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# The design and implementation of a Home Fire Monitoring System Based on IoT

Dong Ling, Zhang Lu

College of Electrical and Information Engineering, Quzhou University, Quzhou Zhejiang 324000, China

## Abstract

**This paper expounds the characteristics and application of Internet of Things technology, analyzes the design and implementation of smart home fire monitoring system, including the architecture design, sensor selection, controller selection and cloud platform selection of smart home fire monitoring system. The application advantages and development trend of intelligent home fire monitoring system in family life are discussed.**

## Keywords

**Internet of Things technology; Fire monitoring system; Smart home; Sensor; Controller.**

## 1. Introduction

Home fire monitoring system connects various devices in the home to various sensors and links real-time data to the Internet to realize the interconnection between devices and provide a more convenient, comfortable and safe life experience. This paper will discuss the design and implementation of home fire monitoring system based on Internet of Things technology.

Nowadays, tall buildings rise from the ground. High-rise buildings can be seen everywhere, and the buildings are also built higher and higher, and the living mode of residents is mostly based on high-rise buildings. The fire protection problem of high-rise buildings has become a world problem, once a fire occurs, the loss is inevitable. The high-rise dense personnel, not easy to evacuate the crowd, the rescue is difficult, especially the various pipelines crisscrossed inside the high-rise building, is an important factor in the rapid development and spread of the fire smoke, easy to form the high-rise smoke effect, and the most deadly fire is often the smoke. In 2022, 825,000 incidents occurred nationwide, killing 2,053 people, injuring 2,122 people, and causing direct property losses of 7.16 billion yuan. Fires are burning in every corner of the country all the time and there are many large fire incidents. The repeated occurrence of fire makes us re-understand the importance of fire safety.

The Internet of Things technology refers to the connection of various devices, sensors and controllers through the Internet to form a network that can eventually realize real-time information exchange. The basic principle of the Internet of Things technology is to collect the data generated by the device through the sensor, and process and control it through the controller, and finally transmit the data to the Internet to achieve intelligent interaction between devices. The core characteristics of the Internet of Things technology are real-time, data sharing, intelligence and interconnection. The real-time nature of iot technology means that devices and sensors can collect and transmit data in real time, allowing users to understand device status and environmental conditions in real time. This feature provides solid technical support for the fire monitoring system.

## 2. Research status

### 2.1. Fire identification algorithm:

It’s the data fusion solution. Flame, smoke, carbon monoxide and carbon dioxide are used as characteristic factors. Based on MATLAB, artificial neural algorithm PNN is used to train and test the data collected by multiple sensors. BP neural network algorithm is used to fuse multi-sensor data, and combined with relevant judgment rules to identify fire, to solve the problem of single sensor false alarm rate, missing report rate and high delay.

### 2.2. Image recognition technology

Jia Jie proposed a fire smoke recognition algorithm based on HIS color model and two-dimensional discrete wavelet transform. Based on HIS color model to segment the smoke region in the collected images, the presence of smoke can be determined by analyzing the correlation coefficient, shape and semi-transparency of the smoke. Bian Yongming combined the RGB and HIS color models to judge the flame region of the image, adopted the weighted Euclidean distance algorithm to process the image gray, segmtioned the flame region by KMEis ++ color clustering, and combined with flame characteristics analysis to identify the flame, so as to improve the accuracy and real-time performance of fire identification. Du Yongguang designed a fire safety remote monitoring system based on the Internet of Things architecture. Hi3515 and STM32 single chip computers completed the collection and analysis of fire channel image data and fire water pressure status data, and transmitted the data to Mysql and mysql based communication modules through MG509 and MG323. NET framework on the background management platform, to achieve the fire channel and fire water pressure data storage, display, monitoring and management, to solve the traditional fire safety system only rely on manual monitoring, low intelligence, false alarm and other problems.

### 2.3. Build intelligent fire protection system

A smart fire APP based on the intelligent fire control system monitoring platform of the Internet of Things and data is designed to provide users with functions including fire alarm, report analysis, hidden danger treatment, fire work supervision, equipment supervision, fire knowledge and so on. To realize the implementation of the hidden danger treatment process at all levels of knowledge, traceability, data, classification and statistics, and the whole process, and through the residents' mobile APP can provide supplementary fire data, to achieve the goal of national fire prevention.

1.Implementation of fire monitoring

In view of the problem that a single sensor system is easy to cause false or missed fire alarms, this project proposes to build a multi-sensor hardware acquisition system based on STM32 as the core processor, and through the analysis of the electrical characteristics, working principle and circuit principle of modules such as temperature and humidity, flame, smoke and camera, to realize the collection of multi-fire factor data. Combined with Esp8266 module and relay module, wireless communication and remote device control between One NET cloud platform are realized.

The hardware design of this system takes STM32F407ZGT6 as the core, and realizes the collection of smoke, flame, temperature, humidity and other fire characteristic factors in the monitoring environment through external temperature and humidity sensors, smoke sensors, flame sensors and cameras. Among them, the signals collected by smoke sensors and flame sensors are analog signals. An AID converter is required to convert analog to digital quantities. The camera uses DCMI interface for data communication with STM32, and the data collected by the sensor is uploaded to One NET cloud platform by the external Wi-Fi wireless communication module Esp8266. The communication between the wireless module and

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STM32 is serial communication (USART). Esp8266 realizes data upload and command delivery between the lower computer and the cloud platform through the transparent transmission function. The execution of the command is realized through the external relay module and the electronic fire water valve. The overall hardware structure is shown in Figure 1.

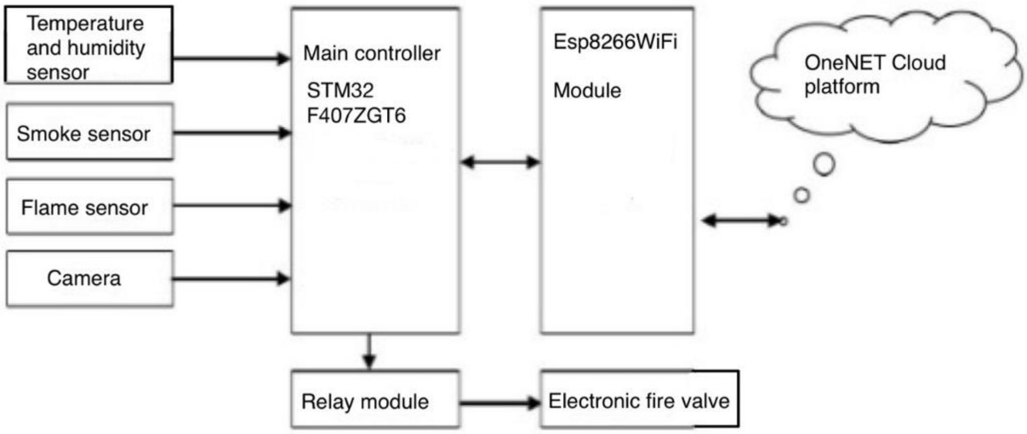


Figure 1 Overall architecture of the system

2.Intelligent terminal controller

The system adopts the development board with STM32F407ZGT6 as the intelligent terminal controller, which mainly realizes the connection and communication with peripheral modules and the processing of the original sensor data collected. At the same time, it also realizes the connection and data communication with the One NET cloud platform and makes timely response to the commands issued by the cloud platform. According to the design requirements of this system project, the hardware integration resources of two parts of the development board are mainly used, which are peripheral hardware interface and STM32 main control chip function.

Interface is used to realize the analog voltage acquisition of smoke sensor and flame sensor. USART asynchronous communication interface is used to realize the communication with computer and wireless Wifi module. At the same time, there are multiple 3.3V and 5V DC power interfaces, which can provide power support for the sensor module and controller module.

3.Esp8266 Wireless module

The Esp8266 wireless transmission module, as the only module for communication between STM32 and the cloud platform, is responsible for connecting the Internet of Things cloud platform and uploading sensor data, while transmitting user commands issued by the Internet of Things cloud platform. Esp8266 is a serial to WiFi chip module, with built-in firmware, simple user operation, no need to write timing signals, low power consumption, stable RF performance, versatility and reliability, support wireless 802.11b/g/n standard, can quickly configure the module and connect to the network through SocketAT instruction. Built-in TCP/IP protocol stack, support TCP Client multi-channel connection, support board PCB antenna, suitable for home environment.

4.Temperature and humidity sensor module

The DHTll digital temperature and humidity sensor is a temperature and humidity composite sensor with a calibrated digital signal output. Detection section is mainly composed of a sense wet resistance and a thermistor, in order to improve the stability and accuracy of the data, the module after accurate laboratory calibration, the calibration parameter into program internal memory stored in the module, the sensor in the process of collecting environment temperature and humidity data, module internal call calibration parameter data calibration, at the same time using digital module acquisition technology and temperature and humidity sensing technology, make DHTll sensor module has super fast response speed, super anti-interference ability, high cost performance. The data adopts the form of single bus, and the data transmission distance is larger, so that it can be used in a variety of different scenarios. In fire application scenarios, temperature and humidity as an important characteristic factor to identify fire, the sensitivity, dynamic response time, accuracy and other parameters of the sensor will directly affect the accuracy and real-time of the system.

5.Flame sensor module

The flame sensor module is mainly used for the monitoring of the flame in the home environment, and the object will produce a flame when burning, and the thermal radiation of the flame will produce infrared light with a certain wavelength, whose wavelength is in the range of 750-2500nm. The infrared light has a strong penetration ability and is not easy to be absorbed, and the wavelength is longer than the visible light. This system uses far infrared flame sensor module can detect infrared light source, for specific wavelength infrared most sensitive, can also through the adjustable resistance adjustment sensitivity, using the characteristics can quickly detect the fire, achieve the role of real-time fire monitoring, at the same time the module of a low cost, small size suitable for household environment.

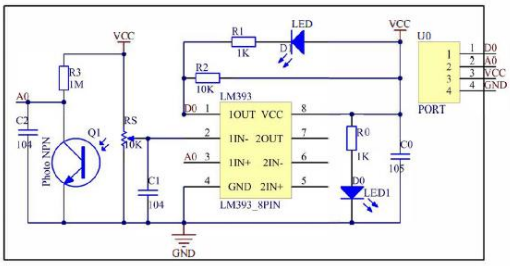

Figure 2. Schematic diagram of the far-infrared flame sensor module

6.The MQ-2 smoke sensor module

MQ-2 smoke sensor is mainly used for the monitoring of home environment smoke. When the fire occurs, the object burning will produce a lot of smoke, so as to warn the fire. MQ-2 smoke sensor has the advantages of small size, simple drive circuit, fast response, good performance, anti-interference, long life, and has high sensitivity to natural gas, alkanes and smoke, which is suitable for a variety of scenarios. It is commonly used for fire and gas leakage monitoring and warning.

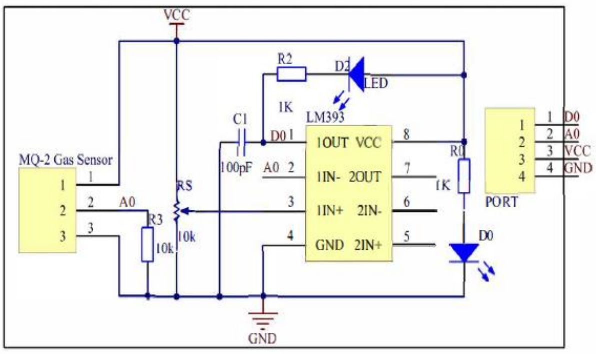

Figure 3 Schematic diagram of the MQ-2 circuit

7.OV2640 Camera camera module

The image acquisition module adopted in this system is OV2640 camera module, which is a CMOS type digital image sensor that supports the image output up to 2 million pixels (1600 x 1200 resolution), supports the use of VGA temporal output image data. It can also compensate the collected images, and support basic processing such as gamma curve, white balance, saturation and color. Depending on the resolution configuration, the frame rate of the sensor output image data is adjustable from 15-60 frames.

## 8.DS evidence theory

Fire occurs, combustible combustion will produce a variety of physical phenomena such as flame, smoke, heat, gas, etc., so can use the way of sensor environment monitoring, through the sensor to the change of the output of the electrical signal, into the characteristics once the fire can timely find fire, but the actual fire environment, the fire of various physical signal change is not stable, lead to the sensor to the signal change is not stable, just from the sensor data it is difficult to accurately determine whether the real fire. In addition, such as the monitoring environment temperature rise, dust, smoking, sunlight and other interference source will cause the change of the sensor output signal, the randomness, uncertainty directly affect the stability of the fire monitoring system, so this scheme using DS evidence theory of statistical algorithm for the multi-sensor data fusion processing, so as to improve the accuracy, stability and reliability of the system.

Based on the traditional DS evidence theory of the sensor data in the process of decision, there will be high conflict evidence information processing cannot get the right decision, and based on the evidence correlation coefficient conflict evidence touch algorithm, can reduce the credibility of interference data, reduce the influence of sensor fault or noise interference for fusion results, so as to get more accurate decision. In this scheme design, the fire characteristic information in the monitoring environment is collected through the temperature and humidity sensor, smoke sensor and flame sensor. By thousands of various sensor data characteristics of halo range is different, the difference between data is bigger, so need to normalize the collected data, by the normalized data after the database, according determine the basic probability assignment, finally use the evidence theory improvement fusion method to data fusion, so as to get the final decision. The data fusion process of the fire monitoring system is shown in Fig.

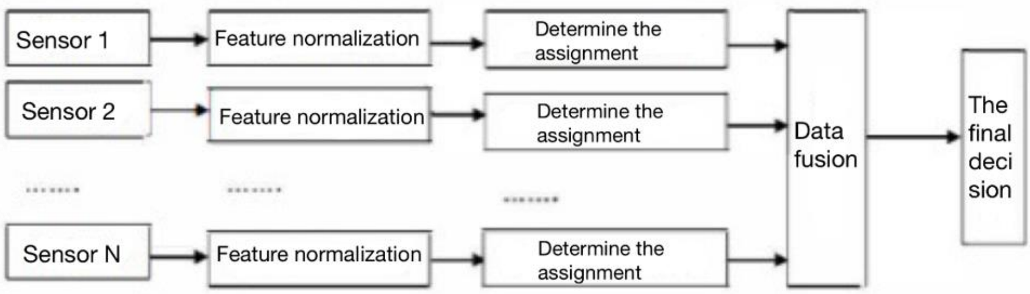


Figure 4 Data fusion process of the fire monitoring system

## 9.Adaboost

Adaboost Is an iterative algorithm, whose core idea is to train different classifiers (weak classifiers) for the same training set, and then assemble these weak classifiers to form a stronger final classifier (strong classifier). The algorithm itself is implemented by changing the data distribution, which determines the weights of each sample according to the correct classification of each sample in each training set and the accuracy of the last overall classification. The new dataset with modified weights is given to the lower classifier for training, and the classifier from each training is finally integrated as the final decision classifier. Cascade classifier belongs to a binary tree of taxonomic regression in the Cart decision tree classification, Its structure is shown in Fig, Each node is a first-level classifier, Each node is combined from multiple strong classifications, Each node has two branches, Represents two different judgment results, among, The input end is the image sample to be detected, Samples were first examined by a first-level classifier, If judged to be a flame, Continue to enter the next level of classifier for detection and judgment, Until all level classifier tests have passed, To finally decided to be a flame, Otherwise, as long as the first level of detection is a non-flame, All the processes will end, Direct judged as non-flame.

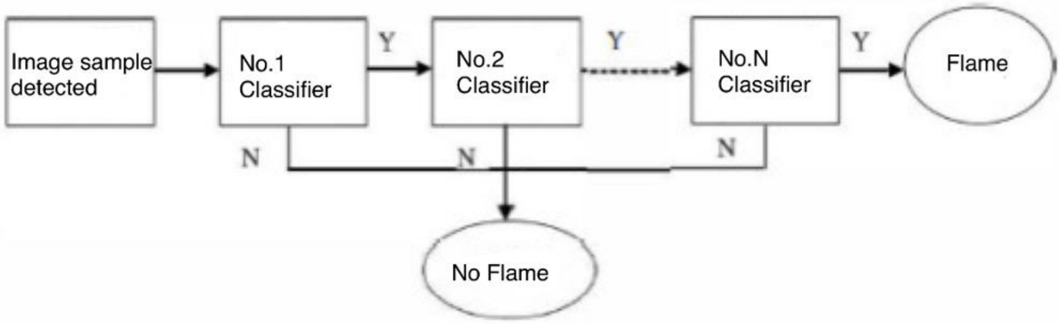


Figure 5 Adaboost Cascade classifier structure

In the design of this system, The training of flame recognition Adaboost cascade classifier is mainly composed of two parts: early classifier training and learning and real-time detection and recognition, Early classifier training and learning uses the offline training method, After collecting the positive and negative sample maps of large numbers of flames, Obtain the required Adaboost cascade classifier based on Haar feature recognition training, among, Adaboost Cascade classifiers are all combined out of multiple strong classifications, The strong classifier is composed of the optimal weak classifier according to the weight mode, The optimal weak classifier is generated by training with the Adaboost algorithm, This cascade classifier has a low error rate after training on a large number of samples, This training process takes some time, It can be performed before real-time detection and identification. The real-time detection and identification of the thousand flame is mainly based on the cascade classifier generated in the previous classifier training. The cascade classifier is used to directly identify the input images, so as to achieve a low error rate and improve the detection pass rate.

## 3. Conclusion

The design and implementation of the home fire monitoring system based on the Internet of Things technology, through the application of sensors, controllers and Internet technology, provides families with a more convenient, safe and comfortable home life experience. With the continuous progress of the Internet of Things technology and artificial intelligence technology, the home fire monitoring system will achieve greater development in the future, and be closely combined with the development of smart city.

## Acknowledgments

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