Design of air quality monitoring system based on light scattering sensor

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Abstract: The current air quality detector mainly detects the PM2.5, temperature and humidity of the environment at a single point, and the official website data is also a large range of regional data. The traditional cable transmission and wiring is complex, limited by the environment and high cost. In this paper, a data service air quality detection system based on light scattering sensor is proposed, which can detect PM2.5, temperature and humidity, and upload data to the Internet of things platform for real-time analysis and historical data statistics. It can also upload data to the Internet of things platform for real-time analysis and historical data statistics. The system collects three kinds of sensor modules to monitor indoor air environment in real time. Monitoring data is sent to mobile terminal equipment or PC terminal through WiFi. Its historical data can be viewed and called for data statistics through mobile phones. The system is stable and convenient to use. The paper also studies the detection characteristics and improvement methods of light scattering sensor.

1. Introduction
About half of the students' daily study is in the training room. Students' physiological and psychological state is directly affected by indoor air quality[1]. The indoor and external ventilation of modern buildings is less, which easily leads to the deterioration of indoor air quality[2]. An air quality monitoring system including light scattering sensor is designed and implemented in this paper, the system uses a variety of sensor modules to detect indoor temperature and humidity, dust and formaldehyde. It can also upload data to the Internet of things platform for real-time analysis and historical data statistics.

2. Overall design of the system
The system consists of air quality detector and Internet of things platform,[3], CC2430 is used as the control center of signal acquisition and data processing. The dust concentration signal is collected by laser scattering PM2.5 sensor, The formaldehyde content was collected by sensor ZE08-CH₃O, DHT11 was used to collect environmental temperature and humidity information. After being processed by single chip microcomputer, the information of dust content, temperature and humidity, formaldehyde content and other information are displayed on the LCD screen. After connecting the router through WiFi module, the data is uploaded to the Internet of things platform for real-time monitoring and recording [4], the system design block diagram is shown in Figure 1.
3. Hardware design of the system

The main hardware of the system includes: CC2430 single chip microcomputer, DSM501 dust sensor, SHT11 temperature and humidity sensor, formaldehyde module ZE-08.

3.1. MCU control core

CC2430 is a system chip (SOC). It meets the requirements of 2.4GHz ISM band application based on ZigBee. [5]. It contains an 8-bit 8051 microcontroller core and a DMA controller, 8K bytes of static RAM. CC2430 has four oscillators for system clock and timing operation. The interrupt controller serves a total of 18 interrupt sources, including four timers, and supports typical timing / counting functions[6].

3.2. DSM501 light scattering dust sensor

DSM501 is based on the principle of light scattering, it detects dust concentration using particle counter[7]. The appearance and principle of dust sensor are shown in Figure 2.

A heater is arranged in the dust sensor, which heats the air to make the air flow rise and force the external air into the module. When dust particles pass through, LED light source will be weakened due to light scattering, The photosensitive element detects weak light source and outputs low potential; When the passing dust particles are small, the photosensitive element detects strong light and outputs high potential, the PWM signal is amplified. The signal waveform is shown in Figure 3, the figure shows the PWM signal waveform output by the sensor in 30s (one measurement cycle). The low pulse rate of dust sensor is linear with the number of dust particles, the characteristic curve is shown in Figure 4, its low pulse rate is: \((\frac{LT}{UT}) \times 100\%\). As long as the low pulse rate per unit time is calculated, the number of particles detected can be obtained by referring to the characteristic curve, and then the parameters of PM2.5 can be calculated[8].

![Figure 1 system design block diagram](Image)

![Figure 2 Schematic diagram of DSM501 module appearance and principle](Image)
3.3. SHT11 temperature and humidity sensor
The system uses DHT11 digital temperature and humidity sensor to detect the temperature and humidity of the environment. DHT11 is a temperature and humidity composite sensor with calibrated digital signal output[9]. The sensor includes a resistance type humidity sensing element and a NTC temperature measuring element. The humidity accuracy is ±5%RH, the temperature accuracy is ±2°C, the range humidity is 20–90% RH, and the temperature is 0–50°C. Its small size, low power consumption, fast response, strong anti-interference ability, it can be applied to harsh environment. The appearance of SHT11 temperature and humidity sensor is show in Figure 5.

3.4. ZE08-CH2O formaldehyde sensor
ZE08-CH2O has good selectivity and stability. It is built-in automatic temperature compensation, with digital output and analog voltage and other output. The appearance of ZE08-CH2O formaldehyde sensor is show in Figure 6.

3.5. Data transmission unit
In order to carry out multi-point environmental monitoring and data analysis and query, the system realizes data transmission through WiFi wireless transmission, and uploads the collected
environmental data to the Internet of things platform. The WiFi module uses an ultra-low power UART WiFi transparent transmission module with esp8266 as the core.

4. Preprocessing of sensor signal

The data acquired by the above sensors need to be preprocessed before being input into single chip microcomputer and finally displayed on PC[10]. For the dust sensor, the percentage of low level in every 30s is the final required dust concentration data.

Temperature and humidity sensor needs linear compensation for the collected signal[11]. According to the manual, the calculation is carried out according to the following formula:

\[
\text{RHlinear} = C_1 + C_2 \times \text{SORH} + C_3 \times \text{SORH}^2 \text{(RH)}
\]

In equation (1), RHlinear is the humidity value after linear compensation, SORH is the relative humidity measurement value, C1, C2, C3 is the linear compensation coefficient, when the accuracy of relative humidity is 12bit, C1=−4, C2=0.0405, C3=−2.8×10−6.

Because the actual temperature is different from the test reference temperature of 25℃, the humidity signal needs temperature compensation. The temperature correction approximately corresponds to 0.12%RH/℃@50%RH. Temperature compensation coefficient: RHtrue = (T-25) × (t1+t2 × SORH) + Rhlinear

In equation (2): RHtrue is the humidity value after linear compensation and temperature compensation, T is the temperature at which the humidity value is tested (℃), t1 and t2 are temperature compensation coefficients t1=0.01, t2=0.00008

Calculation formula of actual temperature: T=d1+d2 × SORH

In equation (3), d1 and d2 is a specific coefficient, they are related to the working voltage of SHT11 and the resolution of internal A/D converter respectively.

The communication mode of formaldehyde sensor is the default active upload module, Data is sent every 1s interval. Gas concentration value of sensor module = high gas concentration value×256 + low order of gas concentration value.

5. Software design of the system

The function of the system software is to analyze the collected environmental information, display the current environmental information, and upload the information to the Internet of things platform[12]. After the initialization of the system, the collected information will be sent to the MCU. If the environment does not change, the information will be displayed directly, otherwise, it will be collected and uploaded again.

The program flow chart is shown in Figure 7.

![Figure 7 system software flow chart](image)

The software can realize the following functions:

(1) System login: system login requires user name and password, There are two types of users: system administrator and ordinary user;
(2) User management (for system administrators only): the system administrator can establish, authorize, edit and delete ordinary users;

(3) User operation: users can complete data acquisition, display and change user password;

(4) Monitoring point setting: users can select monitoring points, add or delete a monitoring point, and set alarm threshold of each monitoring point;

(5) Data browsing: users can browse current and historical data, and view alarm history records.

6. The realization of system

The hardware experimental connection of the system is shown in Figure 8.

Connect the power supply with CC2430 wireless transmitter, and then connect the dust sensor, temperature and humidity sensor with CC2430 wireless transmitting unit to form a front-end monitoring point.

Connect the serial communication USB interface board with CC2430 wireless receiving unit, and connect with PC through USB port.

The equipment is placed in the laboratory environment to be monitored, the system is started, and the wireless communication network of monitoring point and receiving end is established. Start the monitoring function, the system can monitor the dust concentration and air temperature and humidity, and display it in real time. The operation display of the system is shown in Figure 9.

7. Conclusion

The system uses CC2430 single chip microcomputer as processor and uses WiFi technology to establish monitoring data network. The information can be easily viewed on the mobile phone or PC, which realizes the wireless monitoring and display of multi parameters.

The results show that the consistency of the output signals of DSM501 sensor is poor[13], its experimental value is between ± 32%. Because DSM501 is an infrared sensor, the signal of infrared LED light scattering is weak, only particles above 1μm can be detected. The sampling number of DSM501 is small, and the data calculation is completely carried out by the upper computer, so it is difficult to achieve the consistency less than ± 20%[14]. The reasons that affect the consistency are sensitivity of photosensitive element, focal length of lens, fan speed. If laser dust sensor is used, it can achieve better data consistency than infrared dust sensor [15].

Ammonia, benzene, ethanol and other gases are the main interference gases of ZE08-CH2O, which have great influence on formaldehyde detection. In chemical laboratories, formaldehyde monitoring data are often not available.

The system only detects the dust concentration, formaldehyde concentration, temperature and humidity, and has no data statistical analysis function. The function of graphical display of statistical analysis of monitoring data will be studied. The system can complete real-time collection, real-time
display and analysis and statistics.

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