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Intelligent Monitoring System of Residential Environment Based on Cloud Computing and Internet of Things

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ABSTRACT With the development of society and the improvement of living standards, people pay more and more attention to their own living environment and life safety, and more people are gradually paying attention to the impact of the quality of the living environment on their health and work efficiency, and to meet this demand of people, it is necessary to effectively monitor and control the living environment. Based on this, this article applies cloud computing and Internet of things technologies that have developed rapidly in recent years, and proposes to design a residential environment intelligent monitoring system based on cloud computing and Internet of things, and use Internet of things and sensor technologies to achieve target connection and communication. It then uses distributed computing, a cloud computing technology, to implement integrated, standardized management of this system for truly intelligent monitoring. In this article, we first gathered a large amount of information through literature search methods, systematically introduced cloud computing and Internet of Things technologies, and introduced two applications in environmental intelligent monitoring. Next, we propose a design experiment of a residential environment intelligent monitoring system based on cloud computing and the Internet of Things, and propose an overall concept of system design, system hardware and software design requirements, and device selection and comfort evaluation. And living environment data integration is introduced in detail. We then tested the performance of the system in a specific application of the system in a real residential environment, using data parameters collected at different points in time as experimental data. Finally, it is concluded that the fuzzy close fusion algorithm used in the experiment can obtain data parameter values that are in good agreement with the real values, and the error range is controlled within 0-0.01; the indoor environment comfort is judged by 1 as the standard. $PMV > 1$ indicates that the comfort level is excellent, and in the test experiment, each parameter value at 5 time points is all >1, indicating that the indoor environment comfort level detected by the system is excellent.

INDEX TERMS Cloud computing, Internet of Things technology, living environment, intelligent monitoring system.

I. INTRODUCTION

A. BACKGROUND AND SIGNIFICANCE

Since the beginning of the 21st century, although the rapid development of industrialization and urbanization has promoted the overall improvement of social economy on the one hand [1], it has also caused pollution to people's living environment on the other hand, and this environmental pollution has affected people's normal live and work to a certain extent. The enhancement of economic capacity and the improvement of living standards have made people no longer merely satisfied with basic living needs. More and more people have begun to pursue a safe and high-quality living environment, especially an indoor living environment.

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A poor living environment can easily induce various diseases such as respiratory diseases and leukemia, while the use of electricity, water and gas will affect home safety. Effectively monitoring and controlling the living environment, adjusting the comfortable indoor environment, improving the quality of people's living environment, and protecting the environment of people's lives, work and physical health are very practical. It is important [2].

In recent years, with the rapid development of science and technology, the application of cloud computing and the Internet of things in smart homes and environmental monitoring has become more and more common, and the results achieved have become more and more significant [3]. The Internet of things technology is based on computer Internet technology. If the Internet realizes the long-distance communication between people, then the Internet of things satisfies the communication between people and things, things and things. Using cloud computing and Internet of things technology to design a set of intelligent monitoring system for the living environment [4], so that people can effectively monitor and adjust the indoor temperature and humidity, light intensity and toxic and harmful gas content in the company or outdoors or even farther away. Let people clearly understand the condition of every item in the home and can control indoor electronic equipment, such as air conditioners, lights, etc., through terminal devices such as smart phones or computers, to achieve true intelligence, and all these rely on the Internet of things technology can be realized [5].

B. RELATED WORK

Someone has done research on how to realize the intelligent management of the environment. Valenzuela, Victor L and de Lucena, Vicente F have proposed that environmental intelligence can be defined as an improvement to traditional automation systems. They believe that traditional automation systems are a collection of ubiquitous computers, sensors and actuators whose purpose is to facilitate the performance of everyday tasks. They said that a very important derivative of environmental intelligence is a supported living environment, which is a complex system designed to help people interact with other devices [6]. When talking about users with disabilities, they said it is easier to observe the impact of such systems in their daily lives. To this end, they modified the electric wheelchair. By modifying the control system of the electric wheelchair, and then remotely controlling it through mobile devices such as mobile phones and computers, they realized the intelligent management of the electric wheelchair and helped improve the quality of life of the disabled [7]. In addition, Yang, Chao-Tung and Chen, Shuo-Tsung believe that the Internet of things can achieve effective monitoring of indoor ambient air quality. They stated that indoor environmental monitoring and management systems play a vital role in public health sustainability. By monitoring the indoor air quality in public areas such as schools, offices, homes or other buildings, the authorities will get a better picture of indoor air quality and take the right steps to ensure better air quality for people in buildings. They believe that this monitoring system can also provide society with information about indoor air quality [8]. To achieve this goal, they developed a monitoring system to issue warnings using information technology based on big data and cloud computing environments [9]. In their research, they proposed an intelligent indoor environment monitoring system (iDEMS) combined with ZigBee wireless sensor network technology to store and process environmental data in HBase. The mechanism of the proposed system is divided into three stages: data collection, data processing and information monitoring [10]. In order to understand smart indoor environment monitoring, they first collected gas from smart indoor environment monitoring through environmental sensors using ZigBee wireless sensor network technology; after that, the environmental data collected in the first stage will be stored and processed in HBase, which will support massive amounts Data storage, and can freely increase the storage capacity for analyzing and processing big data. At this stage, they also compared several data input methods, which are more efficient to import data in HBase; then, the smart control socket has been integrated into iDEMS, if the air quality exceeds the officially authorized air quality index rules, then Issue a warning; finally, iDEMS provides result information through a Web-based monitoring platform so that users can use the Internet to monitor the environment and enable them to use these wise decisions to manage and improve the environment [11], [12]. Judging from the research content of other scholars, they study the application of the Internet of things in a specific aspect such as wheelchairs or indoor air quality, while this article studies the entire living environment of people, including the temperature, humidity, and light of the indoor environment. Monitoring and adjustment of toxic and harmful gases, dust, and control of various indoor home appliances, such as air conditioners, lights, water pipes, etc. At the same time, the monitoring system proposed in this paper also has functions such as remote viewing and warning for users. The content of this paper is an effective expansion of previous research results.

C. INNOVATIONS IN THIS ARTICLE

The innovations of this article are mainly reflected in the following aspects: (1) With the improvement of living conditions, people pay more and more attention to their own living environment and quality, realize intelligent monitoring and management of the living environment, and improve the quality of living environment. Based on the demands of many people, based on this, the research content of this article is of great social practical significance and discussion value; (2) This article creatively proposes the design of a residential environment intelligent monitoring system based on cloud computing and the Internet of things, using the Internet of things with sensor technology, it collects data on various parameters of the living environment, then uses cloud computing to process the data, and finally feeds the results back to the user and uses the system's functions to implement intelligent control of the living environment;

(3) The residential environment intelligent monitoring system designed in this paper can not only effectively monitor the common parameters of the residential indoor environment, but also can effectively monitor water flow, electricity, and gas. At the same time, it can also achieve effective control and control of various indoor home appliances.

D. ARTICLE CONTENT FRAME

The second part of this article mainly introduces some related theoretical knowledge of cloud computing and the Internet of things and their applications in home environment monitoring;

The third part proposes the design and establishment of an intelligent monitoring system for the living environment based on cloud computing and the Internet of things by using cloud computing and Internet of things technology, which introduces the overall design ideas of the system and the introduction of hardware and software facilities in detail;

The fourth part mainly analyzes the realization of the residential environment intelligent monitoring system designed in this paper and the testing of the system;

The fifth part summarizes the research results of this article.

II. APPLICATION OF CLOUD COMPUTING AND INTERNET OF THINGS IN INTELLIGENT MONITORING OF RESIDENTIAL ENVIRONMENT

A. CLOUD COMPUTING

1) THE PROPOSAL AND DEVELOPMENT OF CLOUD COMPUTING

Cloud computing is a popular technical term in the IT field [13]. It was first proposed in 2006 and has become a hot business computing model. Cloud computing is a kind of distributed computing. It not only has massive storage capabilities and strong perception capabilities, but also has super data computing capabilities. Its computing mode is to decompose huge data computing tasks into small computing programs and distribute them. In the resource pool, these small programs are analyzed and processed by connecting to multiple servers, and then dynamic and easily expandable virtualized resources are obtained and fed back to users. At the same time, various application systems connected to it can also obtain resources according to their needs, which greatly improves the usability and reliability of the software. Cloud computing includes not only the delivery and use mode of IT infrastructure [14], but also the delivery and use mode of specific services. It is an abstract representation of the traditional Internet and network, because it has the same computing service characteristics as the cloud and water cycle in nature. So it is vividly called ''cloud computing'' [15], [16].

2) SERVICE CHARACTERISTICS OF CLOUD COMPUTING

First, autonomous demand services. The services provided by cloud computing to users are autonomous. Users only need to pay related fees to cloud computing technology providers through the network according to their needs to obtain cloud computing resources without interacting with providers. At the same time, there is a cloud service catalog in the cloud system, and users can choose the service items they need in a self-service manner [17].

Second, the resource pool can be shared by multiple people [18]. Cloud computing moves computing and data from computers to big data centers, virtualizes the computers in the network as a resource pool, and provides services to all users. Users only need to pay a certain fee to enjoy cloud computing resources, which can be used for all netizens provide services [6].

Third, dynamic resource allocation. Whenever a user increases a service demand, the cloud system can match by increasing the available resources to realize the rapid and elastic provision of resources; and when a computing resource is no longer needed, the cloud system can filter out these resources by releasing them, and realize the dynamic and scalability of resource utilization [19], [20].

Fourth, take the network as the center. The various components and structures in the cloud computing system are connected by the network and exist in the network with the network as the carrier. The services provided to users are also in the form of the network. At the same time, users also need to rely on terminal equipment to enjoy cloud computing resources. Perform network access to obtain cloud computing resources [21].

Fifth, services can be monitored and measured. Because cloud computing has dynamic characteristics, and the acquisition of its resources requires payment of corresponding fees, in order to ensure the security of cloud resources and the rights and interests of users, the cloud system has a monitoring function, and all services provided by the cloud system can be effectively monitored and measured. Test [22], [23].

Sixth, the pooling and transparency of resources. Because cloud resources can be effectively monitored and measured, all resources can be uniformly managed, scheduled, and shared [24]. Therefore, the resources provided by a cloud system are like a resource pool, servicing all the users who need it. The resources are all ''clearly marked'', pay-as-you-go, very transparent, users do not need to understand the internal structure, and can get them as needed [25], [26].

3) SERVICE FORM OF CLOUD COMPUTING

First, infrastructure-level services;

Second, platform-level services;

Third, software-level services [27], [28].

B. INTERNET OF THINGS

1) OVERVIEW OF THE INTERNET OF THINGS

The Internet of things is based on the Internet, allowing ordinary objects with independent functions to be interconnected. By using various physical devices, including various electronic devices, broadband, network connections and other sensor-like hardware components, combined with different communication methods, an intelligent technology that connects objects and objects to the Internet to realize the collection, transmission and processing of information. Through the Internet of things, the communication and interconnection between people and things, and things and things can be realized. It is a technological leap based on the Internet. At the same time, the Internet of things also has intelligent processing functions that can realize intelligent automatic control [29], [30].

2) THE NETWORK STRUCTURE OF THE INTERNET OF THINGS

The network structure of the Internet of things is divided into three levels, namely the information perception layer, the network transmission layer and the application layer.

First, the information perception layer. Including sensor module and communication module, it mainly completes data collection and short-distance transmission. The sensor module is equipped with a variety of sensors, radio frequency RFID devices and other smart devices to realize the collection of sensor information; the communication module refers to a short-distance communication network, which mainly transmits the collected data to the smart gateway [31].

Second, the network transport layer. It includes two parts: the gateway and the network. The gateway is responsible for receiving the data information from the information perception layer and sending it to the network after integrating the data information. The network, namely the computer network and the communication network, is responsible for transmitting the data information.

Third, the application layer. The application layer is responsible for the connection between the network and users, combining perception information with the characteristics of needs and applications, analyzing and processing sensor information and providing services according to user needs [32]–[34].

3) SMART SENSORS AND WIRELESS COMMUNICATION TECHNOLOGY

Smart sensors, also called wireless sensors, are an important part of the Internet of things technology and are mainly responsible for data collection and information processing and transmission. With the vigorous development of the Internet of things and its wide application in various fields, smart sensors have also attracted more and more attention. Smart sensors distribute multiple sensor nodes in each preset target area, and wirelessly connect each sensor node into a network, collect and transmit information, and sense the number of target objects through the cooperation of multiple sensor nodes. The location information is transmitted to the network for users to monitor and control the target area, so it is often used in the intelligent monitoring of the home environment [35].

In the area of intelligent monitoring, data collection and transmission are often implemented using ZigBee wireless communication technology. Short-distance wireless communication equipment can realize the free matching of computer peripherals with portable electronic equipment and household appliances, thereby realizing information transmission and resource sharing [36]. ZigBee technology is mainly used for data transmission between various electronic devices that do not require high transmission speed in short distances. Compared with traditional wired communication and other wireless communication technologies, ZigBee technology has greater advantages in energy saving and transmission distance. ZigBee's network topology has three forms: star network topology, mesh network topology and cluster network topology [37]. The powerful networking function makes ZigBee both a router node and a terminal device node [38].

C. IPRACTICAL APPLICATION OF CLOUD COMPUTING AND THE INTERNET OF THINGS IN THE INTELLIGENT MONITORING OF THE RESIDENTIAL ENVIRONMENT

1) THE EMERGENCE OF THE CONCEPT OF SMART HOME

Smart home, as the name suggests, is a new concept that integrates modern smart technology into the traditional home appliance industry to help people achieve effective monitoring and control of the living environment, thereby improving the quality of the living environment. Smart home originated in the 1980s, from the earliest electronic homes to autonomous homes, and then to today's smart homes, each evolution symbolizes technological progress and leaps. Smart home is a new residential model that integrates multiple advanced technologies such as computer Internet technology, Internet of things technology, and automatic control technology [39].

2) THE APPLICATION OF THE INTERNET OF THINGS IN RESIDENTIAL ENVIRONMENT MONITORING

One of the most widely used areas of the Internet of things is in the intelligent monitoring and control of the environment. With the increasing requirements of people for the living environment, the application of the Internet of things in residential living environment monitoring is becoming more and more common. At present, the application of the Internet of things in the monitoring of the living environment is mainly in two aspects: the intelligent security of the indoor environment and the automatic control of the home [40]. Use smart sensor technology to install multiple sensor nodes in the indoor target area of the house, such as sensors for detecting fires and toxic and harmful gases, and connect these nodes into a network through wireless communication technology [41]. The network architecture of the Internet of things achieves various indoor environments. Item parameters, such as the collection, transmission, analysis and feedback of harmful gases such as indoor temperature and humidity, light, dust, formaldehyde, etc., so as to achieve effective monitoring of the indoor environment; at the same time, the Internet of things technology can also integrate various indoor electronic devices, such as air conditioners. Lights, gas, electric switches, etc. are connected to the Internet to remotely monitor and control them, and adjust their working status as needed [42], [43].

3) APPLICATION OF CLOUD COMPUTING IN RESIDENTIAL ENVIRONMENT MONITORING

Cloud computing is mainly used in the smart home system of the Internet of things. Due to the repeated construction, poor scalability, and difficulty of later maintenance in the design of a smart home environment monitoring system based on the Internet of things, the smart monitoring system needs to be optimized. Cloud computing can better solve these problems. Through cloud computing technology, the storage capacity of the monitoring system can be expanded, and the efficiency of data information processing can be improved. At the same time, due to the pooling and transparent characteristics of cloud computing, the intelligent home system can be connected to all parts of the world, breaking through the limitations of time and space and realizing Fully popularize and promote. Compared with cloud computing, the scope of the Internet of things is actually larger. Cloud computing is only specifically applied at the application layer of the Internet of things, and it is fed back to users in the form of resources by processing data in the computer network center. The application of cloud computing in the residential environment intelligent monitoring system is beneficial to provide users with a more comfortable, convenient and safe environment [44].

III. DESIGN EXPERIMENT OF A RESIDENTIAL ENVIRONMENT INTELLIGENT MONITORING SYSTEM BASED ON CLOUD COMPUTING AND THE INTERNET OF THINGS

A. OVERALL SYSTEM DESIGN IDEAS

The intelligent monitoring system for residential environment based on cloud computing and the Internet of things proposed in this paper mainly uses Internet of things technology, sensor technology, communication technology and cloud computing technology. The comprehensive application of these technologies can make the designed and constructed monitoring system perform better. The parameter monitoring of the living environment is more accurate and convenient, which helps to improve the quality of people's living environment.

1) THE OVERALL ARCHITECTURE OF THE SYSTEM

Based on the three-tier architecture of the Internet of things, this paper designs the overall architecture of the system into a three-tier structure of environmental information detection perception layer, information transmission layer and application layer. The collection and short-distance transmission of environmental information parameters; the gateway of the transmission layer is responsible for receiving the data information from the perception layer and uploading it to the network after integrating and processing the data information. The network here is the IoT cloud platform; finally, the application layer transmits the perception information from the network to the remote terminal device. The concrete system structure is shown as in Figure 1.

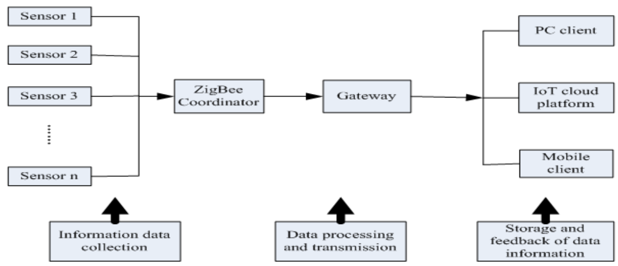

FIGURE 1. The overall architecture of the residential environment intelligent monitoring system.

2) THE FUNCTION OF THE SYSTEM

Based on the foregoing, the residential environment intelligent monitoring system designed in this article is mainly divided into two aspects: health and safety environment monitoring and comfortable environment monitoring.

First, health and safety environmental monitoring, monitoring of harmful gases such as carbon monoxide, methane, and formaldehyde in indoor air, monitoring of natural gas content and water supply flow. These functional indicators are designed to monitor and control the quality of gas, water, and air in the room. When these indicators reach a preset threshold, the system will automatically alert and provide feedback to the user. In addition, by configuring fire smoke sensors and human infrared sensors to warn and monitor emergencies such as house fires and breach.

Second, comfortable environment monitoring, which monitors indoor temperature, humidity, heat, light and air pressure, and through the collection, transmission and feedback of parameters of comfort indicators, to meet the needs of users to remotely control and adjust the work of various indoor appliances state, adjust various indoor comfort index parameters to meet their own needs.

3) SYSTEM DESIGN REQUIREMENTS

The design of the system mainly includes two parts: system hardware design and software design. Specific requirements are as follows:

Hardware design requirements:

First, low energy consumption. Each sensor node and coordinator in the system are powered by batteries, and the equipment has a long working time, so it is best to choose low-energy-consumption devices to extend the service life [45].

Second, miniaturization. In order to improve the aesthetics of the room and reduce the space occupied by the device, a smaller sensor device should be selected as far as possible.

Third, it has high reliability. In order for the system to maintain a stable working condition for a long time, the quality of the hardware must be guaranteed, and more reliable hardware facilities should be selected.

Software design requirements:

First, the software is modularized. In order to reduce the impact of a single software failure on the overall system, all software is modularized during software design to improve software compatibility.

Second, the data transmission format must be unified. The unified format of the data transmitted by each software function module is the basis and prerequisite for ensuring communication and improving transmission efficiency. Therefore, the interface for transmitting data must be unified and formatted.

B. SYSTEM HARDWARE DESIGN

According to the overall architecture of the system design and the functional requirements of the system, we divide the hardware design of the system into three parts: the environmental information detection and perception layer, the information transmission layer and the application layer, which can be specifically divided into the front-end sensor signal of the indoor living environment, the collection uses the star network topology of the ZigBee network; the home gateway is mainly a variety of processors and memories for analyzing, processing and uploading the collected data; terminal equipment, various smart phones, computers, etc., to realize the docking between the user and the network interface, which is convenient for the user to monitor and control various parameters of the living environment.

1) SIGNAL ACQUISITION BY ZIGBEE NETWORK

According to the overall design concept of the system, the front-end sensor signal collection section includes the collection of parameters such as methane, formaldehyde, carbon monoxide, dust, water flow switch, temperature, humidity, light, heat and air pressure..First of all, we have to choose a suitable sensor. Since the sensor is the primary tool for collecting environmental signals, all subsequent steps are carried out on this basis. The quality of the signal collected by the sensor will directly affect the performance of the monitoring system, so the selection of the sensor is very important. Choosing a sensor with high sensitivity, strong stability and low energy consumption is the primary key.

First, the selection of hazardous gas sensors. The sensor's sensing and collection of harmful gases are judged by the concentration of the gas in the room. When the concentration of harmful gases reaches a preset threshold, the sensor will react and give an alarm. The harmful gas sensor selected in this article is a resistive semiconductor gas sensor TGS2611, which is used to detect indoor harmful gases such as methane, formaldehyde and natural gas.

Second, the selection of temperature, humidity and air pressure sensors. Indoor temperature, humidity and air pressure are the key factors that determine whether the indoor environment is comfortable or not. This article uses a high-precision, high-performance combined digital sensor that can simultaneously detect temperature, humidity and air pressure. It is worth mentioning that the sensor body. It is very active and consumes very low energy. It can be used in modules such as mobile phones and watches. This combined digital sensor has three modes: sleep mode, forced conversion mode and normal mode. The mode conversion can be set by a software program.

Third, the dust sensor selection. The dust sensor used in this article is an optical air quality sensor. It is different from the general dust sensor in that its internal structure adopts the optical principle, which is not easily affected by temperature, and the data collected is more accurate.

2) PROCESSING AND TRANSMISSION OF DATA SIGNALS BY THE GATEWAY

In the monitoring system experiment designed in this article, the gateway's processing and transmission of environmental information is mainly done through circuits connected to sensors and home appliances. According to the environmental signal indicators monitored by the system, we have designed signal acquisition circuits for harmful gas sensors, temperature and humidity, respectively. And air pressure sensor signal acquisition circuit, dust sensor signal acquisition circuit and water flow switch control circuit. When the front-end sensor collects the information of these signal indicators, the sensor converts these environmental signals into digital signals, and transmits them to the network connected to the user terminal device through the circuit.

3) FEEDBACK OF TERMINAL EQUIPMENT TO INDOOR ENVIRONMENTAL SIGNALS

After the gateway processes the collected environmental signals and uploads them to the network, the network will transmit them directly to the user's terminal equipment. This link is the signal output process and the user's direct and remote monitoring of the indoor living environment. The link of control. All indoor monitoring target objects are connected to sensors, the sensors are connected to the home gateway, and the gateway is connected to the network of user terminal devices, thus forming an IoT cloud platform. Users can use mobile terminal devices such as smartphones, tablets, or PCs. The terminal equipment effectively monitors and controls the home environment.

C. SYSTEM SOFTWARE DESIGN

In the entire residential environment intelligent monitoring system, the sensors used to collect various parameters will be subject to different degrees of external interference during the signal collection process, such as noise, which will bring great errors to the measurement results and make the collected environmental information inaccuracy, so it needs to be compensated by software facilities. In addition, the process of environmental signal transmission and feedback also requires the support of software, and the processing and analysis of data and the display of data on the user terminal equipment all require software to complete [46]. The system designed in this paper mainly includes 7 parts of software programs, namely system startup, data information collection, data information analysis and processing, data information fusion, data judgment, data information transmission, and data information display. Among them, the fusion of data

TABLE 1. PMV value and human body thermal sensation.

PMV value	-3	-2	-1	0	1	2	3
Hot feeling	Cold	Cool	Slightly cool	Moderate	Slightly warm	Warm	Hot

TABLE 2. Indoor air quality grade standards.

Composite Index	<0.5	0.5-1	1-1.5	1.5-2	>2
Grade	Excellent	Good	Medium	Poor	Bad

information involves the integrated calculation of various indoor environmental parameters, and the indoor environmental evaluation situation is obtained through the comprehensive calculation of various indoor parameters through the algorithm model.

1) THE OVERALL DESIGN PROCESS OF THE SOFTWARE SYSTEM

First, the environmental signal parameter acquisition stage. After the system is powered on, first format all data, perform unified processing of all data transmission, develop sensor node software, and connect all nodes to ZigBee into a network.

Second, the environmental signal processing and upload stage. The key to this stage is how to convert environmental signals into data signals and how to achieve accurate transmission of environmental signals. The conversion of environmental signals into data signals requires data fusion, during which cloud computing technology and data fusion technology must be used. After the gateway receives and processes the signal, it needs to continue to transmit the signal to the network. During this period, the indoor environment signal undergoes two transformations. In order to ensure that the signal is always accurate, the data interface must be consistent during transmission. Perform data analysis on the serial port of the gateway through software.

Third, the feedback of environmental signals. The feedback of the signal is actually the transmission and display of the signal. After a series of stages such as data collection, processing and uploading of the environmental parameters, the software program must be set to determine whether the parameter index has reached the preset threshold. To start the alarm pre-warning, it is finally transmitted to the user terminal device and displayed.

2) COMFORT EVALUATION MODEL

In order to detect the comfort of the indoor environment and better adjust the indoor temperature, humidity, heat and air pressure, we need to establish a comfort evaluation model and set the thresholds of various parameters.

First, the popularity evaluation index. The indoor heat evaluation is based on the human body's perception and adaptability to the thermal environment. Here we propose a thermal environment evaluation model whose calculation formula is:

$$PMV = \left(0.303e^{-0.036M} + 0.0275\right)\left\{(M - W) - 3.05 \times 10^{-3} \times [5733 - 6.99\,(M - W) - P_a]\right\} \quad (1)$$

Among them, M is the human metabolism rate, W is the thermal resistance rate of clothing, and P_a is the partial pressure of water vapor. After calculation, we have summarized the value of PMV and the human body's perception of heat, as shown in Table 1.

Second, the air quality evaluation index. After collecting various parameters of the indoor environment, the data needs to be analyzed and processed to obtain the sub-index values of each evaluation index, and then these indexes are classified and processed through cloud computing to obtain a comprehensive index, which is used to represent indoor air quality.

Assuming that the concentration of pollutants in indoor air is M_i, the standard upper limit value is N_i, the ratio of the two is the sub-index, and P is the sum of each sub-index, then

$$P = \sum_{i=1}^{k} \frac{M_i}{S_i} \quad (2)$$

where k is the number of detected parameters.

Calculate the arithmetic average index from formula (2)

$$Q = \frac{1}{k} \sum_{k}^{1} \frac{M_i}{N_i} \quad (3)$$

Obtain the comprehensive index from the maximum value of each sub-index and the arithmetic mean,

$$I = \sqrt{\max\left(\frac{M_i}{N_i}, \frac{M_i}{N_i}, \ldots\ldots, \frac{M_i}{N_i}\right) \times \frac{1}{k}\sum_{i=1}^{k} \frac{M_i}{N_i}} \quad (4)$$

In the end, we summarized the classification standards for indoor air quality, as shown in Table 2.

3) DATA FUSION

Since multiple different sensors are used in the collection of environmental parameters, there will be some differences in the amount of collected data, and it is impossible to quantitatively measure these data information. Therefore, when the data information is fused, we adopt a fuzzy close algorithms to perform fusion calculations on the data to maximize the accuracy of the data.

TABLE 3. Sensor weight distribution.

Sensor node	Measured value at a certain point in time	Fuzzy closeness	Sensor weight
1	23.4	0.1240	0.0758
2	24.2	0.2385	0.1274
3	25.0	0.3471	0.1935
4	22.4	0.5301	0.2537
5	23.5	0.0014	0.0012

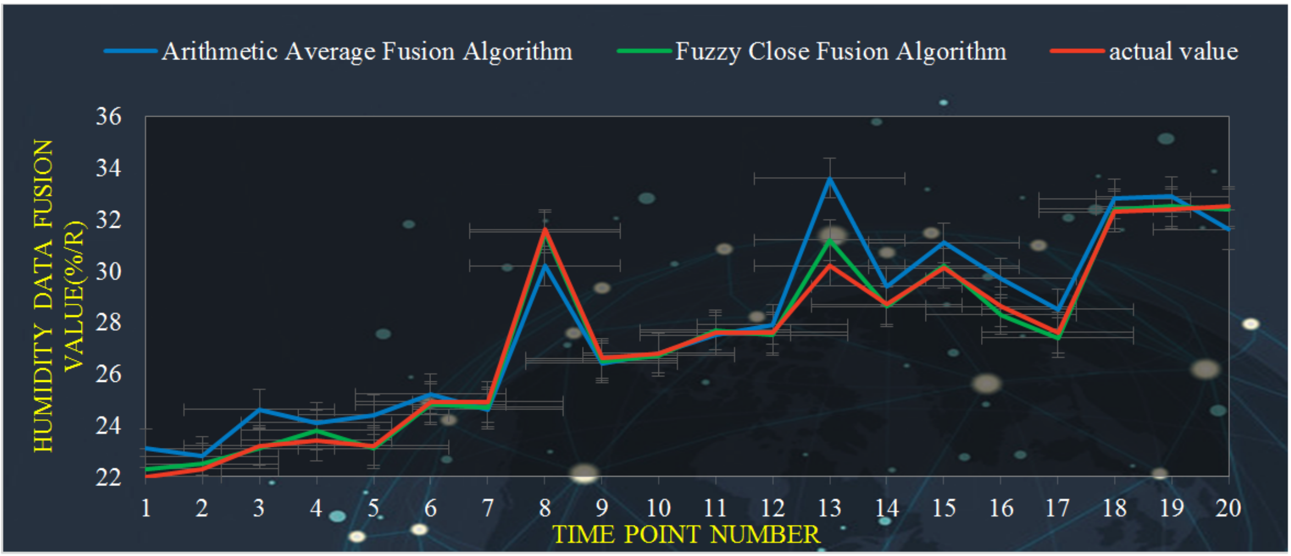

FIGURE 2. Humidity data fusion results at different time points.

Assuming that the corresponding weights of n sensor are $a_1, a_2, \ldots\ldots, a_n$ respectively, a mathematical model of weighted fusion is established:

$$M = \frac{a_1A_1 + a_2A_2 + \ldots\ldots + a_nA_n}{\sum_{i=1}^{n} a_i} \tag{5}$$

Set A_i as the fuzzy set formed by the sensor measurement data, B as the fuzzy set formed by the measured real data, and the fuzzy closeness $R(A_i, B)$ is the closeness between the sensor measurement data and the target real data. Then there is a weighted fusion model based on the fuzzy closeness:

$$M = \frac{r_1A_1 + r_2A_2 + \ldots\ldots + r_nA_n}{\sum_{i=1}^{n} r_i} \tag{6}$$

In order to compare the advantages of the fuzzy close algorithm, we introduce the arithmetic average algorithm for data fusion processing.

Suppose there is n data collected by each sensor, and n raw data is divided into k groups, the group median value of each group is $n_1, n_2, \ldots\ldots, n_k$, and the frequency of each group is $f_1, f_2, \ldots\ldots, f_k$ respectively, then the arithmetic average fusion algorithm is

$$M = \frac{n_1f_1 + n_2f_2 + \ldots\ldots + n_kf_k}{\sum_{i=1}^{k} n_i} \tag{7}$$

IV. REALIZATION AND TESTING OF A RESIDENTIAL ENVIRONMENT INTELLIGENT MONITORING SYSTEM BASED ON CLOUD COMPUTING AND THE INTERNET OF THINGS

Aiming at the residential environment intelligent monitoring system based on cloud computing and the Internet of things designed in Chapter 3, in this chapter we will apply the system to the environmental monitoring of family residences and test the hardware and software facilities of the system.

A. PERFORMANCE TEST OF VARIOUS PARAMETER SENSORS

In order to test the performance effects of the sensors used in various parameters, we verify the effectiveness of the fuzzy close algorithm and arithmetic average algorithm used in data fusion. Select the humidity values collected by the five sensor nodes at the same time as the experimental verification data, use the measured values of the hygrometer as the estimated values of the true values at the time of data collection, and the humidity values measured by each sensor node are data. It is

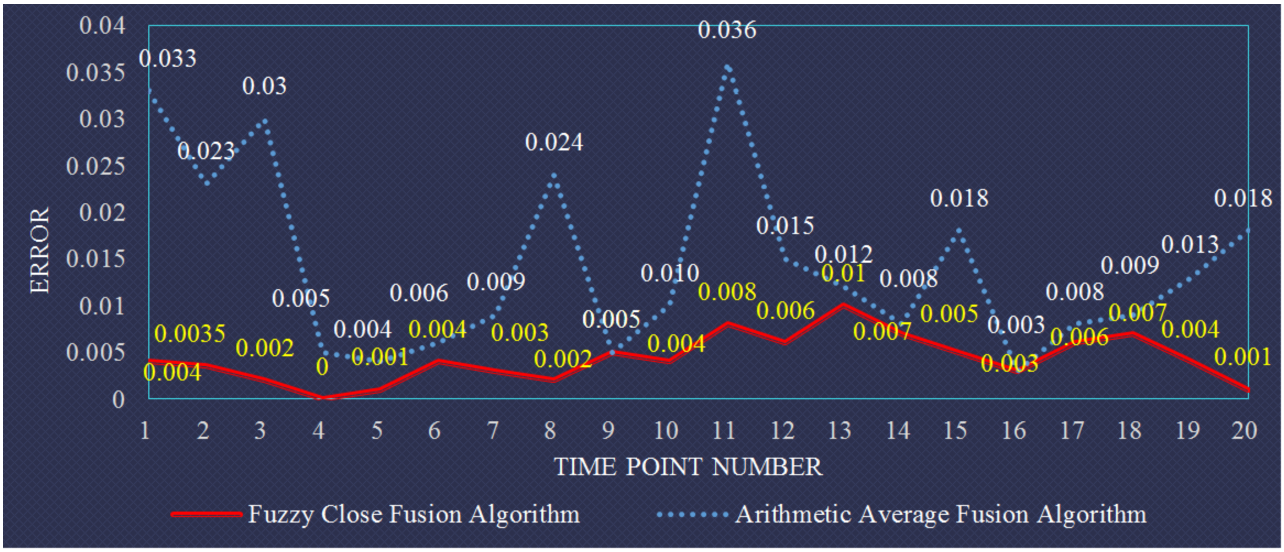

FIGURE 3. Error comparison of the two fusion algorithms.

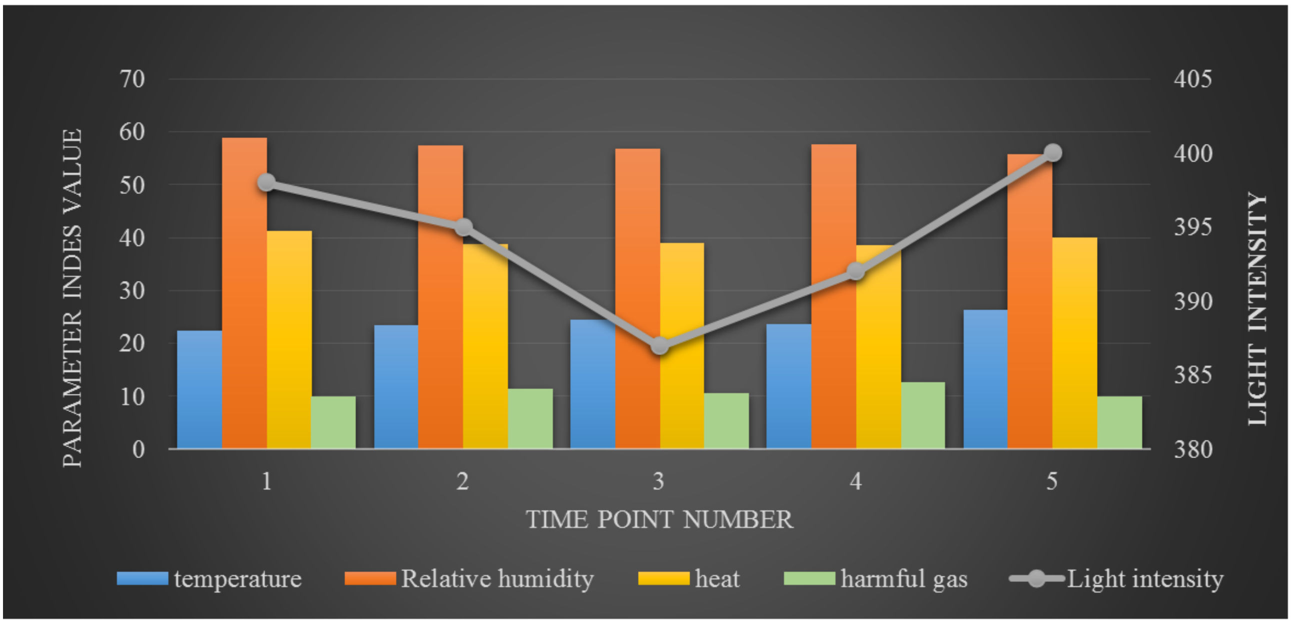

FIGURE 4. Comprehensive evaluation results of residential environment parameters.

calculated according to the fuzzy proximity fusion formula and the error is calculated by comparing it with the estimate. The fusion and error values are calculated according to the formula of the arithmetic mean fusion algorithm. The results are shown in Table 3.

It can be seen from Table 3 that the smaller the fuzzy closeness is, the smaller the weight assigned to it. On the contrary, the higher the closeness is, the larger the weight is assigned, which can be suppressed to a certain extent. Outliers ensure the accuracy of the overall fusion value.

In order to further verify the inhibitory effect of the fuzzy close algorithm on the sensor abnormal value, we again selected 20 sets of humidity data collected at different time points, and calculated the fusion value of each humidity data using the fuzzy close fusion algorithm and the arithmetic average fusion algorithm. The real value is compared, the error value of the two is calculated, and the result is shown in Figure 2 and Figure 3.

According to the graph in Figure 2, the fuzzy close fusion algorithm used in this paper is closer to the true value of the humidity parameter. Compared with the fuzzy close fusion algorithm, the fusion curve obtained by the arithmetic average fusion algorithm is less consistent with the true value curve. The two curves are far apart. Figure 3 shows the error

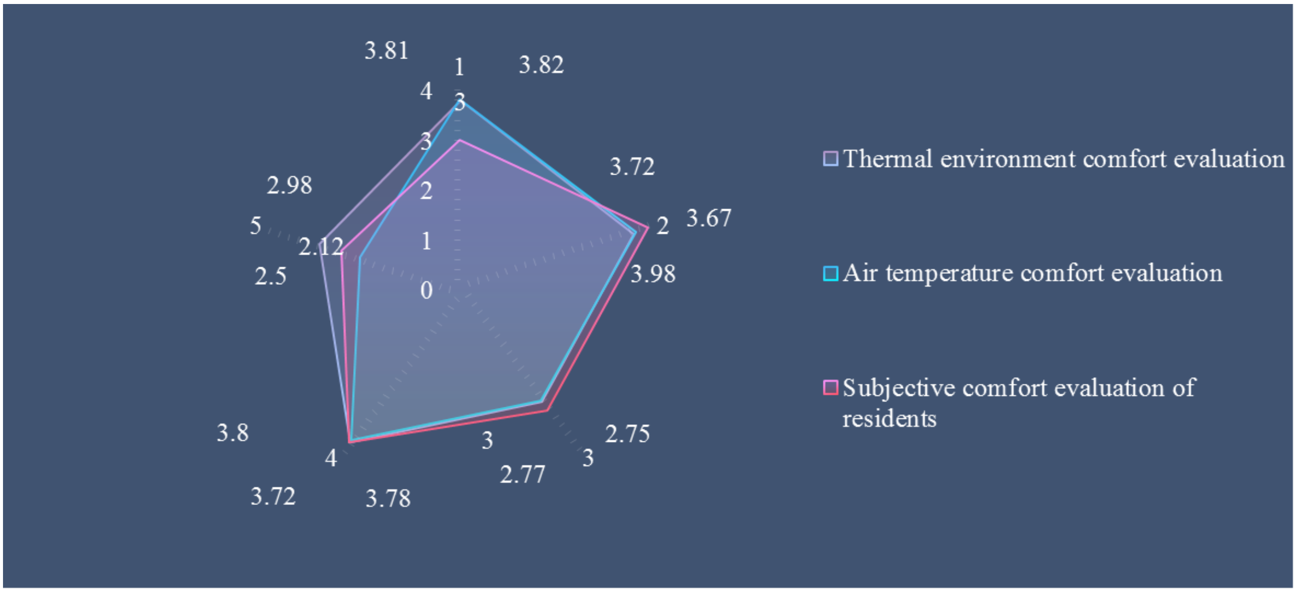

FIGURE 5. The relationship between thermal environment and air temperature comfort evaluation and the subjective comfort evaluation of occupants.

curves and true values for the two algorithms. We can see that the error curve of the arithmetic mean algorithm has a clear variation, with a maximum error of 0.036 and a minimum error of 0.003. On the other hand, the fuzzy proximity fusion algorithm has quite a few errors. The maximum error value is only 0.01, and the minimum error is only 0. This shows that the use of fuzzy close fusion algorithm for data fusion calculation can improve the accuracy of data and the sensitivity of sensors to data collection, which has good practical application value.

B. EVALUATION AND ANALYSIS OF THE COMFORT OF THE LIVING ENVIRONMENT

According to the comfort evaluation model established above, we separately evaluate the air temperature, thermal environment and air quality of the living environment, and analyze the corresponding parameter index values in the most comfortable environment, so as to improve the living environment comprehensive evaluation of comfort. Select the values of various parameters collected at 5 different time points to compare the indoor comfort at different time points. The comprehensive comfort evaluation results of each environmental parameter are shown in Figure 4. The relationship between the thermal environment comfort evaluation and indoor air temperature comfort evaluation and the subjective comfort evaluation of indoor occupants is shown in Figure 5.

According to Figure 4, the environmental parameters collected at five different time points are basically the same, and the parameter values have not changed significantly, indicating that the data information collected by the sensor is relatively accurate. In this study, we take 1 as the standard, each parameter value > 1 indicates that the living environment is excellent and the comfort is excellent, and <1 indicates that the comfort standard is not reached. According to the data in Figure 4, it can be seen that the values of various parameters are all greater than 1, indicating that the living environment comfort detected by the system is excellent. In Figure 5, for the thermal environment evaluation index, air temperature evaluation index and subjective comfort evaluation index of occupants calculated by fusion, it can be seen that the corresponding relationship among the three is basically the same.

V. CONCLUSION

In today's society, with the improvement of living standards, people pay more and more attention to improving their quality of life, especially the quality of family living environment. A good living environment is not only conducive to the pleasure and relaxation of the body and mind, but also can greatly reduce the occurrence of diseases, it has a great positive impact on people's work and life. Effective monitoring and control of the family's living environment can help improve the quality of life, so people have more and more demand for intelligent monitoring of the living environment.

Internet of Things technology demonstrates powerful advantages in monitoring and controlling smart homes. In recent years, it has become more and more common in related fields. However, current smart home environment monitoring systems based on the Internet of Things are generally repeatedly built and have low scalability. Therefore, this research proposes to integrate cloud computing into the research and design of the system, and establish an intelligent monitoring system for the living environment based on cloud computing and the Internet of things.

Through experiments, this research combines cloud computing, Internet of things, smart sensors and data fusion technology and other technical means to design and establish a home living environment intelligent monitoring system, which can not only monitor various indoor parameter information in real time, but also can control and regulate various electronic equipment, water flow, and gas burning in the room. In the implementation and testing of the system, by selecting the parameter values at different time points as experimental data, the effectiveness of the sensors used in the system was verified, and the practicability of the monitoring system designed in this study was verified.

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