Intelligent Urban Street Lighting System based on IoT Cloud Platform

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***Abstract*—Urban street lighting is an important basic part of all urban facilities construction, which can not only provide practical convenience for the daily life of citizens but also an important symbol of modern urban construction. There are many problems in the management of urban street lighting, such as street damage can not be found in time, the street lighting control mode is single, etc. The intelligent lighting system of urban street lighting based on the Cloud platform of the Internet of Things can effectively solve the problems encountered in traditional management work. The system realizes the functions of a voice control lamp, light control lamp, infrared remote control lamp, and remote control street lamp switch. Meanwhile, the data is uploaded to the Cloud platform of the Internet of Things. The administrator can remotely control and monitor the working state of street lamps in the server to prevent potential safety hazards caused by short circuits and power leakage. The realization of effective and safe lighting of city street lamps provides a great guarantee for citizens' travel at night.**

Keywords-internet of things; urban street lighting; intelligent lighting; remote control; security monitoring

I. INTRODUCTION

With the continuous development of urban construction in the world today, the scale of cities is also expanding, and urban street lighting has become an important part of urban infrastructure work[1]. The number of city street lights is growing exponentially, and the shapes of street lights are also various and diverse. In the realization of urban street lighting, to create conditions for the public night activities, there are also many real problems. In the pursuit of urban image of the guiding principle, some cities to street lights the brighter the better, a light to solve the problem bias to install two lights, street lighting levels far beyond national standards, resulting in a great waste of energy; there are certain cities over the pursuit of street lighting aesthetics, pay attention to the shape of street lights during the day, thus ignoring the actual lighting needs of street lights; at the same time there are many cities to spend their thoughts on the construction of urban night lighting At the same time, there are also many cities that put a lot of time and energy into researching and planning the city's "lighting night scenery", trying to beautify the city, while neglecting the construction of street lights, which are closely related to the lives of citizens, paying less attention to street lights, which are marginalized [2], often appearing in places where there are roads without street lights, and some roadside street lights installed do not work [3]. Street lights have a great impact on the development and activity of the city's citizens at night. With reasonable street light settings and a comfortable lighting environment, citizens will be more willing to go out at night and the city's roadscape will be more attractive; with a low number of street lights and low safety, citizens will reduce their outdoor activities at night and the city's night landscape will become boring [4].

With the continuous urbanization, street lighting has become an essential infrastructure support facility in modern life. Although traditional street lights have brought convenience to cities, there are problems such as serious waste of resources, high maintenance cost, difficulty in monitoring and poor flexibility. In the context of the development of Internet of Things technology, wireless communication technology [5], positioning technology, the concept of "smart street light" has been proposed in recent years, and, in some cities, tourist attractions and other areas have been applied to the smart street light monitoring system, compared with the traditional street light, its diverse functions [6], high degree of intelligence, but in the process of operation there are also some However, there are also some problems in the process of operation, such as high power consumption, high cost, and difficulty in popularization [7].

Cloud platforms are the hottest technology in the Internet of Things. The cloud platform virtualizes a resource pool composed of large-scale servers [8]. Users can obtain computing resources, storage space, and information services anytime and anywhere on demand. Externally, the "cloud" is like a server rich in computing and storage resources [9], but internally it is a large cluster of servers that can be self-maintained and managed.

The main function of the system is to realize the four lighting ways of street lamps, so that street lighting is more flexible, which are the function of sound control lamp, light control lamp, infrared remote control lamp and remote control of street lamp switch function. At the same time, the data will be uploaded to the cloud platform of the Internet of Things, and the administrator can remotely control and monitor the working status of street lamps.

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II. RELATED WORKS

Reference [10] studies the design and development of an intelligent streetlight control system for small cities and villages. The system allows for automatic sensor-based light intensity modulation by default, with the possibility of manual adjustment or override of the lighting. It also includes a device error notification system with a tool to navigate faulty devices. The system is a low-cost solution for intelligent street lighting control, designed for smaller cities or villages. Reference [11] designed an intelligent lighting and ventilation system capable of sensing human presence to control lighting, monitoring humidity, temperature, CO_2 and smoke to ensure efficient ventilation and accidents caused by fire and smoke. And a user-friendly embedded system and software is developed for IoT-based autonomous lighting and ventilation systems for indoor places such as houses and offices. Reference [12] focuses on the integration of building services and smart devices to create smart buildings using high-speed, low-voltage data networks, combined with LiFi (a wireless technology that can transmit multiple gigabits) technology for wireless communication. Instead of using expensive, special LED lighting units that work for the LiFi system, smart LED lighting networks will be used for data transmission inside and outside the smart building and connected to centralized drivers through a structured cabling system. Reference [13] reduces energy consumption by implementing a smart lighting system with integrated sensor technology, a distributed wireless sensor network (WSN) using the ZigBee protocol, and lighting control rules. The sensing module consists of occupancy sensors, including passive infrared (PIR) sensors and microwave Doppler sensors, ambient light sensors and lighting control rules. The brightness of each luminaire is controlled by rules that take into account occupancy and daylight harvesting. Reference [14] proposes an urban intelligent lighting system that is capable of autonomously controlling street lighting levels using data related to vehicular (e.g., buses, cars, motorcycles, and bicycles) and pedestrian traffic in a given area. And the system is able to set the lighting levels as needed, thus reducing energy costs. Reference [15] designed a smart lighting system that uses a smart Android application (app) and communication technology to adjust the light intensity according to the user's comfort and behavior, and smart sensors. This paper presents the implementation of smart app for smart lighting system based on individual user's location.Android app can be used to adjust the lighting intensity based on user's location to provide better visual comfort. The Android app can be operated in manual, automatic and hybrid modes. And it describes the back-end control and message flow of the smart app.

This paper mainly realizes the automatic adjustment of a street lamp, fault report, real-time data monitoring, remote control, safety monitoring, and other functions. In the system design process, the hardware and software two parts are adopted a certain practical design, effectively improving the practicality of the system.

III. HARDWARE DESIGN

In the system hardware design stage, it mainly includes: sound sensor module for receiving sound waves; photosensitive sensor module for light measurement; infrared remote control module mainly consists of two parts: infrared transmitting and infrared receiving, the main controller module ATmega328 chip is used to guarantee data transmission stability, signal control orderliness, and program execution efficiency; wireless communication module uses ESP8266 chip to data transmission to the IoT cloud platform; The security monitoring module monitors abnormal points. As shown in Fig. 1.

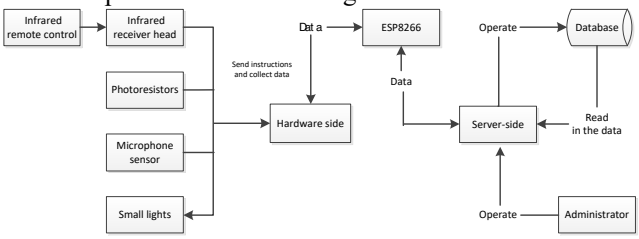

Fig. 1. Overall hardware architecture

The hardware system is mainly to realize the design of four lighting modes of street lights and to collect light intensity data and upload information related to the status of street lights.

(1)Data collection requirements: Arduino controls the photosensitive sensor and collects the data collected by the sensor.

(2)LED light automatic control demand: pre-set the light intensity threshold, when the actual light intensity value is greater than the threshold, the street light will turn on; when the actual light intensity value is less than the threshold, the street light will turn off.

(3)Sound-controlled light module requirements: the sound sensor to achieve the sound-controlled light function.

(4)Infrared remote control light module requirements: infrared sensors and LED lights connected, through the infrared remote control to control the LED lights on and off.

(5)Remote control light module requirements: set the light on command and light off command in advance in Arduino IDE, and control the LED light on and off by different commands.

(6)Data upload requirement: Arduino uploads the collected light intensity data and street light status information to the server side through ESP8266 module.

(7)Security monitoring requirements: the administrator can see the status of each street lamp on the server side, and can timely warn abnormal points.

A. Main Controller Module

The main controller module is the core of the entire hardware part, which is connected to other modules through the serial port to realize the overall control of the system . For the main controller module choose the Arduino UNO chip. Arduino has many advantages, such as cross-platform, simplicity, clarity, openness and rapid development. With the development of sensor technology, more and more Arduino-compatible sensors have been developed.Arduino UNO is an Arduino development board based on the

ATmega328P. It has 14 digital input and output pins, a 16 MHz crystal oscillator, a USB interface, a DC interface, an ICSP interface, and a reset button. As shown in Fig. 2.

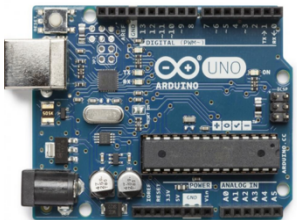

Fig. 2. Arduino UNO

The Arduino IDE can program the Arduino UNO. On the Arduino UNO, using the ATmega328 chip, a bootloader program is stored that allows the user to upload programs to the development board. This uploading process is done using the STK500 protocol. The uploader can also be connected to the programmer via the ICSP interface to the Arduino UNO.

B. Wireless Communication Module

The ESP8266 chip is a WiFi serial module, and its function is simply: receive data from WiFi, output from serial port; receive data from serial port, output data from WiFi. Data transfer to IoT cloud platform. As shown in Fig. 3.

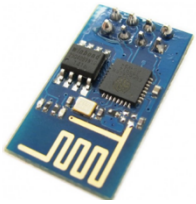

Fig. 3. ESP8266 module

C. Sound sensor module

The sound sensor has a built-in capacitive electret microphone that is sensitive to sound. The sound waves cause the electret film inside the microphone to vibrate, resulting in a change in capacitance that generates a small voltage that corresponds to the change. This voltage is then converted into a 0-5V voltage, which is accepted by the data collector through A/D conversion and transmitted to the computer. As shown in Fig. 4.

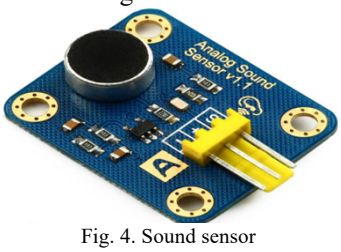

Fig. 4. Sound sensor

D. Photosensitive sensor module

Photoresistors are generally used for light measurement, light control, and photoelectric conversion. The photoconductive resistor is a kind of resistor whose value changes with the intensity of incident light by using the photoconductive effect of a semiconductor, also known as a photoconductive detector; Incident light intensity, resistance decreases, incident light intensity, resistance increases. And then there's another incident light intensity, the resistance goes down, the incident light intensity, the resistance goes up. As shown in Fig. 5.

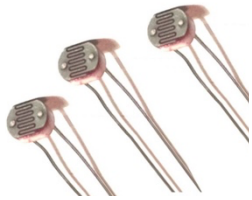

Fig. 5. Photoresistor

E. Infrared remote control module

Infrared remote control module is mainly composed of two parts: infrared transmitting and infrared receiving. The infrared transmitting and receiving signals are actually a series of binary pulse codes with high and low levels transformed according to a certain time pattern to transmit the corresponding information. In order to protect it from the interference of other signals during wireless transmission, the signals are usually modulated on a specific carrier frequency (38K IR carrier signal) and transmitted out through the IR transmitting diode, while the IR receiving end has to demodulate the signals and reduce them to binary pulse codes for processing.

The IR receiver has three pins, VOUT, GND and VCC from left to right as shown above. 38K IR carrier signal emitted by IR remote control is coded by the coding chip in the remote control. When the remote control key is pressed, the remote control sends out the IR carrier signal, the IR receiver receives the signal, and the program decodes the carrier signal to determine which key is pressed by the difference of the data code. As shown in Fig. 6.

Fig. 6. Infrared reception and infrared remote control

F. Security monitoring module

Short circuits and power leaks are very likely to cause urban fires, which are also very important and dangerous problems. First of all, is the main reason of the leakage under some special conditions, somewhere in the line of the insulators, all the damage or insulator mud after a long time, the phenomenon of surface oxidation or corrosion, results in the decrease of the dielectric insulation effect, makes the connection between line and line and the surface of the larger problem. Secondly, a short circuit occurs between the material outside the equipment and the live wire of the power network. The main reason for equipment short circuit is that the current does not pass through the electrical appliances, so that the resistance value of the line is greatly reduced, the current continues to rise, leading to

the rise of the line temperature, and finally exceeds its maximum load. Under the interaction of large current, the line will produce strong sparks, causing circuit fire.

The administrator receives the status signal of each street lamp at the service end. For abnormal points, the administrator can timely find them and arrange relevant personnel to deal with them, so as to better realize the effective and safe lighting of urban street lamps.

IV. SOFTWARE DESIGN

In the system software design phase, it mainly includes: light control module design, sound control light module design, infrared remote control light module design, and server remote control module design. This system collects and judges the light, sound data to achieve intelligent lighting and provides remote control for monitoring the changes of street lights and providing better services. The relationship between modules is shown in Fig. 7.

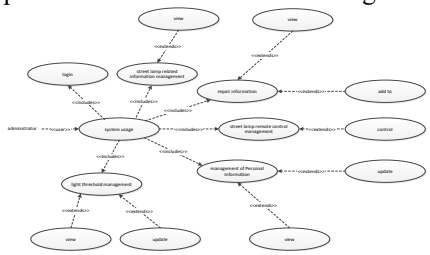

Fig. 7. Module relationship diagram

A. Light Control Light Module Design

Pre-set light intensity threshold, when the light intensity detected by the photoresistor module is greater than the set threshold, the small light will automatically turn on. When the light intensity detected by the photoresistor module is less than the set threshold, the small light will be automatically turned off. The main code of the light control lamp module is as follows.

Code 1 Light Control Light Module

```
1: int light =400; //Set the brightness value
2: int A;
3: void setup (){
        Serial.begin(9600);
        pinMode(13,OUTPUT);
   }
4: void loop(){
        int a = analogRead(A0); //read A0 analog value
        Serial.println(a);
        if (a>=light ){ //When the ambient light is dark and
   the value is greater than 400, the light-emitting diode is
   on. The opposite is not true.
                digitalWrite(13,HIGH);
                A = 1;
       }
       else{
                digitalWrite(13,LOW);
                A = 0;
          }
   }
```

B. Sound-controlled light module design

When there is sound outside, the sound sensor will receive the acoustic signal into an electrical signal sent to the amplifier to amplify and control the LED indicator light on and off. The main codes of the sound-controlled light module are as follows.

Code 2 Sound-controlled light module

```
1: void setup (){
        pinMode(3,INPUT); //set the No.3 digital port as
   input state and No.13 digital port as output state.
       pinMode(13,OUTPUT);
   }
2: void loop(){
       int n = digitalRead(3); //create a variable n to
   which the state of digital port 3 will be captured and
   assigned.
      if (n==HIGH){ //judge whether n is high, if yes,
   execute the following statement, if not, skip.
                digitalWrite(13,HIGH);
                delay(5000);
                digitalWrite(13,LOW);
        }
   }
```

C. Infrared remote control lamp module design

Pre-set the remote control key commands, the on light key and the off light key. The infrared remote control encodes the keys, modulates them to the RF signal, and then transmits the wireless signal, similar to the role of an encoder. Then the infrared receiver will encode the received wireless signal again to get the signal corresponding to the control key, and finally control the corresponding circuit to work, which is equivalent to the role of a decoder. The main code of the infrared remote control light module is as follows.

Code 3 Infrared remote control lamp module

```
1: int RECV_PIN = A1;
2: IRrecv irrecv(RECV_PIN);
3: decode_results results;
4: void setup() {
          Serial.begin(9600);
          irrecv.enableIRIn();
          pinMode(8, OUTPUT);
  }
5: void loop() {
            if (irrecv.decode(&results)) {
                  Serial.println(results.value);
                   if(results.value==16724175){
                            digitalWrite(8, HIGH);
                    }
                    else if(results.value==16738455){
                           digitalWrite(8,LOW);
                    }
                   irrecv.resume();
            }
            delay(100);
   }
```

In the setup() function, settings are made for using the serial port, starting IR decoding, and digital pin mode. In the main function loop(), it first determines whether the IR code is received or not and stores the received data in the variable results. Then once the data is confirmed to be received, the program has to do two things. The first thing is to determine whether the IR code of the power button is received. The second thing, change the state of the LED. Finally, continue waiting for the next set of signals.

D. Server remote control module design

The remote server sends commands to the hardware side to control the small lights on the hardware side to turn on and off. The main code of the server remote control module is as follows.

Code 4 Server remote control module

```
1: int recvlen = wifi.recv(recvbuff, sizeof(recvbuff), 500);
2: if (recvlen ! = 0) {
       String recvcom = "";
       int i = 0;
       while (i < recvlen) {
            recvcom += recvbuff[i++];
       }
       if (recvcom.equals("49")) {
            digitalWrite(7, HIGH);
            delay(1000);
        }
        else {
            digitalWrite(7, LOW);
        }
}
```

V. TESTING AND RESULTS

Burn the hardware system code in Arduino IDE and upload the code to the Arduino board. After the code is uploaded successfully, connect to the server, and the setup end appears to indicate that the server is connected. After connecting to the server, start uploading data. As shown in Fig. 8.

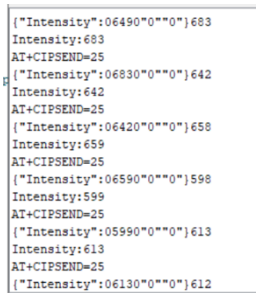

Fig. 8. Upload data graph

A. Light control lamp function test

After the infrared remote control presses the number 1 and transmits the signal, the infrared receiver receives the signal, the program decodes the carrier signal, and the difference in the data code is used to determine that the light is on, and the light is turned on. After pressing the number 0, the infrared remote control transmits the signal, the infrared receiver receives the signal, the program decodes the carrier signal, and the difference of the data code is used to determine that the pressed key is off, and the small light can be observed to be turned off.First of all, block the photoresistor with your hand to create blackness, and you can observe the change of light intensity value uploaded from the hardware system at the server side. The light intensity value becomes larger, and you can see that the number in the column of infrared data becomes 1, indicating that the small light is on. As shown in Table I.

TABLE I
Change of light-controlled light-on servers

Street Light ID	Light data	Infrared data	Sound data
1	924	1	0

The small light can be seen to go off by releasing the hand, and the light intensity value uploaded from the hardware system can be observed to become smaller on the server side, and the number in the column of infrared data can be seen to become 0, indicating that the small light is off. As shown in Table II.

TABLE II
Changes in light-controlled light-off servers

Street Light ID	Light data	Infrared data	Sound data
1	539	0	0

B. Infrared remote control lamp function test

After the infrared remote control presses the number 1 and transmits the signal, the infrared receiver receives the signal, the program decodes the carrier signal, and the difference in the data code is used to determine that the light is on, and the light is turned on. After pressing the number 0, the infrared remote control transmits the signal, the infrared receiver receives the signal, the program decodes the carrier signal, and the difference of the data code is used to determine that the pressed key is off, and the small light can be observed to be turned off.

C. Sound-controlled light function test

When the sound sensor receives external sound, the input interface goes high and the lamp turns on. After a delay of 5 seconds, the sound sensor input interface goes low and the small light turns off automatically. The data changes as shown in Fig. 9.

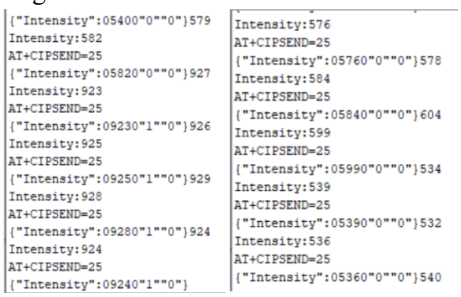

Fig. 9. Change in data of sound-controlled light

VI. CONCLUSION

Through the design and development of hardware and software, the intelligent lighting system of urban street lamps based on the Cloud platform of the Internet of Things is realized. The hardware consists of a sound sensor, photosensitive sensor, infrared remote control, master controller and ESP8266 chip, which can upload the data of acoustic information and optical measurement information to the Cloud platform of the Internet of Things through a wireless transmission module. The system mainly realizes the remote control of the Internet of things for street lamps, checking the real-time working status of street lamps, fault alarm, turning off when the light intensity threshold is set in the daytime, and automatically turning on when the light intensity threshold is reached at night. At night, it can detect whether pedestrians pass the street lamps, and the street lamps have normal brightness when pedestrians pass. The system greatly saves the electricity consumption of street lamps, facilitates the management, operation, and maintenance of street lamps, improves the safety of street lamps, and is expected to be widely used in the construction of smart cities.

In the future, solar panels can be added to store electricity, and ZigBee technology can be used to realize communication, effectively reducing energy consumption. Wireless data transmission modules can also be added to the storage system to prevent data from being uploaded to the Internet of Things in case of network connection failure.

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