A Design of Indoor Air-Quality Monitoring System

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Abstract: With the deepening of people's understanding of the harm of air pollution, indoor air quality is getting more and more attention. This paper designs an indoor air quality monitoring system based on sensor technology and Internet of things technology, the system function includes air quality detection, real-time data display, server transfer, remote display throught Wechat mini programe and others, the system can detect six important environmental parameters and allows users to view the data on mobile phone.Based on the data collected, this paper also designs an air quality evaluation algorithm.

1. Introduction

In recent years, as people pay more and more attention to environmental pollution, air quality has become one of the focuses of public attention[1]. In 2003, the state issued a national standard on indoor air quality[2], in which a series of air quality parameters and air quality test methods were stipulated. The air quality inspection methods specified in the national standard are chemical or biological methods. These test methods can obtain accurate results but the operation steps are complex, which are not suitable for the requirements of long-term monitoring of air quality in general places.

With the development of Internet of Things (IOT) technology, it has many application in the field of environmental monitoring, such as atmospheric monitoring and water quality detection. Jagriti Saini et al. put forward that IoT has great potential in indoor air quality monitoring, which can ensure lower power consumption, negligible time delay and superior ability to interact with the physical world[3]. In the current common Internet of Things indoor air quality monitoring system, there are often the following problems : firstly, only monitoring the air quality without assessment[4]-[5]; secondly, the evaluation of air quality often focuses on the research of algorithms, which uses public data sets and ignores the acquisition of actual data[6]- [7].

In this paper, the Internet of Things technology is used to propose a scheme for indoor air quality monitoring and evaluation aim at the shortcomings of the existing schemes. This scheme includes two functions : real-time monitoring and quality evaluation. Based on this scheme, a set of air quality monitoring and evaluation system is developed in this paper, and the system has good effect in practical application.

2. Design of Real-time Monitoring System for Environmental Quality

2.1 System design objectives and functions

The purpose of this design is to realize the monitoring and evaluation of indoor air quality. According to the national indoor air quality standards, several typical indicators such as temperature, relative humidity, PM2.5, TVOC and formaldehyde are selected as monitoring parameters.

The environmental quality real-time monitoring system should have the following main functions :

1) accurately detect five indoor air quality parameters
2) upload the data of air parameters to the server
3) store uploaded data by database
4) display of data through a client remotely

Based on the above functional design, the monitoring system adopts the following scheme : using sensors to collect data about environmental parameters, using MCU to process data, using WiFi to upload data to the elastic compute service(ECS), the transmission protocol is MQTT, using MySQL database to storage data, using WeChat mini program to access the server and database to display data remotely. Overall technical programme as shown in figure 1.

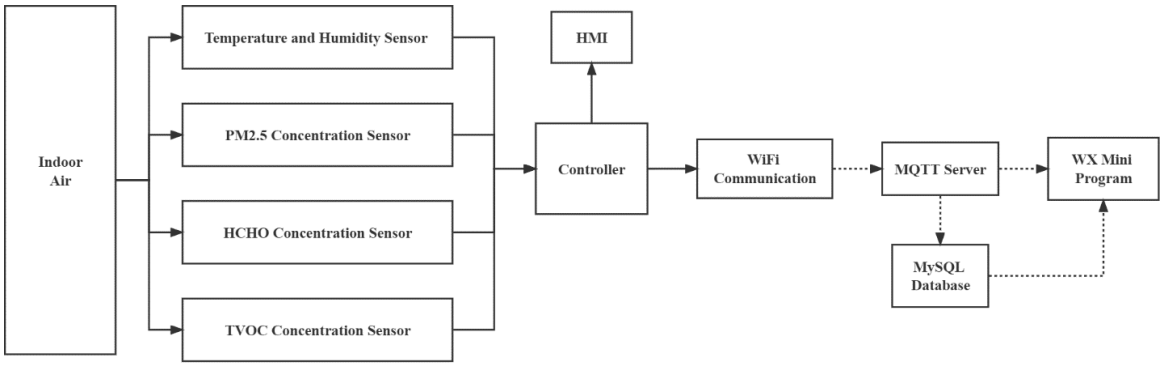

Figure 1 Technical Programme

2.2 Hardware Design of Environmental Monitoring System

An embedded device is designed and fabricated as the hardware platform of the monitoring system. The embedded system can collect, process and transmit data of indoor air quality parameters. The embedded device consists of three parts, controller, sensors and communication module. The controller uses STM32F407ZGT6 as the control chip. The 32 - bit chip is based on the Cortex-M4 core and has rich peripherals, which meets the performance and is economical.

According to the standard and limits of indoor air quality parameters stipulated by national standards, the system selects the following sensors to realize data acquisition function : DHT11 temperature and humidity sensor, FS00202 laser dust sensor, FS00602 TVOC sensor and FS00509 formaldehyde sensor. The sensor selection is shown in table 1.

Table 1 Sensor Selection Table

Parameter	Sensor	Range	Accuracy	Interface
PM2.5	FS00202	0 ~ 1000μg/m³	±10%rd	UART
HCHO	FS00511	0 ~ 1.5mg/m³	±10%rd	UART
TVOC	FS00602	0 ~ 5000μg/m³	±10%rd	UART
Humidity	DHT11	20% ~ 95%	±5%	1-Wire
Temperature	DHT11	0℃ ~ 50℃	±2℃	1-Wire

In this scheme, WiFi is selected as the communication mode of uploading data to the server, and ATK-ESP8266 communication module is adopted. The module has built in TCP / IP protocol stack,Communication module communicates with controller through UART and uploads data to server through WiFi.

This design includes HMI (Human Machine Interface), using 2.8-inch resistive touch screen to display data directly on the device. Based on the above scheme, this paper made a environmental quality monitoring system, as shown in Figure 2.

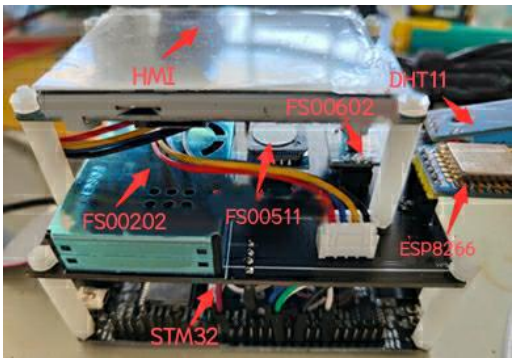

Figure 2 Picture of Environmental Quality Monitoring System

2.3 Software Design of Environmental Monitoring System

The software design of this scheme includes three parts : embedded device software design, server and database design, and WeChat mini program software design, corresponding to acquisition and upload for data, storage and forwarding for data, and remote display.

The embedded system program design includes the main program design and drivers design. The main program design requires the completion of hardware initialization, air quality data acquisition and air quality assessment. The sensors, HMI screens and communication modules are drived by corresponding drivers.

The purpose of the server is to allow WeChat mini program and MySQL database access server to realize remote display and transfer of data. This scheme uses the Aliyun Internet of Things platform to build the server, and buys the MySQL database from Aliyun to realize the function of the database, so as to avoid server operation and maintenance. The database example is shown in Figure 3.

The development of WeChat mini program is based on the mpvue framework, and the application layer protocol is MQTT. When the WeChat mini program successfully connects to the server and subscribes to the topic, it begins to receive the message. and unpacks the received message in JSON format, so as to obtain the data of the corresponding sensor, and display the data on the mini program page.

id	temperature	humidity	pm25	TVOC	HCHO	time
754	25	54	44	220	59	2022-05-23 14:57:16.000000
755	25	53	44	220	62	2022-05-23 14:58:16.000000
756	26	54	44	235	64	2022-05-23 14:59:16.000000
757	26	54	42	237	66	2022-05-23 15:00:16.000000
758	26	54	44	241	66	2022-05-23 15:01:16.000000
759	26	54	44	242	60	2022-05-23 15:03:13.000000
760	26	54	46	254	66	2022-05-23 15:04:13.000000
761	26	53	42	251	69	2022-05-23 15:05:13.000000
762	26	54	42	259	65	2022-05-23 15:06:13.000000
763	26	53	42	260	63	2022-05-23 15:07:14.000000
764	26	53	44	269	63	2022-05-23 15:08:13.000000

Figure 3 Database Example Diagram

3. Air Quality Assessment Algorithm

At present, the most common method for calculating the comprehensive evaluation index of indoor air quality is to use the air quality index (AQI)[8]. The air quality index of each pollutant is calculated according to the air quality classification standard, and the comprehensive evaluation index is obtained according to appropriate method. the individual index reflected by a single pollutant or parameter and the combined quality index of several pollutants or parameters. According to the national standard of indoor air quality and indoor environmental pollution control standard of civil building engineering[9], this design adopts the air quality classification standard shown in table 2.

Table 2 Air Quality Classification Criteria in This Programme

Index	HCHO（ug/m3）	TVOC（ug/m3）	PM2.5（ug/m3）
0	0	0	0
50	35	250	35
100	70	450	75
150	105	650	115
200	140	850	150

Individual indoor air quality index (IIAQI) is the quality index calculated by single pollutant, and the calculation method is as follows.

$$P = \frac{P_H - P_L}{BP_H - BP_L}(C_P - BP_L) + P_L \quad (1)$$

In the formula, P is the individual indoor air quality index, C_P is the concentration of single pollutant item in Table 2, BP_H is the high value of the pollutant concentration limit close to C_P, BP_L is the low value of the pollutant concentration limit close to C_P, P_H is the air quality index corresponding to BP_H, and P_L is the air quality index corresponding to BP_L.

Indoor air quality index (IAQI) can be obtained by individual index through a variety of calculation methods. The following introduces several common formulas for calculating the IAQI by IIAQI, where P is the IIAQI, C is the IAQI, and k is the number of calculation indexes, P_{max} is the maximum in P.[10]

1) arithmetic superposition method

$$C = \sum_{i=1}^{k} P_i \quad (2)$$

2) arithmetic average method

$$C = \frac{1}{k}\sum_{i=1}^{k} P_i \quad (3)$$

3) comprehensive evaluation method

$$C = \sqrt{P_{max} \cdot \frac{1}{k} \cdot \sum_{i=1}^{k} P_i} \quad (4)$$

The above several calculation schemes are common methods to calculate the air comprehensive quality index. The arithmetic superposition method reflects the overall pollutant strength, but it is related to the number of pollutants. When the number of pollutants is large, even if the single pollutant slightly exceeds the standard, the comprehensive quality index may be large. The arithmetic average method reflects the average level of pollutants, but it is easy to cover up some serious pollutants. The comprehensive evaluation method takes the geometric average of the maximum and average of the index, which is more applicable than the above two methods. This design uses the comprehensive evaluation method as the calculation method of the comprehensive quality index. Finally, the air quality evaluation grade is determined by air quality comprehensive quality index[11], and the corresponding relationship is shown in table 3.

Table 3 Air Quality Rating

IAQI	Grade
0-50	Good
51-100	Moderate
101-150	Unhealthy
>151	Very Unhealthy

The air quality evaluation results are displayed through the WeChat mini program interface. Figure 4 shows the WeChat mini program interface examples, including the evaluation results and real-time data display.

4. Conclusions

In this paper, a practical air quality monitoring and evaluation system is designed and produced. This system includes data acquisition terminal, server, database and WeChat mini program, which can realize the monitoring of indoor air quality, data upload and storage, quality evaluation and remote real-time display.

Figure 4 WeChat Mini Program Interface

Combined with the national standard of indoor air quality, this paper provides a suitable calculation method of indoor air quality comprehensive index, and applies this method to the air quality monitoring system. The results show that this method can evaluate the indoor air quality well. Since the calculation method is not complex and occupies less computer memory, it is suitable for real-time comprehensive evaluation of indoor air quality in small air quality monitoring systems such as the Internet of Things[12].

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