2011 International Conference on Intelligence Science and Information Engineering

Design and Implementation of Mobile Robot Remote Fire Alarm System

Hongke Xu, Hao Chen, Chao Cai, Xunzhao Guo, Jianwu Fang, Zhu Sun
School of Electronic and Control Engineering
Chang'an University
Xi'an, 710064, China
e-mail: xuhongke@chd.edu.cn, 317474978@qq.com.

***Abstract*—The current fire fighting robot accomplishes mostly assignments independently, which cannot meet the demand that managers in remote terminal mastery the real-time information of fire scene. Aiming at this problem, this paper designs and implements the mobile robot remote fire alarm system, which is composed of two parts: mobile robot and remote terminal. Modules of the two parts which consist of control module, communication module, flame detection module, remote terminal display module are designed in this paper based on the analysis of system structure and experimental platform. STC89C52 is taken as processor of mobile robot and remote terminal, while photoelectric sensors, infrared sensors and other sensors are combined as the detecting system. The software system designs and implements the algorithm of fire detection, robot's line-tracking, wireless communication and other algorithms, which improves system flexibility and adaptability. The experimental result shows that mobile robot with the ability of accurate fire detection and line-tracking can send the remote terminal real-time information of fire, which can be analysed and processed by the remote terminal to alarm. So it has widespread application value.**

Keywords-remote fire alarm system;mobile robot;remote terminal;wireless transmission

I. INTRODUCTION

Robot as the one of the greatest inventions of mankind in 20st century, since its advent in the early 60s, has undergone over 40 years of rapid development. Fire fighting robots are special robots, which as special fire fighting equipment can replace firefighters near the scene to fight fire and rescue effectively and carry out reconnaissance missions of the fire. The Application of fire robot will greatly enhance the fire department's ability to fight a vicious fire [1]. In some cases, managers in remote terminal process and make decisions according to the information of fire scene. However, the current fire fighting robots [2], [3], [4] accomplish the assignment mainly independently which cannot meet the demand. To solve fire alarm of this problem, this paper put forward a mobile robot remote fire alarm system, which is composed of the mobile robot and remote terminal. Mobile robot sends information of fire scene to remote terminal wirelessly in real time; remote terminal receives fire information and alarms. Through which the remote fire alarm function is completed. This paper studies and implements the method of the system in hardware design and software design. And its feasibility verified by experiments provides a platform for further research of intelligent fire fighting.

II. SYSTEM STRUCTURE DESIGN

Mobile robot remote fire alarm system includes subsystems-mobile robot system and remote terminal system. Mobile robot's functions mainly include: 1) Fire (candle in this design) Detection. It can not only detect the fire on both sides of fixed route, but also detect the fire automatically in the area without fixed route. 2) Smoke Detection. 3) Temperature Detection. 4) Obstacle Avoidance. The robot stops and alarms when the distance of obstacle in front of it is 0.50m (error is 5cm). When the obstacle is removed, the robot removes alarm and moves on. 5) Record Distance Traveled. 6) Remote Wireless Transmission. It can send fire information wirelessly to remote terminal in real time. Remote terminal's functions mainly include: 1) Receiving the fire data sent from robot in real time, and alarming; 2) Displaying fire information, and saving record in real time.

According to the general functional requirements, system structure design is divided into robot structure design and remote terminal structure design. Mobile robot using STC89C52 MCU as control center is assembled by far-infrared flame sensor, infrared obstacle avoidance sensor, smoke sensor, temperature sensor, photoelectric sensor and wireless transmission module and so on. The general structure block diagram is shown in Figure 1. Remote terminal also using STC89C52 MCU as control center is assembled by LCD12864, the clock module and wireless transmission module and so on. The general structure block diagram is shown in Figure 2.

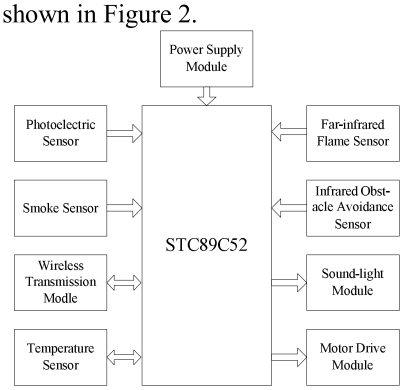

Figure 1. Robot's general structure block diagram.

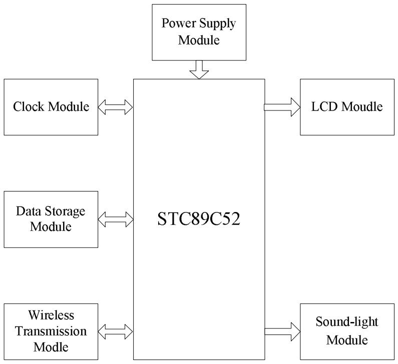

Figure 2. Remote terminal's structure block diagram.

III. BRIEF DESCRIPTION OF EXPERIMENTAL PLATFORM

According to the system structure design, the platform is figured as follows. The work process of robot is divided into two phases: tracking the fixed route, and detecting the fire on both sides of fixed route; finding the fire automatically. In the area of fixed route, fire can be placed on both sides of the route and obstacle can be placed in the route; in the area without fixed route where robot automatically finds the fire, the fire can be put within the radius of 2.3 meters from the robot. Figure 3 shows the experimental platform.

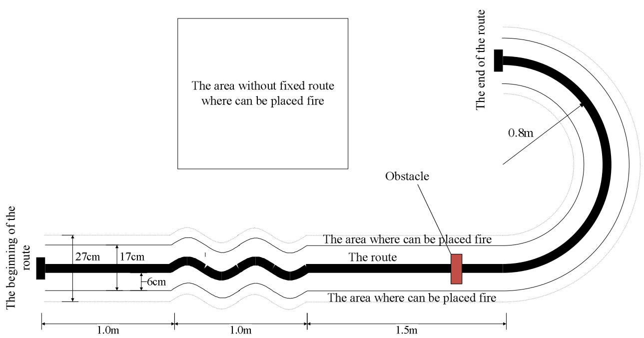

Figure 3. Robot's experimental platform.

The drive mode of mobile robot is differential drive. To complete the system functions well, the design makes a reasonable arrangement in hardware layout. It is shown in Figure 4.

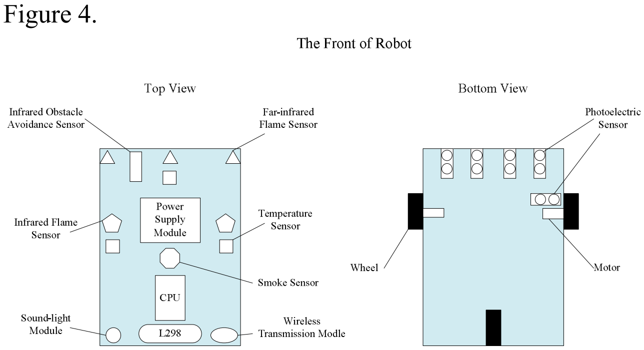

Figure 4. Schematic diagram of robot's hardware layout.

IV. SYSTEM HARDWARE DESIGN

A. Photoelectric Sensor

Mobile robot implements line-tracking mainly through the group of reflective photoelectric sensor which is composed of infrared LED and infrared reception diode arranged side by side, with circuit [5] in Figure 5. The principle of photoelectric sensor for line-tracking is: the road of different color (black and white) makes different levels of infrared reflection. The light received by infrared reception diode will be different after the reflection of the ground with the same infrared emission, leading to the different voltage output, which can be analysed to recognize the road.

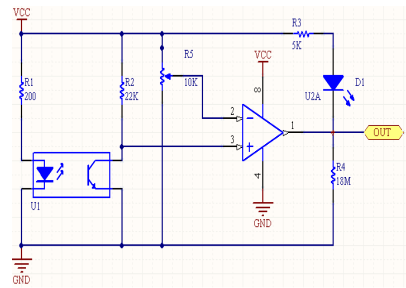

Figure 5. The circuit of photoelectric sensor.

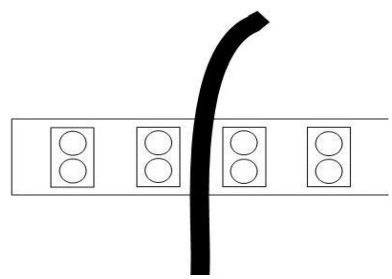

Figure 6. Schematic diagram of line-tracking.

To ensure the accuracy and reliability of mobile robot's line-tracking, the sensor group is composed of 4 units which are arranged on the both sides of the centerline of the chassis symmetrically, with the schematic diagram of line-tracking shown in Figure 6. Robot continuously collects the output of sensor group to adjust its operating state according to some control strategy. In this way, it implements line-tracking.

B. Wireless Transmission Module

As the task of mobile robot is arduous, the wireless transmission module should have the following features: convenient operation, low power consumption, long transmission distance and so on. SRWF-1021, which is transparent to users, exchanges information with the MCU in serial communication mode. Then it sends or receives information by its own radio frequency integrated circuit to complete the remote transmission of information. Information transmitted includes: fire position relative to the robot, the conditions of obstacle in front of robot and smoke in the environment, the temperature near the fire, distance and time traveled.

In the process of data communication, data flow consists of data frame, and the data frame consists of the bytes. Data flow transmitted is divided into three parts: the start frame, data frame and end frame. Start and end frames are composed of one byte respectively, while data frame consists of 15 bytes. Each byte of data flow is defined in Table I.

TABLE I. DEFINITION OF EACH BYTE OF DATA FLOW

Frame	Variable	Definition
Start frame	Fstart	Start variable
Data frame	a[0]	Flag of fire position relative to the robot
	a[1]	Flag of obstacle
	a[2]-a[4]	Temperature near the fire
	a[5]-a[8]	Distance traveled
	a[9]-a[12]	Time traveled
	a[13]	Flag of smoke
	a[14]	Check code
End frame	Ffinish	End variable

In this table, check code is the remainder of the sum of all data and ten, which is $a[14]=\sum_{i=0}^{13}a[i]\%10$.

In the process of data communication, different data represents different frame types. Frame types are shown in Table II.

TABLE II. FRAME TYPE

Data	Frame Type
0x11	Start frame
0x22	Acknowledgement
0x33	Negative acknowledgement
0x44	End frame

C. Far-infrared Flame Sensor

Mobile robot, finding fire automatically in the area without fixed route, need to ensure whether there is a fire around the environment or not at first. If the answer is yes, the robot will determine the direction, and drives fast towards it according to the information detected. The robot stops moving when the distance is about 10cm, then detects information and sends it to the remote terminal. Sensor group as flame sensor system is composed of three units, with the circuit [6] of far-infrared flame sensor unit shown in Figure 7.

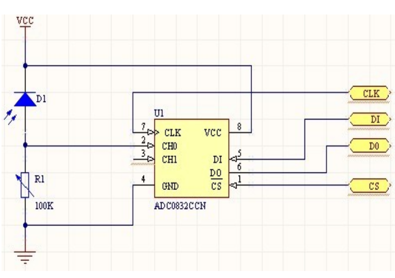

Figure 7. The circuit of far-infrared flame sensor.

Three units are arranged separately on left, middle and right three directions in front of the robot. The more intense the flame is, the large number the sensor will be read, which ranges from 0 to 255. Detection range can be up to 2.3m with a high accuracy.

The principle of fire positioning and heading fire based on the far-infrared flame sensor group works as follows: when the value of any one sensor unit is larger than the minimum threshold value (TRE_{MIN}), it means there is a fire around the robot. The robot uses the left and right unit adopting the differential method to drive towards the fire, and relies on the center unit to determine the distance between the robot and the fire. While the robot is moving to the fire, the detecting value of sensor increases gradually. When detecting value of any unit (mainly the middle unit) exceeds the maximum threshold value ($TRE_{MAX}=180$), the robot stops. In order to detect fire on all sides, the robot will rotate with no fire around it.

The setting of the minimum threshold value is not only to ensure the sensitivity of fire detection, but also to improve the performance of anti-interference. It requires the minimum threshold value cannot be set too high or too low: if it is too high, the sensitivity of fire detection will be reduced, which leads to reduce the range robot can detect; if it is too low, the stability of the robot will be weakened, and some random factors may cause the robot to run unstable. The minimum threshold value of current fire fighting robot [2][3][4] is a fixed value, which greatly reduces the applicability of the detection. To improve the adaptability to different environments, the system adopts dynamic method for determining the minimum threshold: with no fire around, the robot calibrates infrared intensity of the environment. Specific methods are as follows. The robot detects the current infrared intensity ten times without fire in the environment. Adopting the median average filtering method [7], with removal of the maximum and the minimum detection values, it gets the average ($TRE_{\min}$)of the remaining eight detection values. In order to prevent some random interference, it finally adds a limit value ΔT (it is 4) to be minimum threshold based on the $TRE_{\min}$, which is $TRE_{MIN}=TRE_{\min}+\Delta T$.

D. System Power Supply

If mobile robot adopts a single power supply, the large motor starting current will cause system voltage instability, and seriously affects the stability and reliability of controller and input circuit. Therefore, the system uses dual power supply: group A–a rechargeable nickel-cadmium battery of 14.4V/1500mAh,which supplies LM7805 to offer 5V output voltage, supplying power to the sensor and the controller; group B-a rechargeable nickel-cadmium battery of 7.2V/2000mAh, which supplies power to the motor.

The mains supply by step-down and rectification and filtering can supply LM7805 to offer 5V power supply for the terminal equipments. Among them, the timekeeping chip DS1302 adopts dual power supply: 3V fastener cell and 5V power supply. Without the mains supply, fastener cell will make DS1302 continue to work, providing guarantee for the accurate recording of time information.

System power can operate within voltage stability limits for a long time, meeting the needs of the system, which improves system stability.

E. *Other Parts of System Hardware Design*

Mobile robot and remote terminal takes easy to operate and inexpensive STC89C52 MCU as control center [8]. Moving along the fixed route, the robot gets fire information from infrared sensors on both sides of robot. The output of infrared sensor is switching signal, which is simple and reliable, with the receiving circuit shown in Figure 5. Photoelectric switch whose infrared LED and infrared reception diode is arranged face to face is taken as smoke sensor. The different conditions of smoke between the photoelectric switch generate different output state, with the circuit shown in Figure 5. High precision, simple circuit and easy to operate temperature sensor DS18b20 is adopted to collect temperature data in fire scene. The L298 that has the features of convenient operation, high driving capacity, high stability is chose as driver chips for motor. Controller generates two independent PWM waves to control left and right motor speed separately by this chip. E18-D80NK having the features of long detection distance, little interference by the visible light and convenient operation is taken as infrared obstacle avoidance sensor. It integrates transmitter and receiver. Its detection distance（50cm is set in this system） can be adjusted according to requirements. Low-power LCD12864 is used in remote terminal.

V. SOFTWARE DESIGN

The system software adopts the method of modular design. The modular processing of system function [9] can reduce the complexity of system software design, providing a good condition for debugging the overall performance of the system.

A. *Main Program Design*

System software is divided into two parts: mobile robot software and remote terminal software. Mobile robot software design is divided into two phases. The first phase: mobile robot tracking the fixed route, detects fire on both sides of the route and obstacles. When the fire or obstacle is detected, the mobile robot stops to detect and process information, which is sent to remote terminal wirelessly. The second phase: the mobile robot calibrates infrared intensity of the environment at the end of route. Then it starts automatically to find the fire. The mobile robot rotates to find fire if there is no fire around. If it finds a fire, the mobile robot runs towards it constantly. Reaching the fire, it stops to detect and process information, which is sent to remote terminal wirelessly. The flow diagram of main program design of the mobile robot is shown in Figure 8. Remote terminal receives the data, which is processed and displayed to determine whether to alarm, storage information and display historical information or not. The flow diagram of main program design of remote terminal is shown in Figure9.

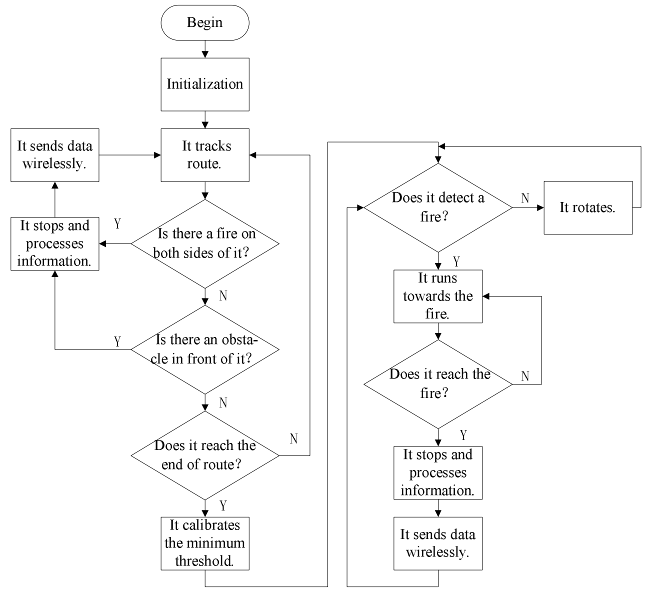

Figure 8. The flow diagram of main program design of the mobile robot.

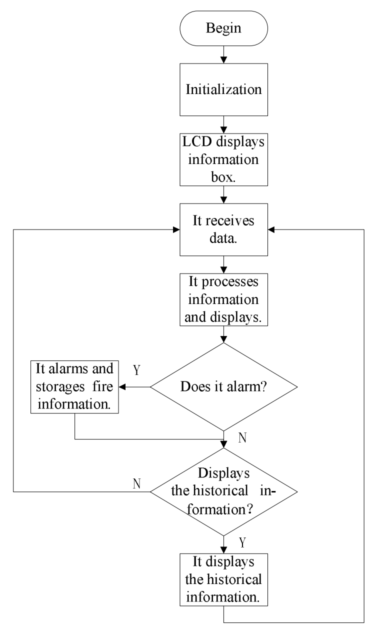

Figure 9. The flow diagram of main program design of remote terminal.

B. *Program Design of Wireless Transmission*

Learning from the mode of RS232 serial communication [10], the system uses the communication mode of start transmission, data transmission and end transmission to implements the wireless transmission. After sending one frame data, sending terminal waits for acknowledgement frame. According to the acknowledgement frame representing correct or wrong, sending terminal determines to send the next frame or resending this frame. While waiting for the acknowledgement frame, the system introduces a timeout processing using timer in order to prevent that accidents lead to loss of communication frame. The flow diagram of sending data wirelessly is shown in Figure 10. After receiving data, receiving terminal checkouts its correct or not to determine whether to receive the next frame or receive this frame, and sends the corresponding acknowledgement frame to the mobile robot. The flow diagram of receiving data wirelessly is shown in Figure 11.

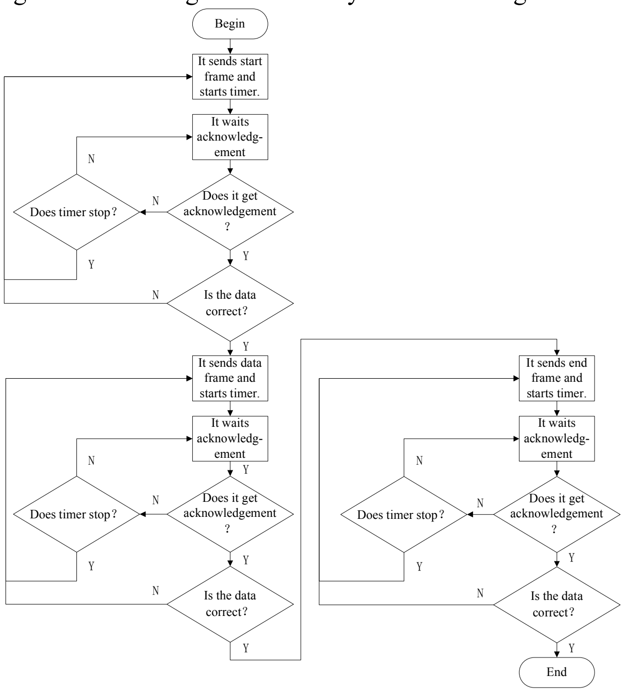

Figure 10. The flow diagram of sending data wirelessly.

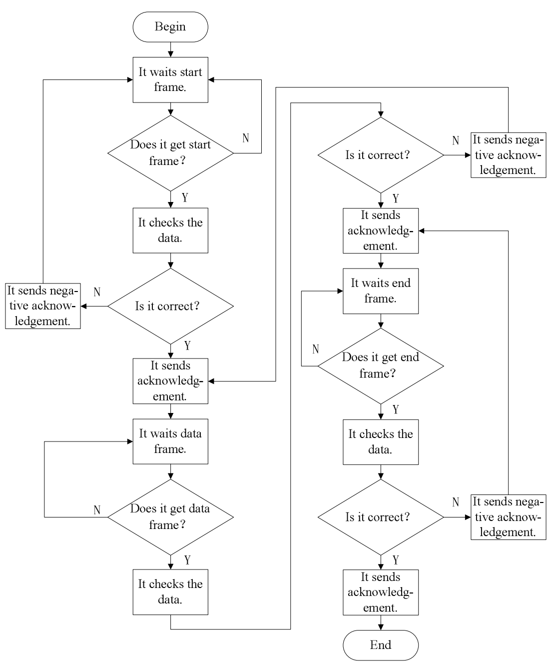

Figure 11. The flow diagram of receiving data wirelessly.

VI. CONCLUSION

The design using STC89C52 MCU as control center, with the careful design of the modules, implements the remote fire alarm system. Compared with the current fire fighting robot, the design has the following two major innovations:

1) Implementation of the remote fire alarm. The implementation of this function, enabling managers more accurately and faster to mastery information on fire scene, greatly improves the capabilities of fire fighting.

2) The robot has a stronger ability of adaptability to find fire automatically. Robot sets minimum threshold value according to the environment, which greatly improves the adaptability of the system.

Experiments show that the system can accurately implement the remote fire alarm with good performance. On the basis of this design, you can add real-time position of the robot displayed in the LCD and fire fighting or other functions.

REFERENCES

[1] H. Li, M. Wang, L. B. Shi, "Development and future application of fire fighting robot," The 11st China Public Security Expo, Nov.2007, pp. 161–164.

[2] W. J. Xi, D. Y. Chen, X. Y. Ma, "Design of intelligent fire fighting robot controller based on ARM9 embedded system," Modern Electronics Technique, vol. 33, No. 10, Jan. 2010, pp.114-117

[3] X. Y. Chen, Y. H. Yan, "Design and implementation of fire fighting robot based on the AVR MCU," Computer and Information Technology, No. 7, Jul. 2008, pp.29-31

[4] W. J. Xi, D. Y. Chen, X. Y. Ma, "Application of fire fighting robot," Mechanical and Electrical Engineering Technology, vol. 38, No. 4, Feb. 2009, pp.103-106

[5] J. X. Gao, "Training tutorial series for national undergraduate electronic contest - analog electronic circuit design," Publishing house of electronics industry, in press, 2007

[6] D. F. Cheng, J. Wang, Z. B. Ling, Y. Z. Wang, "Theory and application of sensor," China machine press, in press, 2008

[7] L. Wang, "Design of temperature measure and control system with high precision based on platinum resistance Pt100," Journal of Jishou University (Natural Science Edition), vol. 30, No. 3, May 2009, pp.71-73

[8] Q. F. Li, K. Xiao, "The principle and interface and application of MCU-the base of embedded system," Tsinghua University Press, in press,2005

[9] T. X. Guo, "C tutorial programming of new concept on 51 MCU," Publishing House of Electronics Industry, in press, 2009

[10] L. P. Chen, "Design of serial communication among Single-chip Microcomputers," Journal of Shazhou Polytechnical Institute of Technology, vol. 13, No. 3, Sept. 2010, pp.11-16