

Universal, Low-cost Temperature, Humidity, and Dust Concentration Environmental Measurement and Visualization

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Abstract. Humans spend most of their lives indoors. A comfortable environment contributes to human health, but an indoor environment can change due to various factors. Monitoring indoor temperature, humidity, and dust concentration can help people improve the environment through various measures based on the current values. The author designed a circuit using Arduino and sensors to detect and visualize the values. In this study, two sensors, SHTC3 and GP2Y1014AU0F, were used for the measurements. And LEDs and speakers were used as indicators. The author used the brightness of the LEDs to show the values of temperature and humidity. The author used a speaker to play a melody to remind people to open the windows or turn on the purifier when the particle dust exceeds the normal range in the room. This detection device can help people to detect the environment and alert them simultaneously in order to continuously maintain a good and healthy indoor environment.

Keywords: Environmental measurement; visualization; indoor environment; SHTC3.

1. Introduction

People's living environment is affected by many aspects. A good environment is closely related to people's health. Due to the complex composition of particulate matter, the impact of human factors on indoor air quality is particularly significant [1]. Common activities such as smoking and cooking may release harmful particulate matter. Since particulate matter is usually odorless, people may inadvertently inhale large quantities of harmful particulate matter. Improper temperature and humidity may also have a negative impact on human health. An environment with high humidity encourages bacterial growth, which can cause allergies and breathing problems. Also, an overly dry environment can lead to respiratory discomfort. With real-time monitoring, people are able to detect and correct these problems early, thus helping to maintain health. In terms of indoor microclimate measurement, the research done in the past has focused on linkages with the Internet of Things and notifications via sending emails [2]. Some studies have focused solely on the detection of a single variable, for example, using humidity measurements to detect dust mites or mold [3]. However, other studies have generally neglected to visualize the measurements, whereas this study visualizes the indoor environment in real-time through the use of LED and speakers. This enabled users to quickly understand the current environmental conditions. Therefore, the goal of this study is to gain a comprehensive understanding of the environmental conditions by detecting dust concentration, temperature, and humidity in real-time and visualizing them so that people can make adjustments when necessary. In this study, two sensors, SHTC3 and GP2Y1014AU0F, were used for the measurements, and LEDs and speakers were used as indicators, which are low-cost integrated circuits or components with high replicability. In order to ensure the universality of the measurements, the author designed a system that can make adjustments to the measurement range to suit different measurement needs of different regions and environments. This design makes our research more practical and applicable.

The author first introduced the parameters of the sensors. Then the author described how the measurements are made and how the values measured by the sensors are visualized in different ways. The author designed the visualization based on the indoor temperature, humidity, and dust concentration that are best suited for human life according to existing research. After completing the circuit design and code design, the author conducted an experimental design. The author took

measurements for three minutes indoors and three minutes outdoors in New York. The experiment was conducted in winter, and the author used outdoor measurements to simulate extreme weather so as to get the effect of weather changes on the results visualized. The final result was that the LEDs would stay on at the right temperature and humidity and the speakers would not play an alarm sound. A good indoor environment is good for all aspects of the human body, and when the user notices that the LED is dimming or going out and the speaker is playing an alarm when using this detection and visualization device, people can turn on the air conditioner, humidifier, purifier, and a host of other measures to improve the quality of the environment.

2. Methods and Materials

2.1. Introduction of the Sensors

2.1.1. SHTC3

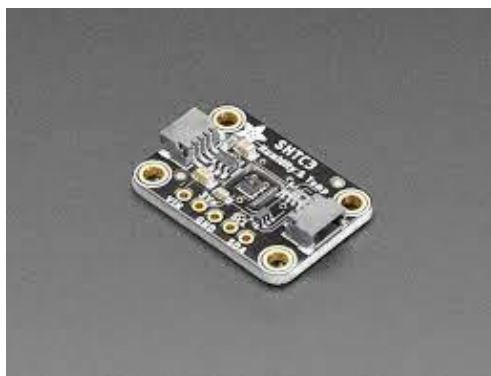


Fig 1. SHTC3 temperature and humidity sensor [4].

Figure 1 showed the temperature and humidity sensor. The SHTC3 is a low-cost digital sensor that measures temperature and relative humidity with high accuracy. The SHTC3 also has the ability to be set to a low-power mode when not in use [5]. The measuring range of SHTC3 was shown in the Table 1.

Table 1. The measuring range of SHTC3.

	voltage	humidity readings	humidity accuracy	temperature readings	temperature accuracy
SHTC3	1.62-3.6V	0-100%	±2%	-40°C -125°C	±0.2°C

2.1.2. GP2Y1014AU0F



Fig 2. GP2Y1014AU0F powered dust sensor [6].

Figure 2 showed the GP2Y1014AU0F powered dust sensor, and GP2Y1014AU0F is a low-cost optical mass sensor. The infrared light emitting diode and phototransistor inside the sensor enable it to detect dust reflected light [7]. The measuring range of GP2Y1014AU0F was shown in the Table 2.

Table 2. The measuring range of GP2Y1014AU0F.

	voltage	current	minimum particle detection value
GP2Y1014AU0F	0.9V	20mA	0.7 μ m

2.2. Detecting the Environment Values

When designing the circuit, SHTC3 must be connected to the Arduino using specific pins since it is an I2C chip. In this study, the author used Arduino Nano and two of the pins for transferring data, SDA and SCL. It needs to be connected to pins A4 and A5 of the Arduino Nano. GP2Y1014AU0F has two pins for transmitting data, one of them is used to emit LED light and its pin needs to be connected to a digital pin, and the other one is used to receive the light refracted by the dust in the air and returns an analog value, so it needs to be connected to an analog pin. Given the characteristics of the GP2Y1014AU0F, it requires to connection of a 150 Ω resistor to protect the circuit and a 220uF capacitor to filter out high-frequency interference signals [8].

2.3. Visualization

2.3.1. LEDs

In order to make the measurement results more intuitive and make the circuit more applicable to real-life scenarios, this study also uses the “analogRead” method to read the values from the Serial Monitor. When the Serial Monitor reads the values from two sensors simultaneously, Serial. Read () is used to read these values and send them to the computer and control the Arduino with other commands for further purposes. In this study, the author shows the temperature and humidity values by the brightness of the LEDs and protects the circuit with a 220 Ω resistor. When the values are transferred to the computer, the map () function is utilized to map the values between 0 and 255 to adjust the brightness of the LEDs. Given that the measurement locations for this study were indoors and outdoors in New York City, this study limited the measurement range to temperatures between -10 and 35 degrees Celsius and humidity between 40 and 60. Scaling this range isometrically to between 0 and 255, thus using the value after the map as the brightness of the LED.

2.3.2. Speaker

At the same time, when Serial. read() reads that the dust concentration is more than 2.0ug/m³, the speaker will play pre-set music to remind people of the high dust concentration and take protective measures in time. The music is defined in advance in an additional file, a note represents a frequency. This frequency will be output to the buzzer. A melody has different beats for each note, one beat corresponds to 1. The duration of each note can be stored in a duration array with different numbers, and the duration of each note can be stored in an array with a different number. Each time a note is played, a different duration is called out of the array to play the melody.

2.4. Circuit Diagram

Figure 3 presented the circuit diagram for the experiment.

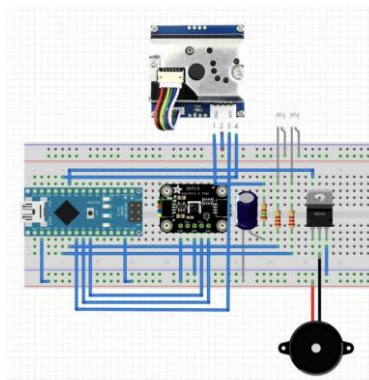


Fig 3. The circuit diagram for the experiment (photo credited: original).

3. Results

3.1. Experimental Procedures

In order to take more comprehensive measurements in different scenarios and regions, this study chose to take data indoors and outdoors in New York, USA as the study population. Each measurement lasted for three minutes. For outdoor measurements, the entire circuit is placed in the outdoor environment for a five-minute acclimatization period prior to measurement in order to ensure the accuracy of the data. The measured outdoor temperatures were used in this study as a type of simulation for extreme environments.

3.2. Experimental Data

3.2.1. Indoor

The final results of the indoor temperature measurements were that the temperature data fluctuated over a small range, fluctuating between 24.53 degrees C to 24.58 degrees C, with a mean value of 24.556 degrees C. The humidity data fluctuated between 44.72% rH to 45.09% rH, with a mean value of 45.067% rH. The dust density fluctuated from 0.12 to 0.15 degrees C, with a mean value of 0.14% RH. The dust density fluctuated from 0.12 to 0.14% RH. The dust density fluctuated between 0.12 and 0.15 with a mean value of 0.1429.

3.2.2. Outdoor

The final measurements of outdoor temperature were temperatures that fluctuated between 11.85 degrees C to 12.98 degrees C with a mean value of 12.222 degrees C. Humidity fluctuated between 38.65% rH to 44.91% rH with a mean value of 41.692% rH. Dust density fluctuated between 0.11 to 0.17 with a mean value of 0.144.

3.3. Experimental Results

When the measurement sensors were placed outdoors, the LED indicators of the temperature and humidity sensors dimmed. When the dust concentration exceeded the set value, the speaker played a piece of music until the dust concentration returned to the normal range. The author conducted the experiment by turning on the air conditioner, humidifier, and purifier to improve the environment when the LED was not bright enough. The final goal was to keep the LED lights bright and the speakers not to play the alarm sound.

3.4. Hazards of Extreme Conditions

The indoor environment affects all aspects of human health. According to existing research, 26 degrees C is the optimal indoor temperature for the human body. Exceeding this temperature may cause problems with breathing, blood pressure, blood sugar, mental health, and physical functioning, and may also speed up the spread of influenza [9]. And for cold winters, keeping the house at least 18 degrees C minimizes the health risks to the human body. For sedentary or elderly people, the temperature should also be raised by at least 2 to 3 degrees C. Humans do not have specific receptors to sense temperature [10], and this LED works well as a secondary indicator to help create an awareness of the current humidity of the environment. When the human body lives in high humidity and dry environments for long periods of time, it can cause irritation to the nose and eyes and increase the risk of bacterial growth [11]. Recommended humidity levels are between 40% and 60%, which will minimize adverse health effects [12]. The range of humidity also corresponds to the measurement range preset by the author in the code, when one notices that the LED does not light up, it proves that the humidity is not in a relatively suitable environment. People can use a steam humidifier to humidify in time in winter time, and use a dehumidifying bag or turn on the air conditioner to dehumidify in time in summer.

4. Discussion

When performing the experimental measurements, the author used an outdoor environment to simulate a cold environment. This is a rapid drop in the temperature, so the change in the brightness of the LED will be obvious and people can easily notice it. However, in real life, the changes in temperature and humidity may be less noticeable over a period of time, so people may ignore the Led as a reminder that the environment is no longer optimal for human habitation. In this regard, it may be possible to add a function to remind people when the measured value is not in the optimal range by adding a Led, digital LOW, and duration to make the Led blink on top of the brightness. As for the SPEAKER, the dust concentration simulated by the author using a lit match remained above the set value of the appropriate ambient concentration for a long period of time during the test. During this process, the speaker kept playing a melody continuously, perhaps corresponding to different intensities of sound, which could give people an idea of the value of the dust concentration while using it, rather than just knowing that it was above the optimal range.

During the 3-minute measurement time, the outdoor environment data fluctuated more compared to the indoor environment data. The reason for this may be that there are more factors influenced by the wind and the vehicles and people around the environment. If the outdoor environment is to be detected and visualized in the future to enable more possibilities, the data can be processed using averaging over a period of time or continuing to monitor for a period of time to see if alerts are needed when the difference between the measured data and the previous and subsequent values is too large. If the data returns to normal on its own, then no alert is needed. Instead, play an alarm sound or change the LED brightness to alert people. For example, if someone passes by smoking in the monitored area, the data will suddenly rise, but people don't need to be alerted to make a change. This is when the design is very user-friendly. People do not need to be distracted by this detection device all the time in some unnecessary way.

5. Conclusion

In this study, SHTC3 and GP2Y1014AU0F are utilized to monitor the temperature, humidity, and dust concentration of the environment in real-time. Two LEDs are used to show the temperature and humidity of the measured environment. When the environment is not at the optimal temperature for human life, the LED will be dimmed or not lit. When the dust concentration exceeds the optimal value for the room, a sound is played to alert people. During the experiment, when the author found that the environment was not optimal, the author made the LED light up and the speaker did not alarm by artificially turning on the air conditioner, purifier, and other measures.

Maintaining a good and comfortable environment contributes to the health of the human body, and this study is able to do so by visualizing and alerting people at the same time of measurement. When people see changes in the LED or hear the sound of the speaker, the author can take measures to improve the quality of the environment. This study visualizes the results of the measurements rather than just taking measurements.

This study could change the values of its measuring range and optimal range by the characteristics of the place where it is measured in the future. It can be adapted to different conditions in different environments. For example, this research can detect the environment where crops are grown for real-time adjustment. It can also be used in warehouses to maintain a good environment for storing goods through detection.

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