Research Article

Design of Remote Real-Time Monitoring and Control Management System for Smart Home Equipment Based on Wireless Multihop Sensor Network

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With the intensification of the pace of modern urban life and the increase of work pressure, people have higher requirements for the safety and comfort of home. However, the rapid development of Internet of Things technology, wireless communication technology, embedded technology, and data fusion technology has made this desire possible, thus making intelligent and safe. Using wireless sensor network, intelligent home system can realize the real-time collection of object location and state information, remote operation of home equipment, as well as the monitoring of the information of personnel activities, etc. However, how to efficiently analyze and integrate these information to be applied to the intelligent home system is one of the problems that need to be solved; further study of the smart home system of personal behavior identifies fire monitoring and remote monitoring of mining applications. Such information collection and integration of technology and method are given based on wireless sensor network transfer of key technologies; intelligent home security monitoring system based on Bayesian networks is proposed and a card. According to the theoretical fire monitoring method, and based on the Bayesian belief network personal behavior identification model, this paper provides the theory and method for the remote safety monitoring and control in the intelligent home environment. In this paper, based on the multisensor data fusion of smart home security, real-time monitoring alarm platform is built. Through the multisensor detection module for the home fire gas human infrared monitoring, the detected data is transmitted to the data fusion center for processing; processed results are uploaded to the cloud through the Internet. When abnormal conditions occur, users can log in to the mobile phone client to view abnormal alarm results.

1. Introduction

At present, living environment occupies the vast majority of people's life; especially after busy work, people want to relax and enjoy from home [1]. Nowadays, with the continuous development of Internet of Things technology, embedded technology, data integration technology, and wireless communication technology, intelligent home life is no longer out of reach Luxury goods. It is slowly into more and more people's family life. In enjoying the smart home that brings comfort intelligent experience at the same time, more and more people are not only concerned about the living environment quality and comfort degree; security awareness has been strengthened [2]. Therefore, building intelligent home security early warning system in the home is of great significance to protect the personal and property safety of users. With the acceleration of social information, the relationship between people's work and life and communication and information is increasingly close. Information society is changing people's way of life and work habits at the same time but also put forward a challenge to the traditional housing. Intelligent household emphasizes person's subjective initiative, controlled by two-way

interactive way, and realizes the person and environment coordination [3, 4], to build low-carbon environmental protection and energy-saving homes.

Smart home provides a kind of intelligent residential conditions, combined with electrical home appliance control technology of wireless sensor network computer network embedded technology of wireless communication technology of computer network as a whole. Intelligent home system uses integration and automatic control technology, organic connection, and integration of each module in the home. As a whole, the wireless network transmits data to monitor the safety index in the home, and the switch control and lighting control of all kinds of household appliances can effectively make the living environment more comfortable and safe compared with the traditional residence; smart home not only provides users with a sense of security and high-quality and comfortable family life living environment, and also, from the original fixed structure into an automatic operation mechanism, by providing comprehensive information communication function, the family and the outside can maintain good information communication. With the development of China's economy and the increase of urbanization process, the number of urban population is also gradually increasing. For the city, new problems and challenges have also emerged in residential security. Household appliances in home life can bring convenience, but the hidden dangers have gradually attracted people's attention. In addition, the change of social environment also has a new impact on people's way of life, so people's demand for a perfect home security system is also more urgent. For the traditional form of civil air defense, security has been unable to meet the new needs of the eyes, so the concept of smart home with the fundamental purpose of providing a safe, comfortable, and convenient living environment has gradually emerged, and the safety monitoring system in smart home system has also become a key research part [5–7].

Therefore, people are constantly seeking ways to control and reduce disasters. Therefore, a reliable family security system has improved home security essentials [8]. With the development of network technology, video technology and computer technology widespread application, made from the technology Wireless remote monitoring has become possible this design of the home wireless remote monitoring system not only to the specific location of the family temperature gas concentration and vibration and other environmental indicators monitoring, can be real-time abnormal information saved in the database and can achieve sound and light alarm, but also through SMS alarm information sent to the finger [9]. At the same time, the user can also through the browser monitor the system for remote information visit to set up this kind of wireless remote monitoring system through a variety of information transmission channels and to achieve a comprehensive monitoring of the family environment, so as to provide a strong guarantee for the safety of family life and property.

Wireless sensor network (WSN) is a network composed of a large number of cheap wireline sensors. As the emerging next-generation network, WSN has changed the way of communication between human beings and the objective world and improved the ability of human beings to obtain information from the objective world.

At the same time, with the development of wireless sensor network, it will provide mankind with the most real, direct, and accurate physical information in the objective world in the next generation of Internet [10]. People can perceive the world more intuitively to obtain the corresponding information. Business week named it one of the most influential technologies of the century in its future technology report, and technology called it one of the top ten technologies that will change the world and one of the top three high-tech industries of the future. With the deepening of wireless sensor technology research, the application of wireless sensor network in smart home system has gradually become a research hotspot [11]. Intelligent home design for human is more convenient makes life more comfortable. The research of intelligent information home appliance and intelligent home system is becoming more and more important. It is of great significance to improve the quality of life of modern human beings and create a comfortable, safe, and convenient living space [12, 13].

The electrical condition monitoring system for network flow mainly adopts the access mode of single point total control and multipoint subcontrol when it is applied in smart home [14]. The choice of two working modes can be set according to the actual application needs. As shown in Figure 1, the energy-saving protection socket (PDU) based on the network flow probe is used as the main control device of the system to connect the management terminal host, the home wireless router, and the TV in the system. After the system is powered on, the subcontrol device is automatically connected to the Wi-Fi wireless network in the local area of the home through the wireless transmission module (NRF24L01), so as to realize data transmission with the master control device and the host of the management terminal [15].

Finally, the management terminal host analyzes and identifies the traffic data collected by the network traffic probe socket. Then, according to the identification results, the corresponding energy-saving protection socket is on and off control. Theoretically, the management terminal host should have low power consumption AC and DC power supply and other performance, so as to carry out power saving control and real-time feedback for household electrical appliances commonly used. It can be concluded from the above structure diagram that the application of network flow-based electric appliance status monitoring system in smart home mainly includes three parts: energy-saving protection socket (PDU) design based on network flow probe for general control, energy-saving protection socket design for subcontrol, and management terminal host system design. [16, 17].

2. Related Work

With the rapid development of China's economy, the increase of social floating population, the complexity of social security, burglary, and other crimes are rising, people pay more and more attention to the safety of life and property, and the traditional mechanical prevention theft has been unable to meet people's needs. Therefore, family security from civil air defense and technical defense two aspects, through the effective combination of two ways, to ensure the safety of people's lives and property [18]. In our country, the illegal invasion of
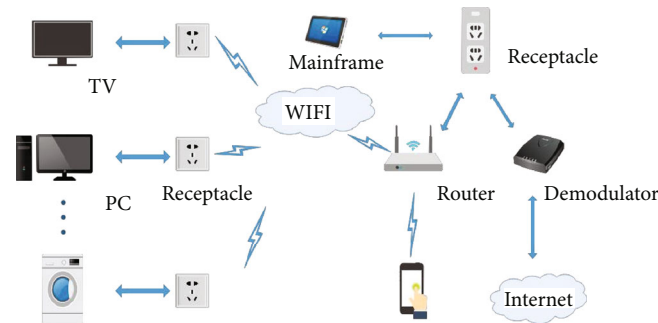
Figure 1: Schematic diagram of the second working mode of smart home application.

gas leakage fire alarm system is decades behind developed countries; it has experienced three stages of development; in the early few years for the early stage, our country began to start the significance on the research production of illegal invasion of leaking gas fire alarm products, and the application of it is mainly limited in special units. In the alarm product development stage, domestic manufacturers began with the large-scale imitation of foreign products and the introduction of foreign production technology; there is no real core technology. Since 2000, in order to improve the alarm products, with the accession of China, foreign enterprises began to enter the Chinese market in large numbers, bringing advanced production technology, while promoting the rapid development of the security industry and the maturity of the market in this period. China's alarm product enterprises quickly started, and some enterprises carried out technical cooperation [19]. Creating a lot of powerful businesses and even a lot of enterprises has been close to the world level; at present, security system has begun to enter all walks of life and security product brands on the market [20].

Smart home system is to adapt to the modern family's several activities to form a diversified network structure; the concept of wuya energy home is first proposed by the United States, Canada, Europe, Australia, Southeast Asia, and other economically developed countries. United Technology company applied the concept of building equipment information integration to the reconstruction of an old building in Hartford, Connecticut [21], using computer system to monitor and control the building's air conditioning, elevator lighting, and other equipment and provide voice communication, E-mail, and other information. Interest service, so far the first intelligent building, was born, opening the prologue of intelligent household development since the first intelligent building appeared in the world. The United States, Canada, Europe, Australia, Southeast Asia, and other developed countries have put forward a variety of intelligent household program. The United States, Germany, Singapore, Japan, and other countries have a wide range of applications [22]. The intelligent household in digital home and digital technology reform is an opportunity to focus on sense of luxury, comfort, and pleasure, but its energy consumption is very big and does not conform to the current worldwide low-carbon environmental protection and section derived from the concept of flow. Germany's

intelligence lives in pursuit of the development of special function pay attention to the basic functionality [23]. The South Korean government of intelligence can plot intelligent household to take a number of policy support. The provisions in the big cities such as new residential area of Seoul must have a smart home system, the new project of Korea national above the smart home system produced like Samsung and other well-known brand of smart home. The intelligent household design construction scale is the development of Japan with collectivization and is people-oriented, paying attention to function, giving consideration to future development and environmental protection, adopting a large number of new materials and new technologies, making full use of information network control and artificial intelligence technology, and realizing the modernization of housing technology [24]. The Prognostic and Health Management (PHM) technique was first proposed by the United States in the late 1990s as part of the JSF f-35 aircraft electronic equipment based military aviation field. In recent years, scholars and scientific research institutions in related fields in China are constantly exploring and developing PHM technology in military network, communication industry, construction, railway, electric power and other fields [25–27].

Although foreign remote control system has been developed relatively early, with leading technology and relatively perfect solutions [28], its configuration process is relatively cumbersome; taking the remote control system in the United States as an example, the first needs to manually select the module driver, followed by the associated module programming, but the number of modules is relatively large, it is difficult to complete its scheduled configuration in time, and the price of installing a set of remote control system abroad is very high [29]. Poor compatibility is not conducive to the widespread promotion and application of the system; international organizations need to specify a unified international standard. The United States in the end of the last century has wireless sensor network technology in military research and promotion application. Intel company is launched in the year for home care wireless sensor network system; the system will be a variety of sensors embedded in household appliances, through the wireless network [30]. The European Union pays more attention to the strategy and planning of Internet of Things technology in the future market, while the Japanese government takes the development of sensor network
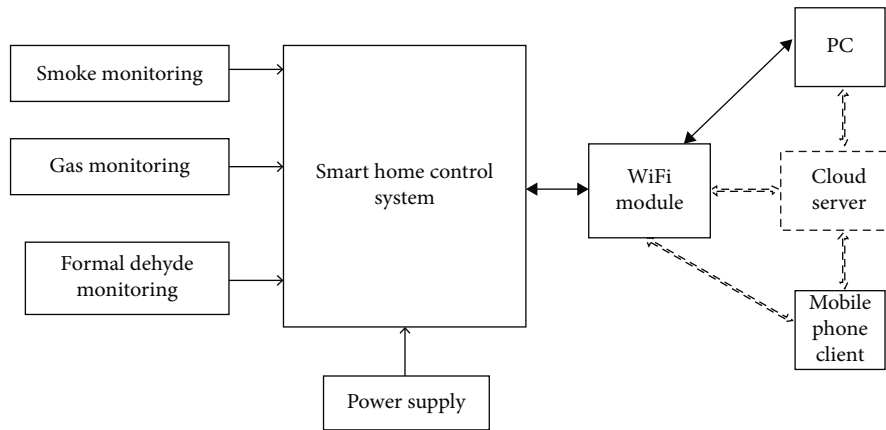
FIGURE 2: System structure block diagram.

technology as one of its key strategies, strengthening the application of Internet of Things technology in medical transportation and environmental monitoring and other fields.

The one-day Shanghai World Expo was successfully held. The scenes of smart home for better city and life were everywhere, such as various robots in the Japan pavilion, cooking robots in the Shanghai united pavilion, future urban life displayed in the future pavilion, smart connected life displayed in cisco pavilion, smart grid and smart home life displayed in the state grid pavilion, and future low-carbon intelligent life displayed in one world. Shandong pavilion shows higher household life wisdom without one not in smart home of a better life [31]. The composition of different types of sensors, such as seismic sensors, photosensitive sensors, and image sensors, can collect corresponding data according to the needs of different applications. For example, sensor nodes such as temperature, humidity, and nuclear radiation diffusivity can be detected through continuous data acquisition events, event identification location detection and nodes control, and other operations; the processed information will be fed back to the base station, while the characteristics of wireless greatly reduce the workload in the deployment and maintenance side, which is mainly applied in the following fields [32].

Multisensor fusion technology as an emerging discipline has been put forward in the early 1980s which began as a military application, dedicated to fighting on enemy target location positioning as well as the enemy army things to collect for abroad, such as the concept of multisensor data fusion first and foremost in the military. At present, data fusion has been applied by many related links, such as marine surveillance, air defense, battlefield reconnaissance and surveillance, target acquisition, and strategic defense, in the United States, Britain, Japan, Germany, Italy, etc. At present, countries have developed some highly practical data information fusion systems in the early 20th century; the United States carried out research on sonar signals with the support of the Department of National Defense, which can be regarded as the earliest research on data fusion. In the early 20th century, the U.S. Department of Defense officially included the concept of data fusion in its white paper. After entering the 21st century, multisensor data fusion technology has been studied in the United

States as the core technical means in many fields. Compared with foreign studies, the domestic research on multisensor data fusion started relatively late at present. For multisensor data fusion, research is still in the primary stage, most still draw lessons from foreign advanced technology about this on the one hand, and there is no more for the further research of multisensor data fusion and more research on the application of data fusion technology. And at present domestic about some automation control system, large. However, with the rapid development of sensor technology and the increasing number of sensor types, China will invest more energy in the research of multisensor data fusion.

3. The Wireless Multihop Sensor Network-Based Smart Home Equipment Monitoring and Control Management System

3.1. The Flow Chart of the Identification Method. The main control chip of this system is single-chip microcomputer, through wireless sensor technology, real-time monitoring of indoor air quality index, and gas concentration, through Wi-Fi module and cloud server as communication solution; data can be sent to users' mobile APP remotely. Users can monitor indoor safety conditions in real time, such as whether there is gas leakage. The system structure block diagram is shown in Figure 2.

The positive and negative terminals of the 3.3 V power module are, respectively, connected with the single-chip microcomputer and the sensor module and the VCC and GND pins of the ESP8266 communication module for power supply, which just serve as a Wi-Fi transmission. The output ports of the sensor module are, respectively, connected with the ports of single-chip microcomputer 14, 15, and 16 to transmit the monitoring signal to single-chip microcomputer 12 and 13 for identification. Pin Nos. (TX and RX) are, respectively, connected to RXD and TXD pins of ESP8266 module for data communication. Single-chip microcomputer and ESP8266 module are connected to download and debug PC firmware through USB to serial port. The client is identified and configured to communicate with the cloud server through Wi-Fi or

the Internet. The mobile client displays the transmitted data through the APP of the cloud server, and the PC displays the data through the web page of the cloud server.

3.2. Multisensor Data Fusion Security Algorithm Model. Generally speaking, the occurrence of abnormal events in the family is accidental, so no amount of security sample data can completely contain every abnormal situation in the home, especially the occurrence of fire in the security of smart home; the occurrence of fire is a complex process, and there are many uncertainties. Therefore, it is necessary to use the adaptive and self-learning characteristics of neural network to solve the problem of such accidental events. There are many structure types of neural network. In view of the complexity and uncertainty existing in the security of smart home, this paper selects the relatively mature BP neural network algorithm to fuse the data information collected by the security detection module:

$$f(x) = \frac{1}{1 + e^{-x}}. \tag{1}$$

The input of neuron of the jth hidden layer is

$$u_j^J = \sum_{j=1}^{J} \left(\omega_{ij} x_{mi} - \theta_j \right). \tag{2}$$

The output is

$$v_j^J = f\left(u_j^J\right). \tag{3}$$

Then, the input of neuron of the kth output layer is

$$u_k^K = \sum_{j=1}^{J} \left(\omega_{jk} v_j^J - \theta_k \right). \tag{4}$$

The output is

$$y_{mk} = v_k^K = f\left(u_k^K\right). \tag{5}$$

The output error of neuron of the kth output layer is

$$e_{-}\{m\,k\}(n) = t_{-}\{m\,k\}(n) - y_{-}\{m\,k\}(n). \tag{6}$$

The sum of error energy of the system output layer is

$$E(n) = \frac{1}{2} \sum_{k=1}^{K} e_{mk}^2(n). \tag{7}$$

Then, the propagation of neural network error is opposite to the forward propagation process of neural network system signal, which is propagated from back to front. Therefore, in the error correction process of neural network system, the system will correct the weight and deviation from back to front. In the BP neural network algorithm, the error energy of the expected output is positively correlated with the partial derivative of the weight of the hidden layer and the output layer, i.e.,

$$\frac{\partial E(n)}{\partial \omega_{jk}(n)} = \frac{\partial E(n)}{\partial e_{mk}(n)} \cdot \frac{\partial e_{mk}(n)}{\partial y_{mk}(n)} \cdot \frac{\partial y_{mk}(n)}{\partial u_k^K(n)} \cdot \frac{\partial u_k^K(n)}{\partial \omega_{jk}(n)}. \tag{8}$$

According to the definition of the system and all known relations,

$$
\begin{aligned}
\frac{\partial E(n)}{\partial e_{mk}(n)} &= e_{mk}(n), \\
\frac{\partial e_{mk}(n)}{\partial y_{mk}(n)} &= -1, \\
\frac{\partial y_{mk}(n)}{\partial u_k^K(n)} &= f'\left(u_k^K(n)\right), \\
\frac{\partial u_k^K(n)}{\partial \omega_{jk}(n)} &= v_j^J(n).
\end{aligned} \tag{9}
$$

Accordingly, there are

$$\frac{\partial E(n)}{\partial \omega_{jk}(n)} = -e_{jk}(n) \cdot f'\left(u_k^K(n)\right) \cdot v_j^J(n). \tag{10}$$

4. Experimental Results and Analysis

4.1. Introduction to Experimental Data Set. The intelligent gateway is not only the outside network and network communication bridge but also the center of the data fusion processing with node collected by the abnormal data that needs to be transmitted to the intelligent gateway to analyze fusion processing data fusion center. Therefore, the data acquisition system of the intelligent data fusion center is very necessary. Therefore, the data acquisition system in this paper is transmitted to the intelligent gateway from the node end of the perception layer to ensure the integrity and availability of data.

Intelligent security gateway data fusion center receives the data acquisition end after the transfer of data information, gateway nodes need to perceive the information fusion processing the data collected, it is involved in the intelligent gateway platform for the design of the data fusion algorithm, and already in the third chapter is data fusion algorithm for security detection system. The model is introduced in detail. The system uses the method of combining BP neural network algorithm and fuzzy logic reasoning algorithm to fuse the data from the sensing node end. The BP neural network is the main judgment basis, and fuzzy logic reasoning is used for auxiliary judgment.

4.2. Experimental Results Analysis. The ESP8266 series wireless modules support standard IEEE802.11b/G/N protocol and complete TCP/IP stack; users can use this series of modules to add functionality to the existing devices or build separate network control systems. This system uses ESP8266-12F wireless communication module, which is an ultralow power Wi-Fi single-chip solution with the microprocessor core inside the Wi-Fi and microcontroller chip. ESP8266 has two usage schemes: one is to use the internal processor directly and through I/O. In addition, the ESP8266 module can be connected to a single-chip microcomputer and can
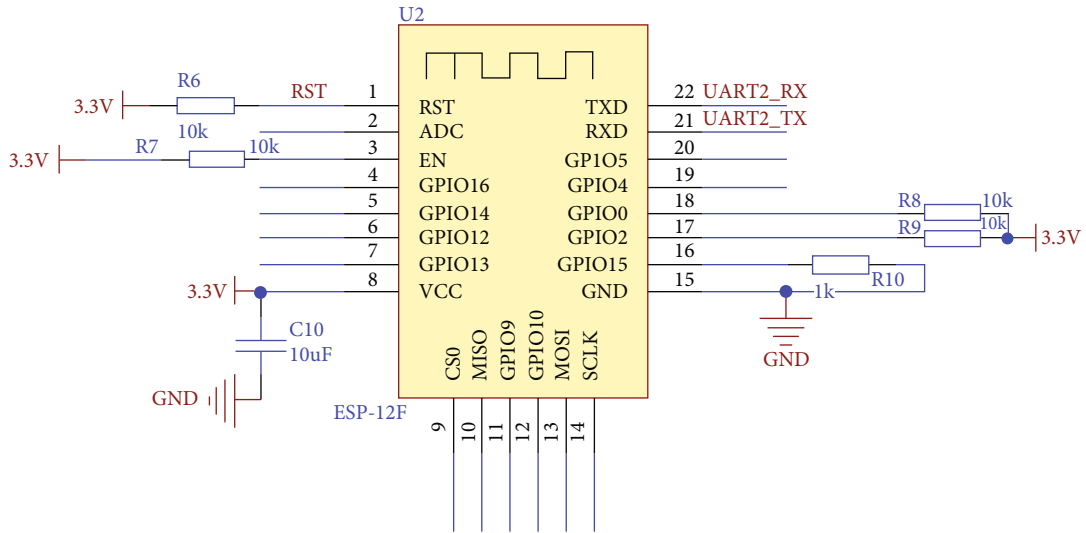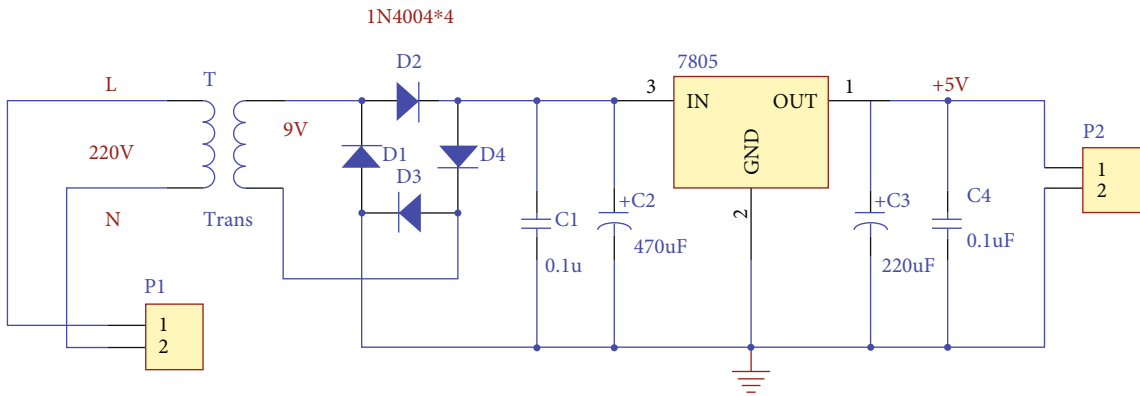
FIGURE 3: ESP8266 module schematic diagram.
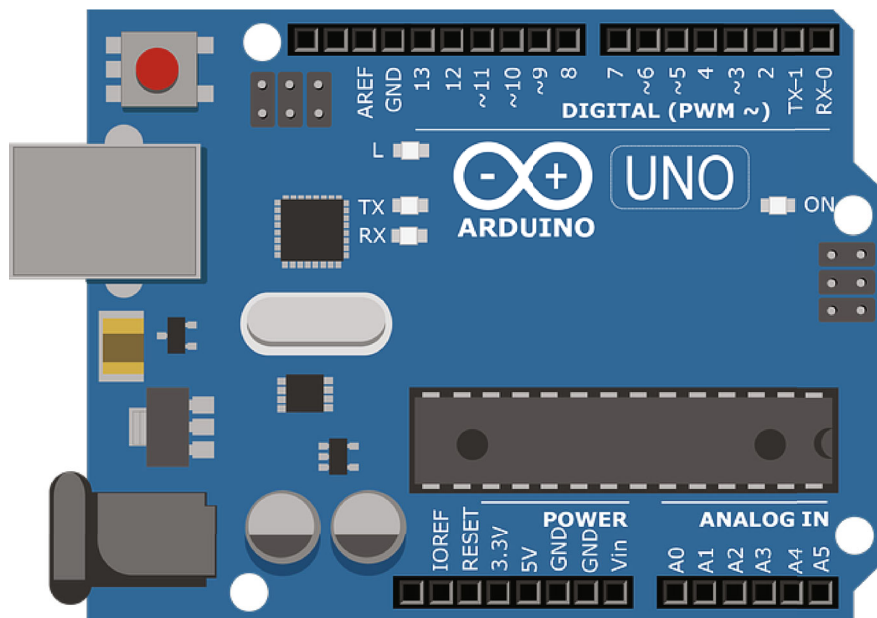

FIGURE 4: 5 V power output.

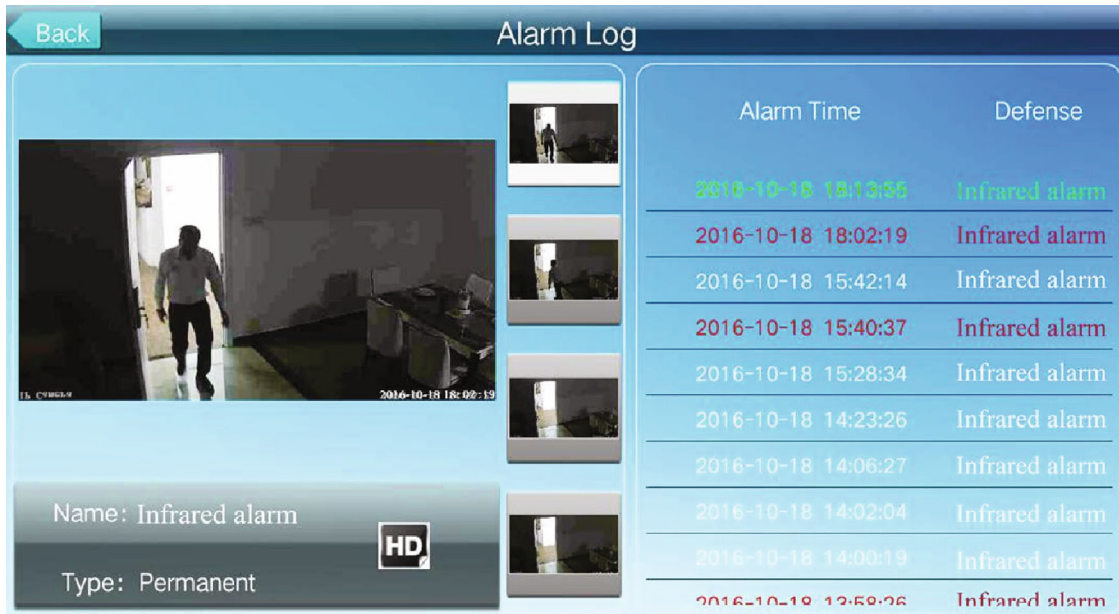FIGURE 5: Arduino UNO control board experimental platform physical picture.

FIGURE 6: Circuit schematic diagram of relay switching module (three-way control).

be used for network-related tasks. It operates using AT commands and communicates with an external MCU through a serial port. The solution is fast and stable but relatively high cost. The ESP8266 wireless module has the following features: (1) ultrasmall 802.11b/g/N Wi-Fi SOC module; (2) low power 32 CPU, which can double the application processor; (3) main frequency up to 160 MHz; (4) Built in 10 bit high-precision ADC; (5) support the UART/GPIO IIC/PWM/ADC/HSPI interface; (6) integrated Wi-Fi MAC/BB/RF/PA/LNA; (7) support a variety of sleep mode and deep sleep current to 20 ua; (8) embedded lwIP protocol stack; (9) STA/AP/STA+AP working mode; (10) Smart Config/Air Kiss one-click network configuration; (11) serial port rate up to 4 Mbps; (12) universal AT instruction quick start; (13) SDK support secondary development; and (14) support for serial port local upgrade and remote firmware upgrade (FOTA). The principle diagram of ESP8266 MCU is shown in Figure 3, from which we know that ESP8266 module consists of multiple subsystems, and they work together to finish the monitoring task.

The system provides a stable DC 3.3 V for the microcontroller and its control of the peripheral circuit in the design of power supply. The voltage of 220 V AC passes through the transformer voltage changing bridge rectifier circuit, rectifier, and filter, and the capacitor passes through the three-terminal voltage stabilizer (7805) to obtain +5 V voltage, which is then stabilized to 3.3 V by the voltage regulator chip LM1117 to supply power to the single-chip microcomputer and other modules. The circuit diagram is shown in Figure 4. It can be seen that circuit diagram consists of multiple subsystems, and they work together to finish the monitoring task.

The main control chip of this system is STM32F103CBT6 microcontroller. With the cloud server as a communication solution, the data can be sent remotely to the user's mobile

FIGURE 7: Infrared sensing measurement of human body.

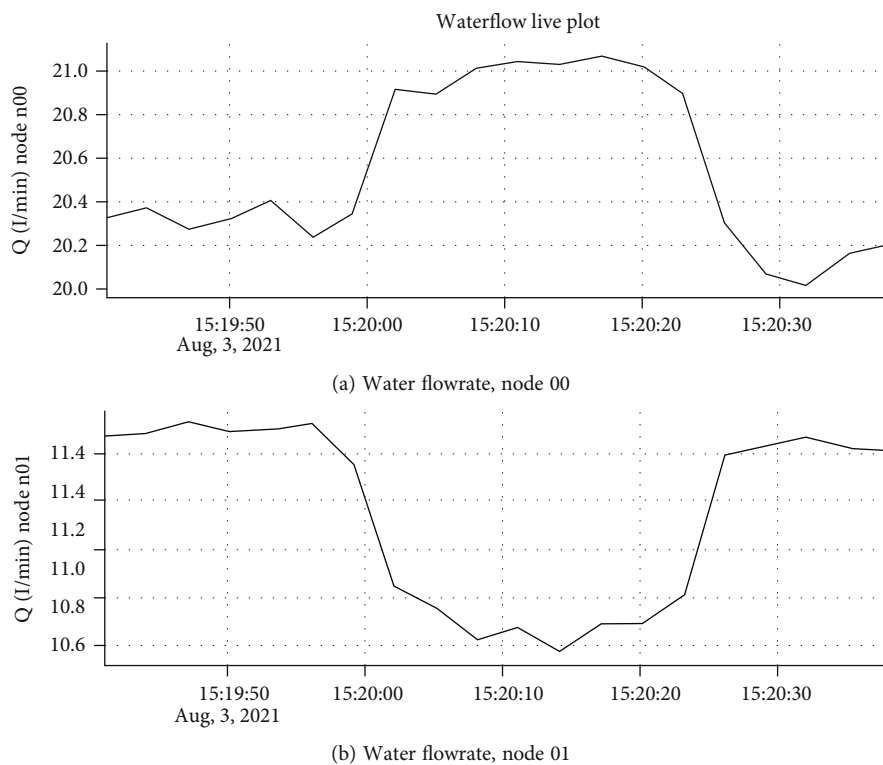(a) Water flowrate, node 00

(b) Water flowrate, node 01

FIGURE 8: Water leakage monitoring alarm subsystem test results.

APP and the user can monitor the indoor security situation in real time. Arduino is the ancestor of open source sensor experimental platform. It is a collection of open source hardware middleware products and provides rich open source interface, compatible with a variety of generic sensor actuators on the market, and other programming methods are relatively easy; you just need to simply master similar JAVA C language in function implementation related functions, and you can realize the program writing program is also very simple, only universal USB. In practical application, Arduino is most widely used in the field of smart home, as a unified access platform for sensors and actuators. Arduino can solve

problems such as heterogeneity of different sensors. It greatly reduces the development cost and improves the feasibility of smart home applications. In addition, Arduino has also been widely used in the field of robot environmental monitoring. The actual figure of the Arduino UNO control board experimental platform is shown in Figure 5. It can be seen from Figure 5 that Arduino UNO consists of multiple subsystems, and they work together to finish the monitoring task.

In this paper, JQC-3FF relay is designed to realize switching control of energy-saving socket power supply. PC0~PC3 pin output control signal of MCU drives the control end of relay. Corresponding relay module can also be configured according to the actual application situation to achieve multichannel control. In order to ensure that the control signal output by MCU can drive the relay module normally, the triode should be connected to amplify the control signal. At the same time, a continuing-current protection diode is also designed below the relay to prevent the reverse induction current generated by the relay coil from damaging the triode and other original devices, as shown in Figure 6.

Human infrared perception test is mainly used to detect illegal entry of aliens. For example, when aliens steal, human infrared detectors are arranged in each main position of the home to carry out real-time monitoring. As shown in Figure 7, when someone enters, the system will set a screenshot of the person and provide relevant records.

The test results of water leakage monitoring and alarm subsystem are shown in Figure 8. The relationship between the probability of water leakage and time can be seen from the figure. Generally speaking, around 3 : 20 PM, the peak period of water leakage is detected quickly.

5. Conclusions

Nowadays, with the continuous improvement of people's living standards, in the pursuit of a comfortable, stable, and intelligent home life at the same time, people are more and more concerned about their personal and property safety. Therefore, this paper designed a set of intelligent home security scheme based on multisensor data fusion and proposed a neural network. The data fusion method combining complex and fuzzy logic reasoning is found to have certain reliability and feasibility through experimental simulation and actual testing. Compared with traditional security detection methods, the multisensor data fusion method has high detection accuracy and seldom has false alarm or missing alarm.

This kind of home system is a complex system engineering, involving communication computer automation architecture and other fields of technology. A lot of programs have been put forward, and the process of improving the home system research is very difficult. In this paper, there are many things needed to improve the place; the follow-up should focus on one concrete application and complete the various modules organically unified together, forming a transition of the prototype system. Although the system in this paper has more innovations and better application effects, how to use wireless sensor network to process big data in home furnishing is a subject worth studying in the future.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] B. Rahmadya, Z. Zaini, and M. Muharam, "IoT: a mobile application and multi-hop communication in wireless sensor network for water monitoring," *International Journal of Interactive Mobile Technologies*, vol. 14, no. 11, p. 6393, 2020.

[2] H. Wang, "Sustainable data analysis framework of smart city based on wireless sensor network," *International Journal of Networking and Virtual Organisations*, vol. 25, no. 2, pp. 114–133, 2021.

[3] J. Liu, Z. Zhao, J. Ji, and M. Hu, "Research and application of wireless sensor network technology in power transmission and distribution system," *Intelligent and Converged Networks*, vol. 1, no. 2, pp. 199–220, 2020.

[4] Y. Cui, L. Zhang, Y. Hou, and G. Tian, "Design of intelligent home pension service platform based on machine learning and wireless sensor network," *Journal of Intelligent & Fuzzy Systems*, vol. 40, no. 2, pp. 2529–2540, 2021.

[5] X. Zhu, "Complex event detection for commodity distribution Internet of Things model incorporating radio frequency identification and wireless sensor network," *Future Generation Computer Systems*, vol. 125, pp. 100–111, 2021.

[6] M. Lewandowski and B. Płaczek, "Data transmission reduction in wireless sensor network for spatial event detection," *Sensors*, vol. 21, no. 21, p. 7256, 2021.

[7] J. Jiang, H. Wang, X. Mu, and S. Guan, "Logistics industry monitoring system based on wireless sensor network platform," *Computer Communications*, vol. 155, pp. 58–65, 2020.

[8] M. Kostrzewski, L. Filina-Dawidowicz, and S. Walusiak, "Modern technologies development in logistics centers: the case study of Poland," *Transportation Research Procedia*, vol. 55, pp. 268–275, 2021.

[9] H. Zongjian, "Application of intelligent sensor technology in steady state operation of power system," *Converter*, vol. 17, no. 1, pp. 9–15, 2021.

[10] M. U. Younus and S. W. Kim, "Proposition and real-time implementation of an energy-aware routing protocol for a software defined wireless sensor network," *Sensors*, vol. 19, no. 12, p. 2739, 2019.

[11] J. Zhao and G. Li, "Study on real-time wearable sport health device based on body sensor networks," *Computer Communications*, vol. 154, pp. 40–47, 2020.

[12] C. Zhou, X. Luo, T. Huang, and T. Zhou, "Function matching of terminal modules of intelligent furniture for elderly based on wireless sensor network," *IEEE Access*, vol. 8, pp. 132481–132488, 2020.

[13] F. Tian, X. Long, and W. Liao, "Design of Smart home system based on basic radio frequency wireless sensor network," *International Journal of Online Engineering*, vol. 14, no. 4, pp. 126–136, 2018.

[14] T. Kim and W. Chiu, "Consumer acceptance of sports wearable technology: the role of technology readiness," *International Journal of Sports Marketing and Sponsorship*, vol. 14, pp. 57–89, 2018.

[15] P. Devan, F. A. Hussin, R. Ibrahim, K. Bingi, and F. A. Khanday, "A survey on the application of WirelessHART for industrial process monitoring and control," *Sensors*, vol. 21, no. 15, p. 4951, 2021.

[16] T. Mahmood, J. Li, Y. Pei et al., "An intelligent fault detection approach based on reinforcement learning system in wireless sensor network," *The Journal of Supercomputing*, vol. 78, no. 3, pp. 3646–3675, 2022.

[17] J. Yang and W. Lv, "Optimization of sports training systems based on wireless sensor networks algorithms," *IEEE Sensors Journal*, vol. 21, no. 22, pp. 25075–25082, 2021.

[18] R. K. Saini, M. K. Saini, and R. Sharma, "Requirements of applications of wireless sensor networks for the Internet of Things," in *Internet of Things for Agriculture 4.0*, pp. 241–254, Apple Academic Press, 2021.

[19] M. Faheem, R. A. Butt, B. Raza, M. W. Ashraf, M. A. Ngadi, and V. C. Gungor, "A multi-channel distributed routing scheme for smart grid real-time critical event monitoring applications in the perspective of Industry 4.0," *International Journal of Ad Hoc and Ubiquitous Computing*, vol. 32, no. 4, pp. 236–256, 2019.

[20] W. Fang, W. Zhang, W. Chen, Y. Liu, and C. Tang, "TMSRS: trust management-based secure routing scheme in industrial wireless sensor network with fog computing," *Wireless Networks*, vol. 26, no. 5, pp. 3169–3182, 2020.

[21] M. T. Arefin, M. H. Ali, and A. K. M. F. Haque, "Node mobility optimization in multi-hop WBAN using genetic algorithm," *International Journal of Computer Science and Information Security*, vol. 19, no. 3, pp. 1432–1445, 2021.

[22] O. Lawal, J. Odiete, and O. Oyediran, "Wireless sensor network: a framework for power and temperature monitoring utility system," *Networking and Mobile Computing*, vol. 34, no. 1, pp. 1–18, 2019.

[23] M. Yan, P. Liu, R. Zhao et al., "Field microclimate monitoring system based on wireless sensor network," *Journal of Intelligent & Fuzzy Systems*, vol. 35, no. 2, pp. 1325–1337, 2018.

[24] A. Yang, C. Zhang, Y. Chen, Y. Zhuansun, and H. Liu, "Security and privacy of smart home systems based on the internet of things and stereo matching algorithms," *IEEE Internet of Things Journal*, vol. 7, no. 4, pp. 2521–2530, 2020.

[25] F. Muzafarov and A. Eshmuradov, "Wireless sensor network based monitoring system for precision agriculture in Uzbekistan," *Telkomnika*, vol. 17, no. 3, pp. 1071–1080, 2019.

[26] Z. Dong, "Research on grid connected control method of single phase inverter based on wireless sensor network," *International Journal of Wireless Information Networks*, vol. 29, pp. 193–202, 2022.

[27] X. Li, H. Liu, W. Wang, Y. Zheng, H. Lv, and Z. Lv, "Big data analysis of the Internet of Things in the digital twins of smart city based on deep learning," *Future Generation Computer Systems*, vol. 128, pp. 167–177, 2022.

[28] G. Shanthi and M. Sundarambal, "FSO–PSO based multihop clustering in WSN for efficient medical building management system," *Cluster Computing*, vol. 22, no. S5, pp. 12157–12168, 2019.

[29] J. Zhang, "Real-time detection of energy consumption of IoT network nodes based on artificial intelligence," *Computer Communications*, vol. 153, no. 2, pp. 188–195, 2020.

[30] D. L. Mythri and J. N. Kuriti, "A brief review on wireless sensor network technologies," *System*, vol. 12, no. 3, pp. 313–335, 2019.

[31] G. Yang and H. Liang, "A smart wireless paging sensor network for elderly care application using LoRaWAN," *IEEE Sensors Journal*, vol. 18, no. 22, pp. 9441–9448, 2018.

[32] M. Abdelhafidh, M. Fourati, L. C. Fourati, and A. Chouaya, "Wireless sensor network monitoring system: architecture, applications and future directions," *International Journal of Communication Networks and Distributed Systems*, vol. 23, no. 4, pp. 413–451, 2019.