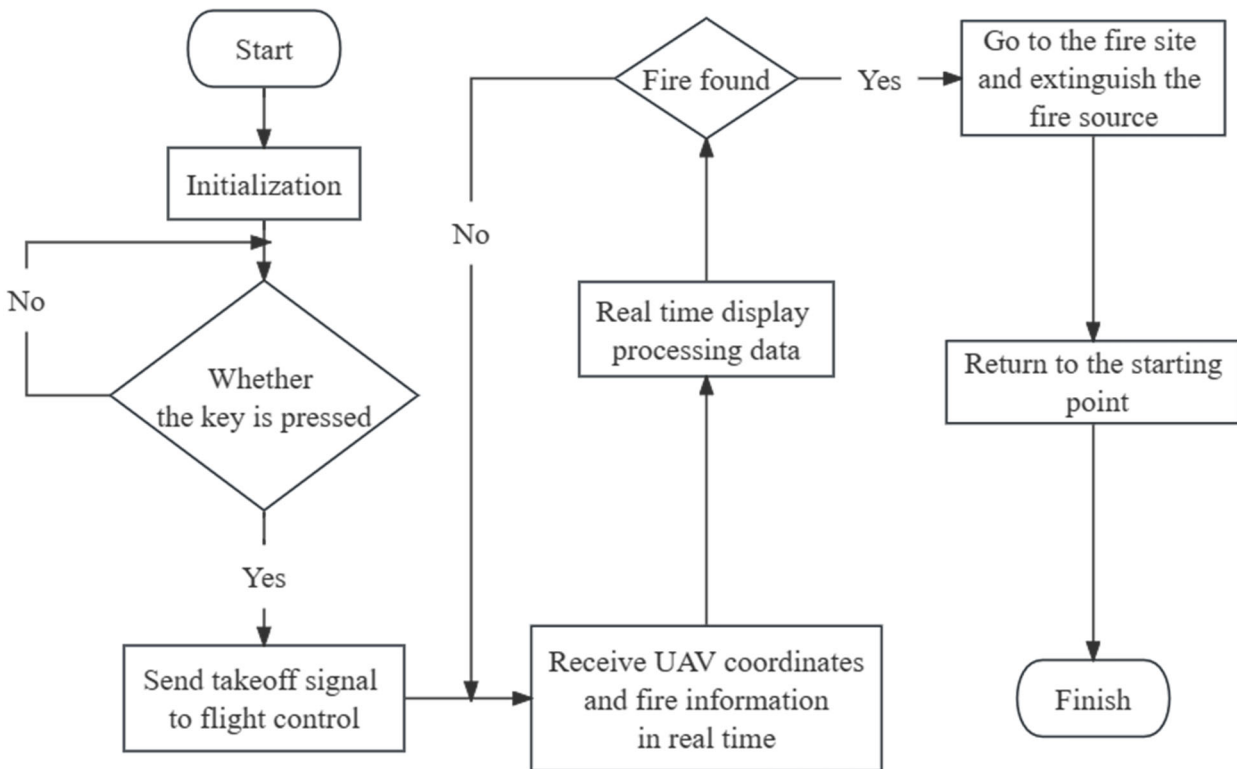


Fig 5. Fire truck owner program flow chart

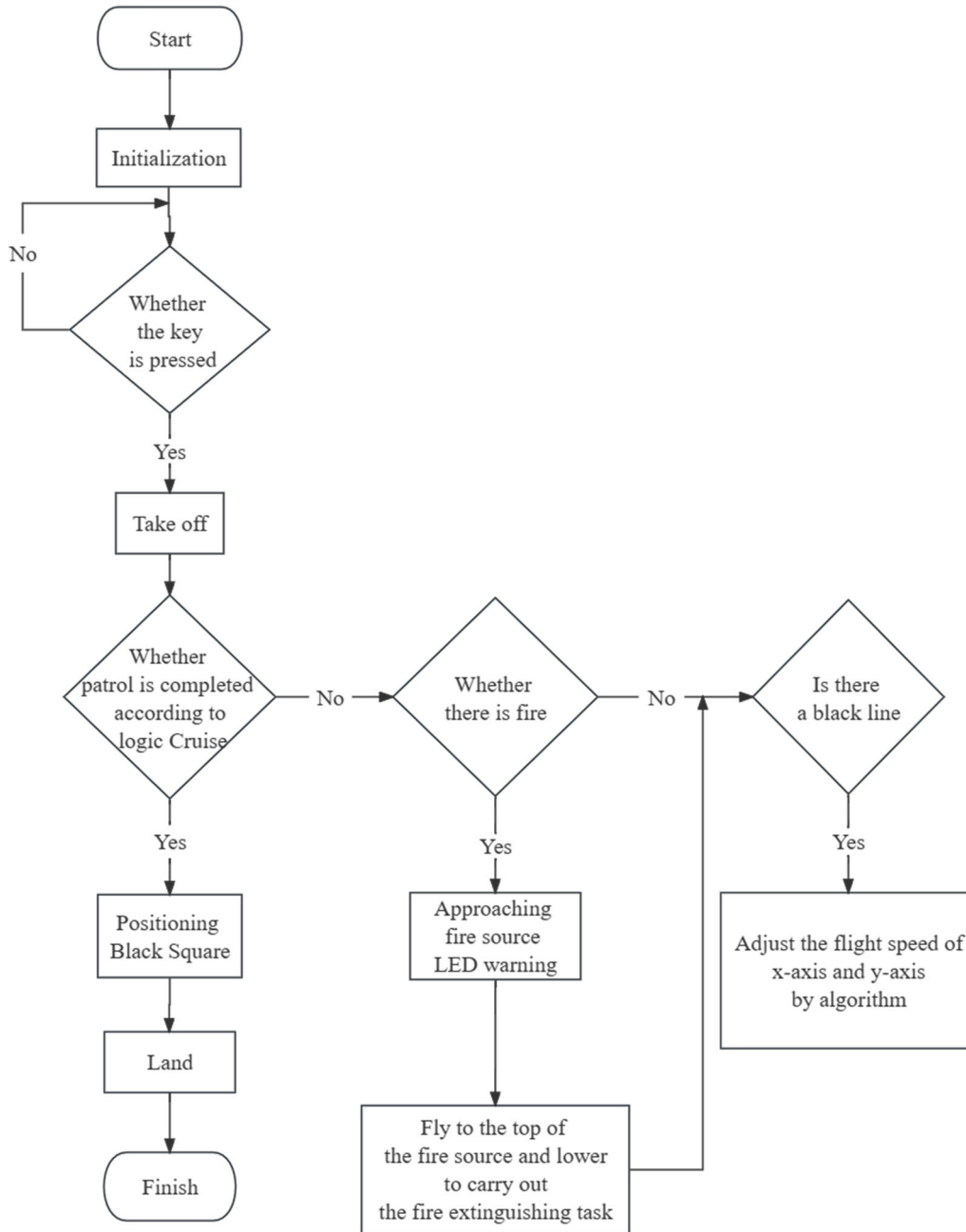


Fig 6. Drone program flow chart

5. Test scheme and test results

5.1. Test Conditions

According to the corresponding test venue of the drone, the test instrument has a homemade simulation fire source, aircraft, and electric car with display screens.

5.2. Test program

Before testing, measure whether the battery power of the drone, electric car and simulation fire source is sufficient before testing, and then call to observe whether STM32F407, STM32F103 and OpenMV work normally. During the measurement, pay attention to observe whether the drone, electric car and simulation fire source complete the corresponding tasks, use the tape measure to measure the height of the flying height of the drone, and use a stopwatch to measure the exercise time of drones and electric cars.

5.3. Test results and analysis

The simulation fire source in the open space collaboration in this article controls its opening or closing under the continuous illumination of laser pens, continuously open for about 2 seconds, and then continue to turn off for about 2 seconds. The test results are shown in Table 1.

Table 1. Simulation fire source test table

Testing frequency	Simulation fire source is continuously illuminated for two seconds whether to turn on/off
1	Yes
2	Yes
3	Yes

The drone takes off to about 18DM height, complete the full coverage patrol in the planned route according to the planned route, and then return and land accurately in the take -off area. The test results are shown in Table 2.

Table 2. Drone patrol test table

Testing frequency	Flying height/cm	Flight time/s	Full coverage	Whether to accurately land and take the take -off area
1	181	110	Finish	Yes
2	182	113	Finish	Yes
3	181	113	Finish	Yes

The empty land collaborative intelligent fire protection system studied in this article can realize wireless communication between the drone and the fire truck. The display on the fire truck displays the location coordinate information of the drone in real time, showing that the patrol track curve is calculated and the patrol range is accumulated. The test results are shown in Table 3.

Table 3. The collaborative function test table of drones and fire trucks

Testing frequency	Whether to display the coordinates in real time	Whether the patrol track curve is displayed	Whether to show accumulation of patrol voyage
1	Yes	Yes	Yes
2	Yes	Yes	Yes
3	Yes	Yes	Yes

During the drone patrol, after the fire was found, it was close to the fire source and alerted it with LED indicator lights. The drone flew to the top of the fire source, reduced to about 10DM height, and the fire extinguishing bag was thrown after hovering for 3S, and then the location coordinates of the fire source location were sent to the fire truck, and then patrolled. Essence The test results are shown in Table 4.

Table 4. Drone fire extinguishing task test table

Testing frequency	Whether to find the source of the fire	Whether LED warning	Whether to complete the fire extinguishing task	Whether to display fire source coordinates
1	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes
3	Yes	Yes	Yes	Yes

When the fire truck receives the fire information, the display on the fire truck can display the location coordinates of the fire source location in real time, and after the arrival of the fire source location, it will extinguish the source of the fire source at 5dm at 5dm from the laser pen. The test results are shown in Table 5.

Table 5. Fire truck fire extinguishing function test table

Testing frequency	Whether there fire information	Whether to display fire source coordinates	Whether to reach the source of the fire	Whether to destroy the fire
1	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes
3	Yes	Yes	Yes	Yes

After many testing, the fire truck can be successfully returned to the departure area after extinguishing the fire source.

6. Conclusions

According to the above test data, fully illustrate the open space collaborative intelligent fire protection system studied in this article that can complete a variety of basic and complex functions. First of all, the self-made simulation fire source can be controlled or closed through continuous irradiation of laser pens. Secondly, the drone can complete the full coverage of the patrol area at a high degree of flight at about 18DM after taking off. Furthermore, in the process of flying, the OLED display on the fire truck can display the coordinates of the drone and the accumulation of drones in real time, and the patrol track curve can be displayed on the LCD display. Finally, during the drone patrol, after the fire was found, it was able to approach the fire source and warn with the LED indicator light. At the same time, the location coordinates and fire information of the fire source location were sent to the fire truck to continue patrol, and they returned to the take-off point after completion. After receiving the fire information, the fire truck went to the fire source location to perform the fire extinguishing task, and returned to the departure area after completion.

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