

## Designing of the Forest Fire Detection Robot

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### Abstract

In order to solve the heavy and difficult task of forest fire detection, a kind of fire detection robot is designed. The accuracy of detection is improved by multi-sensor fusion technology and the corresponding algorithm. The infrared distance sensor is used to implement the obstacle avoidance of forest complex terrain effectively. The built-in GPS chip of the robot is connected to the open interface of Baidu map, and the information of fire position can be accurately fed back to the mobile phone through the wireless transmission module. The experimental results show that the robot has simple structure, low cost, and can implement embers detection and positioning safely and efficiently.

### Keywords

Fire detection robot, multi-sensor fusion, GPS positioning technology, forest fires, embers.

### 1. Introduction

When the forest fire is extinguished, the first thing to do is get rid of the embers. Otherwise, the embers can be easily rekindled in the combustibles such as hay leaves, residual branches and shrubs, and cause greater losses under natural conditions such as strong wind and light. However, the embers are generally smoldering, relatively hidden, often only a small amount of smoke or even smokeless[1]. At present, fire cleaning is mainly carried out by firefighters or the masses. In this way, on the one hand, more manpower input is large, on the other hand, human patrol is passive. Only if the embers extend to a certain range, or if the amount of smoke increases, the fire can be found[1]. And residual fire smoke, toxic gases and so on with the irregular movement of natural factors, always threatening people 's personal safety. Therefore, the study of forest fire detection robots is of positive significance to reduce the economic losses caused by embers, the damage to the ecological environment and protect people' s life safety [2].

### 2. Embers of Forest Fire Detection System Design

This design provides a detection robot for embers of forest fire. The robot uses the structure of track and track wheel as the transmission mechanism to strengthen the stability of the robot operation process and improve the obstacle crossing ability [3]. The fire extinguishing process is equipped with an infrared distance sensor to facilitate march forward on the complex ground in the forest area and effectively avoid obstacles. The robot fulfills the monitoring requirements [4] of embers by installing gas sensors, smoke sensors and flame recognition sensors. When the embers is monitored, the alarm can be triggered, and the accurate location of the embers can be sent to the mobile phone by using GPS positioning technology.

According to the function and main requirements of the robot, the system relationship of the embers detection robot is shown in Fig. 1.

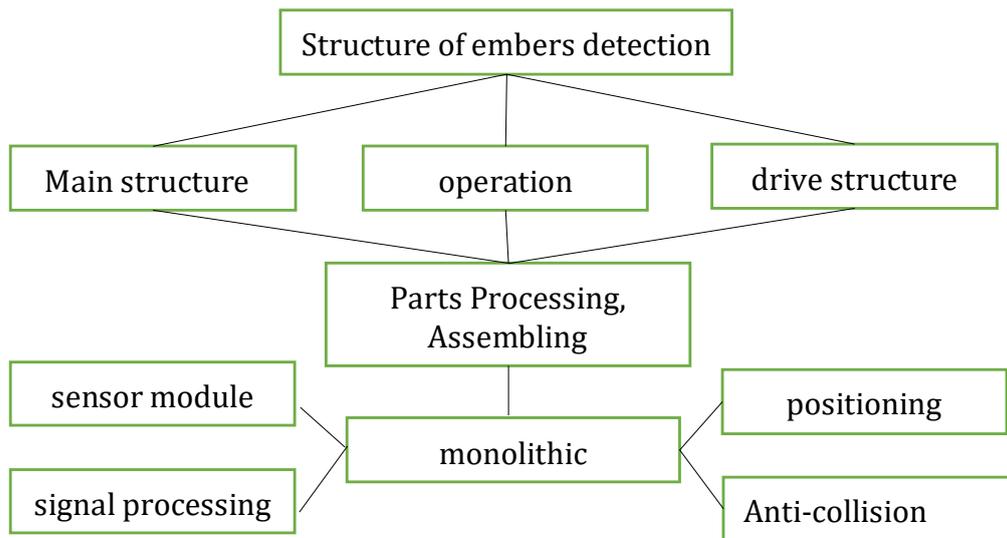


Figure 1: System Relationship of Fire Detection Robot

### 3. Design of Embers of Forest Fire Detection Robot Structure

The structure diagram of the robot is shown in Fig. 2, and the internal structure diagram of the robot is shown in Fig. 3.

The gas sensor and smoke sensor are fixed at the four corners of upper face of the robot shell to monitor the smoke-related signal; the infrared distance sensor is connected to the shell by bolts and avoids obstacles by using the principle of infrared reflection [5].

The rotating shaft of the rotary support is connected with the stepper motor fixed on the shell through the shell, and the stepper motor can drive the rotary support to rotate. The alarm light is vertically set in the middle of the rotary support. When the embers is monitored, the alarm light flashes. In addition, the rotary support is connected with a light and flame identification system through a screw, which is convenient for the robot to work at night; the flame identification system is composed of a bracket and a camera, which are connected by a rotating shaft, and a motor is arranged at one end of the rotating shaft as its power source.

According to the requirements of the design for forest areas, the first track guard plate, the second track guard plate and the chassis are respectively fixed on both sides and the bottom of the shell by screw connection to facilitate robot walking.

The outer rings of each driving wheel, driven wheel and pulley are processed with trapezoidal teeth, and the inner and outer sides of the crawler are trapezoidal tooth structure, which can be effectively meshed and connected. The motor is connected with the rotating shaft through the gearbox to drive the rotating shaft to rotate, and the belt pulleys and the driving wheels on both sides are meshed and connected with the shell and the plate through the rotation shaft [6]. The GPS chip, signal processing system and three motors are fixed on the chassis and electrically connected to the battery. The battery is also fixed on the chassis through the booth. Each sensor, floodlight, alarm lights, flame identification system, GPS chip and motor are electrically connected with the signal processing system.

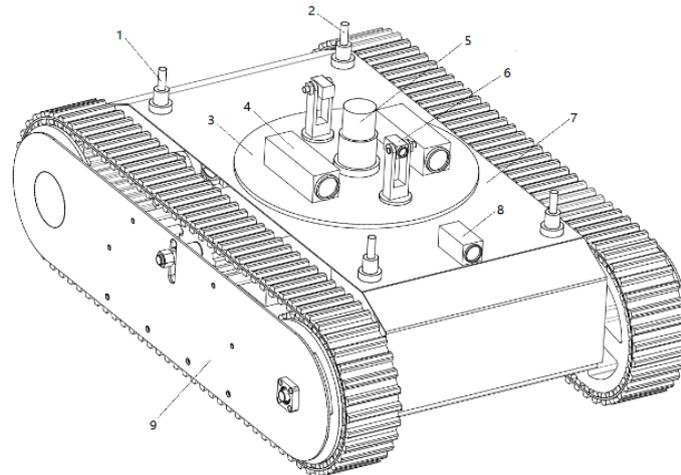


Figure 2: Robot structure diagram

In the figure : 1.Gas sensor; 2. Smoke sensor; 3. Rotary support; 4. Lighting; 5. Alarm lights; 6. Flame recognition system; 7. Shell; 8. Infrared distance sensor; 9.The first track protective board

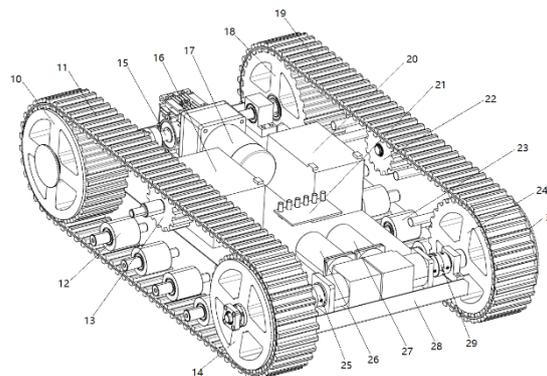


Figure 3: Internal structure diagram of robot

In the figure: 10. First driven wheel; 11. First track; 12. First driving wheel; 13. First pulley; 14. First active wheel; 15. First rotating shaft; 16. GPS chip; 17. First motor; 18. Second driven wheel; 19. Second track; 20. Battery; 21. Signal processing system; 22. Second pulley; 23. Second driving wheel; 24. Second active wheel; 25. Second rotating shaft; 26. Second motor; 27. Third motor; 28. Chassis; 29. Third shaft; 30. Second track protection plate

#### 4. Working principle of forest fire detection robot

The body of robot is driven by a crawler wheel, which is convenient to move in the complex terrain of the forest areas. When the robot moves forward, the three motors drive three rotating axes respectively, and drive the driven wheel and the active wheel to rotate in the same direction, further driving the two crawlers to rotate horizontally, thus driving the chassis and the shell of the robot to move forward. When the robot turns, the second motor and the third motor drive two shafts to rotate, and make the two active wheels rotate reversely to realize the turning operation of the robot [7] . When the front side encounters higher obstacles, the infrared distance sensor will detect the infrared light reflection signal, indicating that there are obstacles, so as to realize the anti-collision of the robot.

The robot tracked chassis is equipped with an integrated sensor for embers detection, which is monitored in a wide range by gas sensor and smoke sensor. The gas sensor and smoke sensor are used for large-scale monitoring. The gas sensor is responsible for monitoring the CO and CO<sub>2</sub> generated by embers, and the smoke sensor is responsible for monitoring the smoke

particles generated by embers [8]. When the robot encounters forest fire, the relevant signals detected by the gas sensor and smoke sensor will feed back to the signal processing system, and then the embers will be accurately identified by the flame recognition system on the rotary support. When working at night, turn on the floodlight to highlight the target range. After the embers location is found, the alarm signal is triggered and the alarm light flashes. And positioned by the GPS chip, the position information is transmitted to the signal processing system.

## 5. Advantages of forest fire detection robot

The tracked wheel drive mode is adopted in the design of the embers detection robot, and the infrared distance sensor is installed on the fuselage, which can effectively solve the driving difficulties and anti-collision problems of the robot in the detection process of forest areas. The robot adopts multi-sensor fusion technology, through corresponding signal extraction and algorithm processing [9], it solves the problem of concealment of embers, greatly improves the detection accuracy and reduces the labor intensity of forest security personnel. Using GPS positioning technology and wireless communication technology to accurately feedback fire location information to mobile phones can not only realize fire location, but also prevent theft by networking and solve the problem of loss. The robot is also installed lighting and alarm devices to facilitate night work.

## 6. Summary and outlook

Aiming at solving the difficulty of forest fire detection, this design proposes a kind of embers detection robot, which can not only realize embers detection function safely and efficiently, but also has simple structure and low cost, which is beneficial to solving the problems of low efficiency, high labor intensity and high risk in the process of traditional fire monitoring. In the future, it can be developed to be intelligent. In view of the situation that multiple residual fire sources or flame sources are monitored, more advanced algorithms are used to achieve the optimization of driving path within the safe distance. In the future, it can cooperate with the firefighting robot which can independently extinguish the fire, so as to realize the integration of monitoring and firefighting, saving time and manpower and material costs. This design can also optimize the system according to the needs of different users, and broaden the business scope of robots, which has great promotion value.

## Acknowledgements

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## References

- [1] Li Jianyou, Zhang Shuifeng, Zhang Siyu: Overview of UAV application in forest fire protection, Forest fire prevention, Vol.1(2018) , p.45-49.
- [2] Bao Mingsong, Sun Hongxiu, Li Xibin, etc: Development and application of crawler special fire reconnaissance and fire extinguishing robot, Electronic production, Vol.7(2020), No.13,p.99-100.
- [3] Yao :*Research on the design of forest fire extinguishing robot*. (Ph.D., Northeast Forestry University, China 2021).
- [4] SONG Qian: *Research on multi-sensor detection system of forest fire residual fire detection and cleaning robot*,(Ph.D., Nanjing Forestry University, China 2017).

- [5] Zhang Nan: *Mechanism Design and Control of Forest Fire Detection Robot*. (MS., Nanjing Forestry University, China 2016).
- [6] Fuxiang Nie, Nie Fuxiang, Wei Hongmei, Li Feng, Jiang Jie: Design of Motion Control System for Fire Fighting Robot, *Journal of Physics: Conference Series*, Vol.1(2020).
- [7] Sridevi Chitti, Chitti Sridevi, Ramchandrarao P., Padmaja Ch., Raghava Kumari D: Fire Detection and Direction Control of Fire Fighting Robot, *IOP Conference Series: Materials Science and Engineering*, Vol.2020.
- [8] Yao Yuan, Li Juan: Fire cleaning technology after forest fire , *Agricultural technology services*, Vlo.3(2013), p.235.
- [9] Zan Xinyu, Zhang Tiefeng, Yuan Jinsha: Mobile robot fire rescue path planning method based on improved ant colony algorithm, *Science, technology and engineering*, Vlo.21(2021).