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Design Of Intelligent Home Temperature And Humidity Monitoring System Based On Zigbee Protocol

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ABSTRACT
This paper aims to explore the design and testing methods of smart home system, so as to ensure the stable and reliable operation of the system and enhance the user experience. Through the comprehensive application of advanced technologies such as Internet of Things and artificial intelligence, the intelligent control and management of household equipment are realized. This paper expounds in detail the software design architecture, functional modules and system test flow of smart home system, including test objectives, test methods, test cases, test environment, test results and analysis. The research results show that through comprehensive system design and strict testing process, smart home system can meet the diverse needs of users and provide a convenient, comfortable and safe living environment. At the same time, this paper also points out the challenges and opportunities faced by the development of smart home system, and puts forward the future development direction and suggestions.

KEYWORDS
smart home system; Internet of things; Artificial intelligence; Software design; System testing; User Experience

1 Introduction

With the rapid development of modern science and technology, information technology has penetrated into every aspect of people's daily life. The extensive application of advanced technologies such as Internet of Things (IoT), big data and artificial intelligence (AI) not only greatly improves the quality of life of residents, but also greatly facilitates people's daily living and travel. As a typical application of information technology in home environment, smart home system realizes intelligent management and control of home environment by integrating various intelligent devices and sensors. Among them, temperature and humidity monitoring is an important part of smart home system, which is of great significance to improve the comfort and health of living environment.

As a short-range, low-power and low-rate wireless communication technology, ZigBee technology has shown great application potential in the field of smart home. Its low power consumption, low cost, high reliability and the ability of self-organizing network make it an ideal choice to build a smart home temperature and humidity monitoring system. Through ZigBee technology, the temperature and humidity sensors distributed at home can be connected to a unified network to realize real-time data collection and transmission, so as to realize accurate monitoring and adjustment of the home environment.

This paper will deeply analyze the temperature and humidity monitoring system of smart home based on ZigBee protocol. Firstly, the characteristics of ZigBee technology and its application

advantages in the field of smart home are introduced. Secondly, the design scheme of the system is described in detail, including sensor node design, gateway design, data transmission protocol and system architecture. Finally, the data processing and analysis methods of the system are discussed, and how to remotely control the household equipment through measures such as mobile phone voice. Through the research of this paper, it aims to provide useful reference for the design and implementation of smart home temperature and humidity monitoring system, and further promote the development and popularization of smart home industry.

2 Architecture of smart home system

In the design of smart home system, an efficient and stable system architecture is the basis for realizing various functions. This system adopts wireless sensor network based on Zigbee protocol, combined with Internet technology, and constructs a comprehensive and intelligent home temperature and humidity monitoring system. The following is a detailed description of the system architecture:

2.1 Overall system architecture

This system is mainly composed of wireless sensor network, Zigbee protocol communication module, GPRS data transmission module, monitoring host, Web client and user's mobile phone. Through the efficient data transmission and exchange mechanism, all parts realize the comprehensive monitoring and management of the home environment.

Wireless sensor network: composed of temperature and humidity sensors distributed in each room, it is responsible for collecting temperature and humidity data in the home environment in real time.

Zigbee protocol communication module: As a communication bridge between wireless sensor network and monitoring host, Zigbee protocol ensures stable data transmission with its low power consumption and high reliability.

GPRS data transmission module: As the main channel of data communication, GPRS module is responsible for transmitting the data in the monitoring host to the remote server or the user's mobile phone, thus realizing the remote monitoring and alarm functions.

Monitoring host: As the core of the system, the monitoring host is responsible for receiving, processing and analyzing data from the wireless sensor network, and performing alarm or control operations according to preset rules.

Web client: Through Web technology, managers can log in to the system at the client, and perform remote control, error reporting, data analysis and other operations, thus achieving full control of the home environment.

User's mobile phone: Users can receive the alarm information of the system through the mobile phone, and view the real-time data of the home environment at any time, thus realizing convenient and efficient remote monitoring.

2.2 Data transmission and processing

In terms of data transmission, this system adopts the combination of Zigbee protocol and GPRS technology. Zigbee protocol is responsible for data transmission in wireless sensor networks, while GPRS is responsible for data transmission to remote servers or users' mobile phones. This design not only ensures the real-time and accuracy of data, but also reduces the power consumption and cost of the system.

In data processing, after receiving the data, the monitoring host will conduct preliminary processing and analysis. If the data is abnormal, the monitoring host will immediately trigger the alarm mechanism, send the abnormal data to the user's mobile phone, and send an alarm to the manager through the Web client. At the same time, the system will also store and analyze historical data to provide decision support for managers.

2.3 System Stability and Self-inspection Function

In order to improve the stability of the system, the system also has self-checking function. During the operation of the equipment, the system will regularly check each module to ensure that the equipment is in normal working condition. If any abnormality is found, the system will immediately give an alarm and try to repair it automatically or prompt the manager to intervene manually.

To sum up, this intelligent home temperature and humidity monitoring system based on Zigbee protocol realizes comprehensive monitoring and management of home environment through efficient data transmission and processing mechanism, stable system architecture and convenient user interface. It not only improves the comfort and health of home environment, but also provides convenient and efficient remote monitoring means for managers.

3 Hardware design of smart home system

The hardware design of smart home system is the key to realize the system function, which covers ZigBee coordinator, gateway, area control, wireless transmission module and smart home actuator. The following is a detailed design description of these hardware components:

3.1 Design of ZigBee Coordinator

ZigBee coordinator plays a core role in wireless networking in smart home system. This system uses CC2530 chip as the hardware main control chip, which can support different terminal nodes and sensors and realize remote monitoring of the internal environment of smart home. CC2530 chip creates wireless network through ad hoc network program and lower computer coordinator, and receives network access requests from all routing nodes and terminal nodes.

In the design process, we pay attention to the independent data collection and detection function of the coordinator. Through the serial port of the chip, each functional module is connected, which meets the actual needs of users and realizes the collection and transmission of terminal node data. In addition, the communication between ZigBee network coordinator, routing module and nodes, as well as the connection between the coordinator host computer and serial module, all ensure the effective transmission of data.

3.2 Gateway Design

Gateway is the key equipment for smart home system to connect external network and home LAN. In this system, the microprocessor of 32-bit S3C6410 chip is used as the core of the gateway, which is connected with the external chip through ZigBee module to realize the effective control of each node in the system. After the gateway is successfully connected, it communicates through the serial interface, and the sensor transmits the relevant information of the equipment or transmits data through the serial port.

Users can connect with smart home nodes through mobile phones, computer terminals and other devices, and use the data storage, communication and controller functions of the gateway to

realize remote monitoring of the home environment. At the same time, the gateway also supports the setting of parameters such as baud rate and serial number to ensure smooth communication.

3.3 Design of area and control mode

In order to achieve accurate control of all areas of smart home, we have set up intelligent lighting panels in bedrooms, restaurants, living rooms and other areas, and users can control the lighting of all areas according to actual needs. At the same time, scene panels are set up in the living room, restaurant and other places, and users can preset the scene content through the smart home APP and start it at any time. In addition, the system also supports remote control of air conditioning, floor heating, curtains and other equipment. Mobile APP control and panel touch control are the main control methods of the system. At the same time, the system also supports Siri voice control, mobile phone voice control and intelligent robot, which improves the user's operation convenience.

3.4 Design of Wireless Transmission Module

Wireless transmission module is the key to realize wireless data receiving and sending in smart home system. This system uses nRF2401A as the core of wireless transmission module, supports the ISM frequency band 2.4G-2.5G, and the data transmission rate is 0-1Mbps. This module realizes CRC check and address check to ensure the accuracy and reliability of communication. During the experimental test, the communication distance of the module reaches 50m, which can meet the wireless transmission requirements of smart home system. At the same time, the module also supports the insertion of 10Pin interface and 61 board, which is convenient and fast to use.

3.5 Smart Home Actuator Design

Smart home actuator is a concrete device to monitor and control the home environment. This system has designed several actuators such as temperature and humidity monitoring, smoke and gas leakage monitoring, security monitoring and photosensitive control.

Temperature and humidity monitoring: DHT11 temperature and humidity sensor is used to collect indoor temperature and humidity data, and the data is received by resistive humidity sensor and NTC temperature measuring element, which is connected with the input and output pins of CC2530 chip and sent to the main controller for processing.

Smoke and gas leakage monitoring: MQ-2 smoke sensor is used to detect indoor gas and environment to improve the stability and sensitivity of detection. The conductivity of the sensor increases with the increase of indoor combustible gas concentration, and the demand of output signal of conductivity and gas concentration is met through the conversion function of the circuit.

Security monitoring: HC-SR501 human infrared sensor is used to monitor indoor security in real time. When illegal intrusion and other behaviors are detected, the alarm is automatically started. This module can reduce the system power consumption and improve the accuracy of security monitoring. Photosensitive control: 5516 photoresistor is used to collect indoor light intensity, and the resistance of photoresistor is inversely proportional to the light intensity. The intensity of illumination can be obtained by measuring the values at both ends of the voltage, so as to control the indoor lights and curtains.

3.6 System Circuit Design

The system circuit design includes two parts: three-terminal voltage stabilizing circuit and relay driving circuit.

Three-terminal voltage stabilizing circuit: The system uses +5V voltage environment to supply power, which provides stable power for relay, infrared receiver and single chip microcomputer. The maximum current of L7805 is used to drive the relay to ensure the stability and reliability of the circuit. Figure 1 shows the principle of a three-terminal regulated power supply.

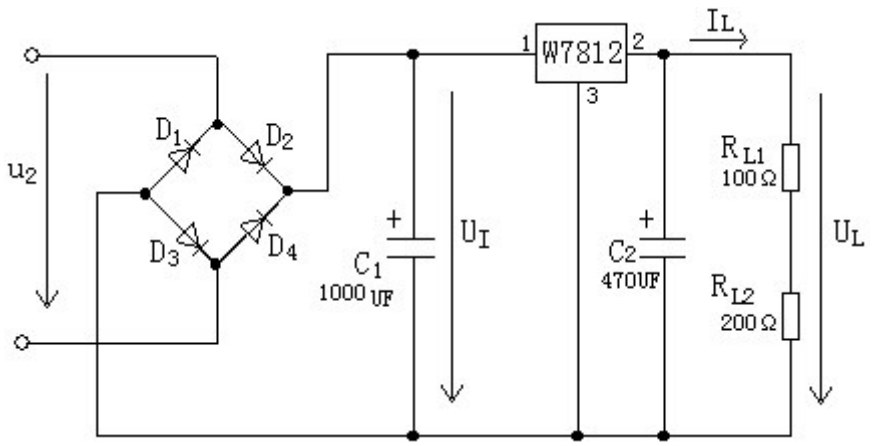

Figure 1 Principle of three-terminal regulated power supply

Relay drive circuit: the relay drive circuit is composed of 8550PNP triode and relay, which can integrate the maximum dissipation power and current of the electrode. Through reasonable circuit design, the pull-in current and power consumption of the relay in the working process can meet the system requirements.

To sum up, the hardware design of smart home system covers many aspects, including ZigBee coordinator, gateway, area control, wireless transmission module and smart home actuator. Through reasonable hardware design and selection, the stability and reliability of the system are ensured, and a convenient and efficient smart home experience is provided for users.

4 Software design of smart home system

The software design of smart home system is the key to realize the intelligent and automatic control of the system. It covers communication protocol design, control logic implementation, user interface development, data processing and analysis. The following is a detailed description of these software design parts, with examples of the main programs in C language.

4.1 Communication Protocol Design

Communication protocol is the basis of data exchange among devices in smart home system. This system adopts ZigBee wireless communication protocol, and ensures reliable communication between devices by defining data frame format, communication flow and error handling mechanisms.

In the C language program, we define the data structure of ZigBee communication, including data frame header, data content and data frame trailer. At the same time, the data exchange between devices is realized by writing the function of sending and receiving data.

C language sample program (communication protocol part):

```
#include <stdio.h>
#include <string.h>
```

```
//Define the ZigBee data frame structure
typedef struct {
uint8_t frame_head; //data frame header
uint8_t address; //Device address
uint8_t data[32]; //data content
uint8_t checksum; //check code
uint8_t frame_tail; //end of data frame
} ZigBeeFrame;
//Send data function
void sendData(ZigBeeFrame *frame) {
//Suppose there is an underlying function send_byte () that sends data.
//The specific sending process is omitted here.
//For example: for (int i = 0; i < sizeof(ZigBeeFrame); i++) { send_byte(((uint8_t*)frame)[i]); }
printf("Data sent: % s\n", frame->data); //For demonstration only, the actual sending process needs to call the underlying function.
}
//Receive data function (simplified version, for demonstration only)
ZigBeeFrame receiveData() {
ZigBeeFrame frame;
//Suppose there is a bottom function receive_byte () that receives data.
//The specific receiving process is omitted here.
//For example: for (int i = 0; i < sizeof(ZigBeeFrame); i++) { ((uint8_t*)&frame)[i] = receive_byte(); }
//For demonstration, we directly fill in an example data frame.
frame.frame_head = 0xAA;
frame.address = 0x01;
strcpy((char*)frame.data, "Hello ZigBee");
frame.checksum = 0x00; //Simplified processing, no actual check code is calculated.
frame.frame_tail = 0xBB;
return frame;
}
```

4.2 Realization of Control Logic

Control logic is the core of realizing automatic control of equipment in smart home system. According to the rules or conditions set by users, this system realizes the intelligent control of household equipment by writing control algorithms and logical judgments.

In the C language program, we define the functions of control logic, including condition judgment, equipment status query and control instruction sending. By calling these functions, the intelligent control of home equipment is realized.

C language sample program (control logic part);

```
#include <stdbool.h>
//Define the device status structure
typedef struct {
bool light_on; //light status
bool heater_on; //floor heating state
//... Other device status
} DeviceStatus;
//Query device status function (simplified version, for demonstration only)
```

```
DeviceStatus queryDeviceStatus() {
DeviceStatus status;
//Suppose there is a bottom-level function to query the equipment status.
//The specific query process is omitted here.
//For example: status.light _ on = query _ light _ status ();
//For demonstration, let's set the device status directly.
status.light_on = true;
status.heater_on = false;
return status;
}
//Control device function (simplified version, for demonstration only)
void controlDevice(DeviceStatus *status, bool light_command, bool heater_command) {
//Suppose there is a underlying function that controls the device.
//The specific control process is omitted here.
//For example: set_light_status(light_command);
//For demonstration, we will print the control instructions directly.
if (light_command) {
printf("Light turned on.\n");
} else {
printf("Light turned off.\n");
}
if (heater_command) {
printf("Heater turned on.\n");
} else {
printf("Heater turned off.\n");
}
//Update the device status (this is only a demonstration, and the corresponding update function
should be called)
status->light_on = light_command;
status->heater_on = heater_command;
}
```

4.3 User interface development

User interface is the bridge between users and smart home system. This system adopts the graphical user interface (GUI) design, and realizes the remote monitoring and control of household equipment by users by writing user interface programs.

Because C language itself does not directly support GUI development, we usually use C language combined with specific GUI libraries (such as Qt, GTK, etc.) or graphical interfaces of embedded systems to realize user interfaces. Here, we only provide a simplified logical framework of user interface, and the actual development needs to be combined with a specific GUI library.

```
C language sample program (user interface logical framework);
//Suppose we use a pseudo code to represent the user interface logic.
//Specific GUI library functions should be used in actual development.
void createUserInterface() {
//Create interface elements such as windows, buttons and labels (pseudo code)
// window = createWindow("Smart Home Control");
// button_light = createButton("Light");
```

```
// button_heater = createButton("Heater");
// label_status = createLabel("Status: ");
//Set button click event handler (pseudo code)
// setButtonClickHandler(button_light, onLightButtonClick);
// setButtonClickHandler(button_heater, onHeaterButtonClick);
}
void onLightButtonClick() {
//Get the device status and update the interface (pseudo code)
// DeviceStatus status = queryDeviceStatus();
// if (status.light_on) {
// setLabelText(label_status, "Light is on.");
// } else {
// setLabelText(label_status, "Light is off.");
// }
//Send control instructions (pseudocode)
// controlDevice(&status, !status.light_on, status.heater_on);
}
void onHeaterButtonClick() {
//Same as above, handle the click event of the floor heating button.
}
```

4.4 Data Processing and Analysis

Data processing and analysis is the key to realize intelligent decision-making and optimization in smart home system. This system collects all kinds of data in the home environment (such as temperature and humidity, smoke concentration, etc.), and uses data analysis algorithms and models to realize intelligent monitoring and early warning of the home environment.

In the C language program, we define the data processing function, including data filtering, statistical analysis and early warning judgment. By calling these functions, the intelligent processing and analysis of home environment data are realized.

C language sample program (data processing and analysis part);

```
#include <stdlib.h>
//Define the environment data structure
typedef struct {
float temperature; //temperature
float humidity; //Humidity
float smoke_level; //Smoke concentration
//... Other environmental data
} EnvironmentData;
//Data processing function (simplified version, for demonstration only)
void processData(EnvironmentData *data) {
//Data filtering (e.g. removing outliers)
// if (data->temperature > 100 || data->temperature < -50) {
////Data marked as invalid or otherwise processed.
// }
//Statistical analysis (e.g., calculating average, standard deviation, etc.)
// float avg_temp = calculateAverageTemperature(...);
// ...
```

```
//Early warning judgment (e.g. early warning when the temperature is too high or the smoke concentration exceeds the standard)
if (data->temperature > 30) {
printf("Warning: High temperature detected!\n");
}
if (data->smoke_level > 0.5) {
printf("Warning: Smoke detected!\n");
}
}
```

Please note that the above C language sample program is only a simplified version, which is used to demonstrate all parts of the software design of smart home system. In the actual development, it needs to be realized and optimized in detail according to the specific hardware platform, communication protocol and user requirements. At the same time, because C language itself does not directly support the development of graphical user interface, the user interface part usually needs to be realized by using a specific GUI library or the graphical interface of embedded system.

5 System testing

System testing is the key link to ensure the stable and reliable operation of smart home system. Through a comprehensive test of the system, potential problems can be found and repaired in time, and the quality of the system and user experience can be improved.

5.1 Test objectives

The main goal of system testing is to verify the functional integrity, performance stability and user experience satisfaction of smart home system. Specifically, it is necessary to test whether the functions of the system work as expected, the performance of the system under different loads, and the friendliness and ease of use of the user interface.

5.2 Test methods

System testing can adopt many methods, including unit testing, integration testing, system testing and user acceptance testing. Unit test: Conduct independent tests for each module of the system to ensure the normal function of each module. Integration test: test all modules together to verify whether the interface and interaction between modules are normal. System test: conduct a comprehensive test of the whole system, including functional test, performance test and safety test. User acceptance test: invite users to participate in the test, and optimize and improve the system according to user feedback.

5.3 Test cases

Test case is an important part of system test, which describes the specific steps, expected results and test environment of the test. For smart home systems, the following test cases can be designed: Function test case: verify whether the functions of the system work as expected, such as lighting control, floor heating regulation, environmental monitoring, etc. Performance test case: Test the performance of the system under different loads, such as response time and throughput. Security test case: verify the security of the system, such as preventing illegal intrusion and protecting users' privacy.

5.4 Test environment

Test environment is the basis of system test, which includes hardware environment, software environment and network environment. In order to ensure the accuracy of the test results, it is necessary to build a test environment similar to the actual application scenario.

5.5 Test Results and Analysis

Through the collection and analysis of test results, we can know whether the performance and function of the system meet the expected requirements. In view of the problems found, it is necessary to repair and optimize them in time to ensure the stability and reliability of the system.

6 Concluding remarks

With the continuous development of science and technology, smart home system has become an important part of modern families. Through the comprehensive application of advanced technologies such as Internet of Things and artificial intelligence, the smart home system realizes the intelligent control and management of household equipment. In this paper, we elaborate the software design, system testing and other aspects of smart home system. Through comprehensive system design and strict testing process, we can ensure the stability and reliability of the smart home system and improve users' satisfaction and experience. However, the development of smart home system still faces many challenges and opportunities. In the future, we need to continue to strengthen technology research and innovation to promote the intelligent, automated and personalized development of smart home systems.

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