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Research on Intelligent Home and Security Risk Warning System

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Abstract: *With the gradual development and popularity of smart home, the importance of the warning function of security risks gradually emerges. Aiming at reducing the personal and property losses of residents caused by security hazards, this paper analyses the causes and warning methods of various safety hazards such as fire, harmful gas leakage and so on, and provides a way of thinking for building a perfect intelligent home system and house danger warning system by choosing various sensor types such as IRS infrared sensor and Fiber Bragg Grating Sensor, the appropriate installation schemes can be developed in order to coordinate the alarm system and alarm the occurrence of danger in time.*

Keywords: *Smart home; Safety monitoring; sensor; Alarm system; IRS infrared sensor; Fiber Bragg Grating Sensor*

1. Introduction

This paper proposes a comprehensive scheme of intelligent home warning system based on multi-directional sensor perception, and establishes an overall system scheme based on anti-theft system, fire alarm system, harmful gas leakage alarm system, falling bed warning and sleep state monitoring system. Carry on the scheme comparison demonstration respectively, and then make the design of part of the signal processing circuit. Finally achieve the function of warning for various family security risks in time.

2. Research Background

The first is the security risk of burglary. Burglary refers to illegal entry into a building to commit theft or other criminal acts, which seriously endangers the property and life safety of the residents. According to the data of Statista, there was 47.4 burglaries per 100,000 households in 2018 in China, and the global average is three times as high. Indoor fires are also a great safety hazard. According to the data of the World Fire Statistics Center of the International Association of Fire Protection (CTIF), the number of indoor fires remains high every year. In 2021, a total of 195,000 fires occurred across China, causing 1,300 deaths, an undisclosed number of injuries, and direct property losses of 3.79 billion yuan. Indoor fires accounted for 78.3% of all fires, causing 78.2% of all deaths. Residents can be harmed by harmful gas leakage unconsciously. Gases such as natural gas and carbon monoxide may leak from the home's gas lines, gas stoves, water heaters, furnaces and other equipment, reducing oxygen levels in the air, causing poisoning and even explosions, which are especially dangerous in semi-enclosed environments such as indoors. In addition, elderly people who live alone at home will also have risks due to their mobility difficulties. In particular, elderly people with underlying diseases will fall out of bed and other risks when sleeping. As the aging society becomes more and more serious, these security risks are also amplified.

In order to reduce the occurrence of the above security risks, intelligent home environment with security risk warning system should be promoted urgently.

3. Intrusion Alarm System

3.1. Scheme Comparison and Selection

At present, the smart home system lacks a fully functional anti-theft alarm system, and most residents can only use anti-theft doors, windows and surveillance cameras to avoid burglary and other dangers.

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There are several schemes for this situation.

Scheme one: Improve the anti-theft measures based on the surveillance cameras. In most cases, the surveillance cameras can only show and record the the monitoring area, and it can't judge whether there is a burglary. Therefore, the image recognition and detection function can be added to collect the positive face images and body features of family members and store them in the database. When someone enters the monitoring area, the computer can judge whether he is a stranger by comparing the data. If its face cannot be recognized or there is no matching image in the database, it will send alarm information to the host's mobile phone, and the host can choose to ignore it or alarm with one button. In the experiment of Nurhopipah and Harjoko, the success rate of action recognition is as high as 92.655%.[1] The experimental results of Mileva have an accuracy rate of nearly 90%. [2] Scheme two: Anti-theft system based on PIR sensor. Passive infrared method is adopted to passively receive and detect infrared radiation from the environment. Once the infrared radiation of human body comes in, the focus of the optical system will make the pyroelectric parts produce sudden electric signal, and send out an alarm. Prithvi Nath Saranu uses a combination of PIR and PR sensors. Once the PIR sensor detects strangers entering the room, it will turn on the camera and generate an alarm.[3]

Scheme one can automatically recognize known face information, improving security and reducing false positives. However, it may raise privacy, ethical and social issues, and should be used properly under appropriate supervision and restrictions. And keeping the camera on requires more power and network resources, increasing costs and maintenance difficulties. In addition, this scheme will be affected by video quality, occlusion, lighting conditions and so on, resulting in reduced recognition results. The second scheme detects motion through infrared radiation, which is not affected by illumination. It is more suitable for the tight and limited space of the room, and can be flexibly matched with buzzer, relay, camera and other equipment to achieve different alarm and control functions. The installation is also relatively simple. The drawbacks of Option 2 are that other heat sources or moving objects may be misreported, and the use of infrared rays may damage the eyes.

After comprehensive consideration, it is found that scheme two has low cost, flexible use, easy installation, and is more suitable for widespread use.

3.2. Selecting and Installing Sensors

After investigation, the most commonly used PIR sensor has HC-SR501, AM312, DYP-ME003 these three kinds. The comparison of these three sensors is shown in Table 1.The HC-SR501 can detect motion up to 5 meters, has sensitivity and delay adjustment, and can be connected to Raspberry PI and other microcontrollers; The AM312 is a small PIR sensor that can detect motion up to 3 meters, has low power and low voltage modes of operation, and can also be connected to Raspberry PI and other microcontrollers; DYP-ME003 is a highly sensitive PIR sensor that can detect movement up to 7 meters with automatic adjustment and dual detection, suitable for high-precision anti-theft systems.

Table 1: Comparison of three sensors.

Type of Sensor	Effective Range(meter)	Characteristic
HC-SR501	5	Adjustable sensitivity
AM312	3	Low power mode
DYP-ME003	7	High precision

Considering the size of the general room and the precision requirements of home detection, HC-SR501 sensor is selected. To ensure successful detection, the sensors should be placed 0.5m above the ground, near corridors, doors and Windows.

3.3. Working Principle and Process

The HC-SR501 sensor is a motion detection sensor based on the principle of pyroelectric, which can sense the infrared radiation emitted by the human body or other objects. The HC-SR501 sensor consists of a BISS0001 micropower PIR motion detector chip, a RE200B pyroelectric induction element, a Fresnel lens, a voltage regulator, two potentiometers and some resistors and capacitors. When the HC-SR501 sensor is powered on, it takes about 30 to 60 seconds to initialize to learn the infrared radiation characteristics of the surrounding environment, that is, to calibrate its own reference value to determine what kind of changes count as motion. When a moving object enters the detection range of the HC-SR501 sensor, it will focus on the RE200B pyroelectric sensing element through the Fresnel lens, resulting in a change in the voltage of the RE200B. The BISS0001 chip amplifies and processes the

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voltage change of the RE200B, and if the change exceeds a set threshold, it outputs a high-level signal indicating that motion has been detected. Two potentiometers on the HC-SR501 sensor can adjust the sensitivity, which is the minimum change in IR radiation to detect motion, and the delay time, which is the duration of the output signal. The output signal from the HC-SR501 sensor can be connected to the digital pins of Arduino or other microcontrollers to control other circuits or devices, such as LED lights, buzzers, cameras, etc. [4]

4. Sleep State Monitoring and Alarm System

4.1. Scheme Comparison and Selection

When the elderly are alone at home without care, it is often inconvenient to get up at night and easy to fall out of bed. It is very important to detect and warn the family in time. In addition, people with cardiovascular disease or other specific medical conditions need to avoid certain sleeping positions to reduce injury and speed up recovery. [5] Scheme 1: Use the surveillance camera action acquisition analysis to judge the sleep state of the elderly. This scheme is similar to the monitoring system compared with the anti-theft system scheme, with high accuracy and small misjudgment, but the cost is high and is not suitable for popularization. Plan 2: Use the smart mattress to detect pressure to judge the user's sleep. The accuracy of this scheme is slightly worse than that of scheme 1, but the accuracy of judgment can be improved by optimizing the artificial intelligence algorithm and increasing the sampling data. T.Li et al. proposed a BP neural network based on SSA to process sleeping position data, with a recognition accuracy as high as 98.1%, and realized remote signal transmission to build a multi-channel and long-distance sleeping position detection system.[6]

After comparison, it is found that scheme two is more suitable for the design requirements.

4.2. Selecting and Installing of Sensors

The data of sleep state collected by the mattress is mainly achieved by the pressure sensor. The more common pressure sensors are piezoelectric sensors, FBG fiber grating pressure sensors and resistance strain gauge pressure sensors.

Piezoelectric sensor is mainly through the pressure change between the capacitor spacing or overlap area pressure signal into electrical signals, fast response speed, wide frequency range, high sensitivity, small size, strong structure, not affected by temperature and humidity. However, the output signal will decay with time, that is, the drift is large.

FBG pressure sensor is a kind of sensor that uses the Bragg reflection characteristics of FBG to measure pressure. Several gratings can be arranged on a fiber to realize multi-point distributed measurement of pressure and improve the accuracy and efficiency of measurement. At the same time, the FBG pressure sensor has a long life and high reliability, which can be monitored online for a long time, reducing the cost and risk of maintenance and replacement.

Resistance strain gauge type pressure sensor changes the resistance value by changing the strain gauge size, so as to convert the pressure into electrical signals, good stability, good linearity, low price, easy to install and use. However, the response speed is slow, the frequency range is narrow, the sensitivity is low, the volume is large, the structure is fragile, and it is susceptible to the influence of temperature and humidity.

Finally, the light intensity pressure sensor based on FBG is selected. According to the main pressure areas in different sleeping positions of the human body, the sensors were arranged according to the herringbone measurement points.

4.3. Working Principle and Process

The specific working process is shown in Figure 1. The light source transmits the light signal to the prism tip fiber through a 3dB coupler, and the light signal returns the original way through the continuous reflection of the mirror. When the user applies pressure to the mattress, the distance between the displacement platform and the fixed support decreases, resulting in a decrease in the light path of the light source signal, thereby reducing the light intensity data. Finally, the change in light intensity is converted into a pressure signal through the modem. Then, the sleeping position data were processed by the BP neural network optimized by the sparrow search algorithm, and the six basic sleeping positions

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were identified. Finally, the results were transmitted to the total monitoring system, which played a real-time monitoring role.[6]

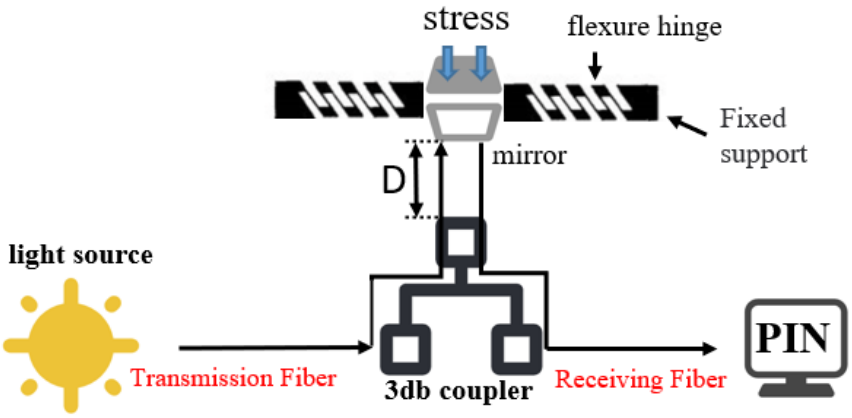

Figure 1: Operating process of optical fiber pressure sensor.

5. Fire Alarm System

5.1. Scheme Comparison and Selection

Smoke produced by fire is the main cause of fire casualties, so smoke sensor is widely used in fire alarm system. Common smoke sensors are divided into ionic smoke sensors, photoelectric smoke sensors and spectral smoke sensors. The differences between them are shown in Table 2. Ionic smoke sensor uses charged particles generated by radioactive substances to detect the impact of smoke on the current in the ionization chamber. The advantage is high sensitivity, can detect hidden combustion fire. The disadvantage is easy to dust, humidity, temperature and other environmental factors interference, easy to false positive. Photoelectric smoke sensor uses light source and photoelectric element, detection of smoke on light scattering or blocking effect. The advantages are good stability, not easy to be disturbed by environmental factors, low false positive rate. The disadvantage is low sensitivity, cannot detect hidden combustion fire. Spectroscopic smoke sensor uses spectrometers to detect the effect of smoke on the absorption or scattering of light of different wavelengths. The advantage is to distinguish different types of flame, improve the accuracy and reliability of alarm. The disadvantages are high cost and complex technology.

Table 2: Comparison of three sensors.

Type of Sensor	Advantage	Disadvantage
Ionic smoke sensor	High precision	Susceptible to environmental factors
Photoelectric smoke sensor	Good stability	Low precision
Spectroscopic smoke sensor	Distinguish between different types of flame	High complexity and high cost

After comprehensive consideration, it is found that photoelectric smoke sensor has better stability and practicability, so photoelectric smoke sensor is selected.

5.2. Selecting and Installing of Sensors

Common photoelectric smoke sensor models are: RS485 photoelectric smoke sensor, CS2108-XXX digital photoelectric smoke alarm circuit, linear light beam smoke detector. RS485 photoelectric smoke sensor adopts RS485 bus communication mode, can be connected with a variety of hosts, with self-check function, real-time monitoring of the working state of the sensor, with low power consumption, high stability, high sensitivity and other characteristics. CS2108-XXX digital photoelectric smoke alarm circuit: using digital ASIC, photoelectric to electronic conversion, with low voltage, low power consumption, high stability, high sensitivity and other characteristics, can output continuous or intermittent alarm sound, can be matched with a variety of smoke detectors. Linear beam smoke detector: using beam scattering principle, suitable for buildings with high ceiling and large space, with high sensitivity, high reliability, high anti-interference characteristics, can detect smouldering fire located on

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the ground.

Obviously, RS485 photoelectric smoke sensor is more suitable for home use, to meet the needs of low cost and high scalability. Generally, fire is more likely to occur in the kitchen and bedroom, so in the kitchen, bedroom ceiling installed on each of the smoke sensor connected to the main engine.

5.3. Working Principle and Process

RS485 photoelectric smoke sensor is a kind of smoke detection equipment using optical inductance smoke detector and RS-485 communication interface, is the use of fire smoke to produce light absorption and scattering to detect a fire device. It consists of a light-emitting element and a light-receiving element. The light-emitting element emits a beam of light to the light-receiving element. When smoke enters the detector, the smoke particles will scatter and absorb the light, making the intensity of the light received by the light-receiving element change, thus generating an electrical signal to indicate the presence of smoke.RS-485 communication interface is a multi-point communication standard, it uses two balanced signal lines, can achieve long distance, high speed, high anti-interference data transmission. It can connect multiple devices, form a bus network, through the signal generator and signal receiver for data exchange.

The RS485 photoelectric smoke sensor sends the electrical signal of the optical inductor smoke detector to the host through the RS-485 communication interface, and the host judges the smoke status according to the change of the signal. If the signal exceeds the set threshold, it means that the smoke has reached the alarm level, and the host will send the alarm sound and indicator light to the people in the house. [7]

6. Harmful gas leakage alarm system

6.1. Scheme Comparison and Selection of Sensors

For the detection of harmful gases, gas sensors are generally used for specific gases. Gas sensor for the kitchen common harmful gases are MQ-4, MQ-5, MQ-7 and so on. The MQ-4 sensor is used to detect flammable gases such as methane and natural gas. Its gas-sensitive material is tin dioxide (SnO2). When flammable gas is present, its conductivity will increase with the increase of gas concentration. MQ-5 sensor can be used to detect flammable gases such as liquefied gas, natural gas and gas. Its gas-sensitive material is also tin dioxide, and its conductivity will increase with the increase of gas concentration. MQ-7 sensor is used to detect combustible gases such as carbon monoxide, and its gas-sensitive material is also tin dioxide (SnO2). The high and low temperature cycle detection method is adopted to improve the sensitivity and selectivity of detection.

Considering the diversity of kitchen gas, the above three sensors are installed into the circuit in parallel.

6.2. Working Principle and Process

The gas-sensitive materials of MQ-4, MQ-5 and MQ-6 sensors are all tin dioxide (SnO2), which has a low conductivity in clean air. When flammable gases (such as methane and natural gas) exist, the gas molecules react with oxygen ions on the surface of the gas-sensitive materials to reduce oxygen ions, resulting in an increase in the conductivity of the gas-sensitive materials. The conductivity of the sensor is proportional to the concentration of the gas, and the change of the conductivity is converted into a voltage signal through the circuit, and then converted into a digital signal through the analog-to-digital converter, which is sent to the MCU for processing and display. The MQ-5 sensor has a high sensitivity to flammable gases such as liquefied gas, natural gas and gas. Its working process is similar to that of the MQ-4 sensor, but its sensitivity curve is different from that of the MQ-4 sensor, and it can be calibrated according to different gas types. MQ-7 has a high sensitivity to combustible gases such as carbon monoxide, and adopts a high and low temperature cycle detection method. Low temperature (1.5V heating) detects carbon monoxide, and high temperature (5.0V heating) cleans the adsorbed stray gas at low temperature, which can improve the sensitivity and selectivity of detection.

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7. Conclusions

Considering the cost and interference, it is necessary to install the appropriate number of sensors and alarms in the appropriate positions. After analysis, the system installation position diagram is shown in Figure 2.

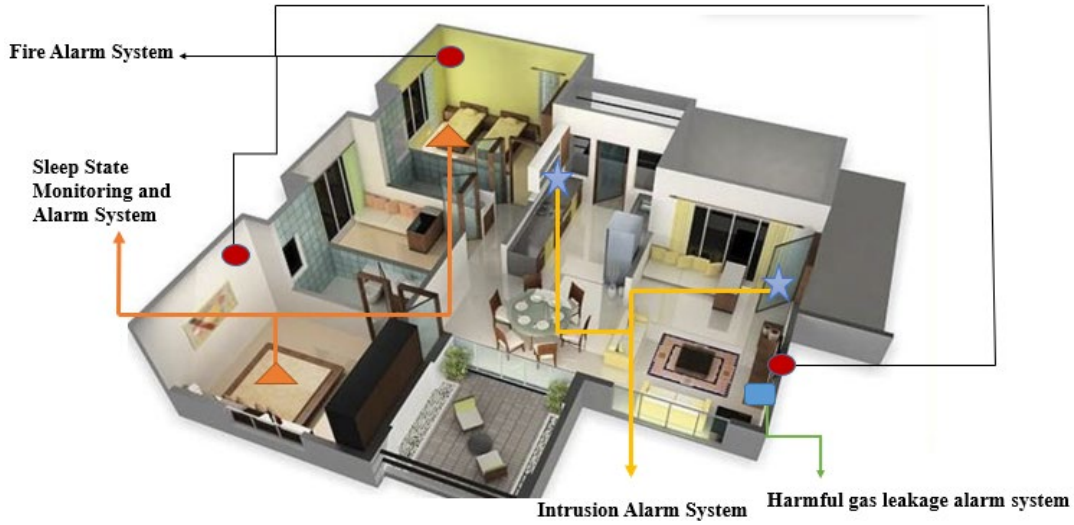

Figure 2: Diagram of the system installation position.

Through such installation method and the scheme selection above, a home security monitoring and early warning system based on multi-signal perception can be built, which can timely report home security threat information such as burglary, indoor fire, elderly situation and gas leak to the police or residents. This system can be used as an improvement of the current smart home system, which will better bring convenience and security to residents.

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