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IoT-Based Data Logger for Weather Monitoring Using Arduino-Based Wireless Sensor Networks with Remote Graphical Application and Alerts

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Abstract: In recent years, the monitoring systems play significant roles in our life. So, in this paper, we propose an automatic weather monitoring system that allows having dynamic and real-time climate data of a given area. The proposed system is based on the internet of things technology and embedded system. The system also includes electronic devices, sensors, and wireless technology. The main objective of this system is sensing the climate parameters, such as temperature, humidity, and existence of some gases, based on the sensors. The captured values can then be sent to remote applications or databases. Afterwards, the stored data can be visualized in graphics and tables form.

Key words: Arduino; weather station; internet of things; wireless; sensors; smart environment

1 Introduction

Nowadays, the application of Internet of Things (IoT) affects all habitual domains[1]. The invented IoT systems are attempted to control, manage, and monitor human usual actions, environmental parameters, or animal movements. So, all these innovations are developed to facilitate human work and make the life easier than before. In this stage, the environmental monitoring systems are invented to measure and control the environment parameters[2–6].

For many years, humans try to understand their environment. So, humans have invented many objects to measure various parameters. For example, humans have created thermometer, barometer, and pyrometer for measuring temperature, atmospheric pressure, and solar radiation, respectively. However, those traditional tools must be used locally. On the other hand, with the invention of IoT, humans can measure all environment parameters remotely[7–10]. Thus, the procedure of quantifying and measuring environmental parameters has become simple than in previous days.

The recent environmental monitoring systems[11–14] are based on the sensors, such as temperature, humidity, and pressure sensors. Some of these sensors can support different environmental conditions. But, others require specific conditions. These sensors can capture the corresponding physical or chemical weather values and convert them to an electric signal. Hence, the captured values are transferred as electric signal to an electronic card. The last one is able to understand the received signals and give its respected value to each one.

In this context, we propose a framework of weather monitoring station in this paper. Our system is based on internet of things technology. In our system, the Arduino card plays a fundamental role. In fact, it can process the measured value and take some decisions. It can also be considered as the intermediate between the sensors and the monitoring application. The local

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and remote communications between our system and other correspondent devices are provided through Wi-Fi module.

The rest of this paper is arranged as follows. Section 2 presents related works to our study. In Section 3, we give our proposed system. In Section 4, the experiment results and discussion are detailed. Lastly, the paper is concluded in Section 5.

2 Literature Review

In recent time, the new technology applications allow us to measure various air parameters in distance, thus to monitor air quality remotely. These applications are developed thanks to the advantage of internet of things and the innovation of new devices. The monitoring systems necessitate the application interface that can be web page, software, or mobile application for visualization of the received values or controlling the systems[15].

In 2016, Rao et al.[13] presented the system for monitoring weather based on IoT. The system measured various parameters such as temperature values, light intensity, and CO level[16]. In the same year, Ram and Gupta[12] developed weather visualization system based on wireless sensor networks. This latter is able to capture temperature, light, and humidity values. The sensed data are then transferred to web page for monitoring.

In 2017, Kumar and Jasuja[17] designed a new system based on the internet of things technology by using the Rasberry Pi card. The system aimed to evaluate air quality by measuring its parameters, such as temperature, monoxide and dioxide carbon, and air pressure and humidity.

In 2018, Reddy et al.[18] proposed a low-cost weather monitoring based on the internet of things technology. The proposed system used several electronic sensors for sensing the air conditions including hydrocarbons, sulfur dioxide, nitrogen oxides, and so on. In case of reception of the dangerous gas values, the system activated the warning alarm. Furthermore, it can communicate an Short Message System (SMS) message to final user. Finally, it was connected to distance database designed for storing the historical measurement.

Afterwards, Kumari et al.[19] proposed an intelligent environment monitoring system based on Android and the internet of things technology. The designed system is capable to measure some air, water, and soil parameters that are used to evaluate the environment. For these reasons, the system is equipped with various sensors that are connected to Rasberry Pi card. Upon getting the measured parameters, the card transfers their values to the remote database via wireless network.

In 2019, Durrani et al.[20] proposed a smart weather station for monitoring weather parameters. This system is equipped with various sensors that collect data from their location and then send them to the cloud. In addition, they can predict the future stations of weather by using machine learning algorithms.

3 Design of Air Quality Measurement System

In order to monitor the air and weather conditions, we have implemented a new application that is illustrated in Fig. 1. Our application can capture both weather and air parameters. The realized framework includes an Arduino card as a central management unit. Then, all

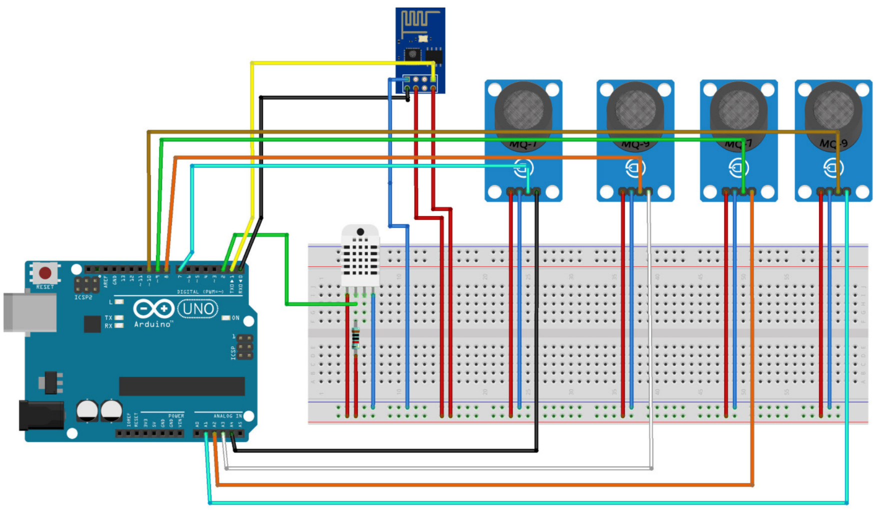


Fig. 1 Block diagram.

sensor and devices can be connected with it directly or indirectly. The connected sensors are able to measure weather and air information from their environment. The captured values are transmitted to Arduino card for local processing. After a simple treatment, the Arduino card transmits the processed values to computer that includes database. The stored information can be accessed remotely via page web. When an undesirable value is detected, an alert message is transmitted to final user via email-message. The main components of the proposed system are depicted in Fig. 1 and they are detailed in the following.

(1) Arduino UNO R3 card

In our system, we have used the Arduino UNO card illustrated in Fig. 2a. As we can see, it is a small electronic card that integrates microcontroller. Arduino UNO card is given the ability to be programmed for receiving the sensed values by sensors and control the actuators. On the other hand, the sensors and actuator can be connected to Arduino via the digital and analog pin. Besides, the Arduino is powered via USB connector or via Direct Current (DC) jack connector. Arduino UNO card is linked with an integrated voltage regulator. Hence, the power source for connecting has to be between 5 and 12 V[21].

(2) Wi-Fi module

In this application, we used the Wi-Fi module ESP8266 as shown in Fig. 2b. The stack of Transmission Control Protocol/Internet Protocol (TCP/IP) is included in this device[22]. After connecting to an access point, our system will get an IP address automatically. This module plays an important role in our system. In fact, it is the part that allows the system to transfer captured values to the extern word via the internet network. It also permits distance application to control the system remotely.

(3) Sensors

Our system contains various sensors, such as temperature, humidity, and CO_2 sensors, which are illustrated in Fig. 3. These sensors will measure air parameters distinctly, but not limited to temperature, ozone (O_3) level, sulfur dioxide (SO_2) level, carbon monoxide (CO) level, nitrogen dioxide (NO_2) level, and relative humidity. This sensor gives the simple voltage that corresponds to a specific climatic factor. Subsequently, the Arduino integrated microcontroller will convert this voltage into numerical values[23–25].

4 Experimental Result and Discussion

With aims to evaluate our proposed system, we have done some experimental tests. Hence, after compiling the program code source and downloading it in Arduino board, we have tested each parameter separately.

(1) Humidity and temperature sensor experiment

In our system, the sensor used for sensing the humidity and temperature is DHT22 sensor. In order to

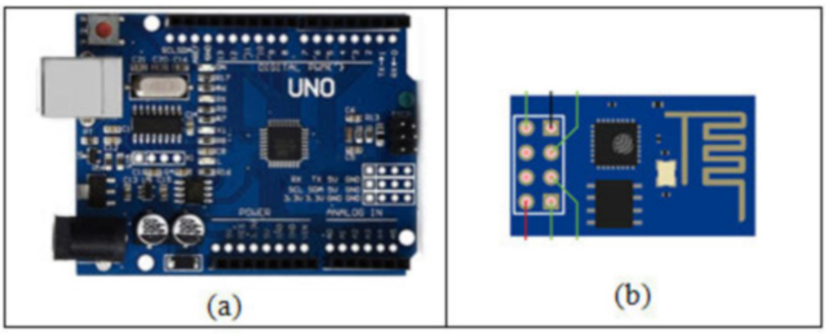


Fig. 2 (a) Arduino UNO card and (b) Wi-Fi module.

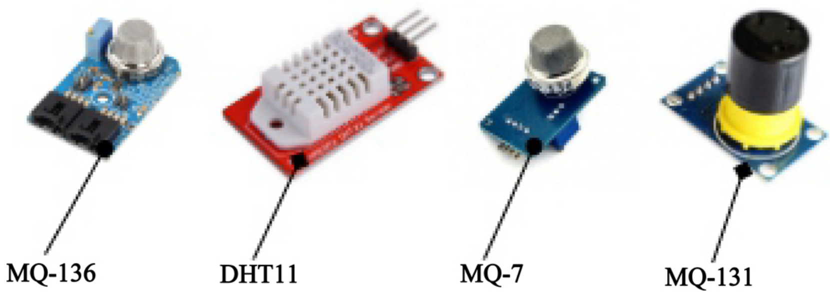


Fig. 3 Used sensors.

monitor the humidity in given zone, we have performed this basic test: The DHT22 sensor was placed in an extremely humid location, then we had noticed that the system began to register various values of humidity. The received values are exposed graphically in Fig. 4.

The result of this experiment is considered as a demonstration that confirms the reaction of the sensor to the humidity levels. Consequently, it also shows that our system is efficient for monitoring the humidity remotely.

On the other hand, we have done another simple test for surveying the temperature values. During this examination, we used a small flame to change the air temperature. Then, the sensor DHT22 was positioned near the flame to perceive the variation of the air temperature. The obtained temperature measurement is illustrated in Fig. 4b in form of graph. The temperature value was augmented from about 32 ℃ at first to more than 38 ℃. This change confirms the ability of the system to sense the various temperature values.

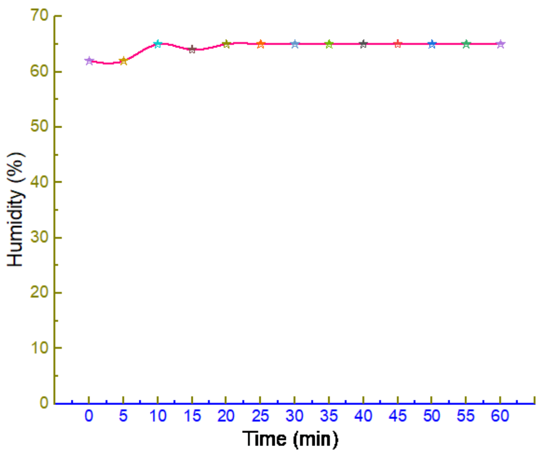
(2) Ozone sensor experiment

In order to evaluate the capability of our system to detect the existence of ozone gas in the air, we have connected the ozone sensor to our system and then exposed it to an air that contains ozone gas. The recorded data are displayed in Fig. 5. In our test, we have used the laminar flow chamber to product ozone gas. This chamber is equipped with an Ultraviolet (UV) lamp that is turned on after putting the sensor in the chamber. So, the UV ray transforms the oxygen in the air on ozone. In Fig. 5, we can observe that the graph is growing by the time and the level of detected ozone is growing continually. However, this development is stable after 240 s.

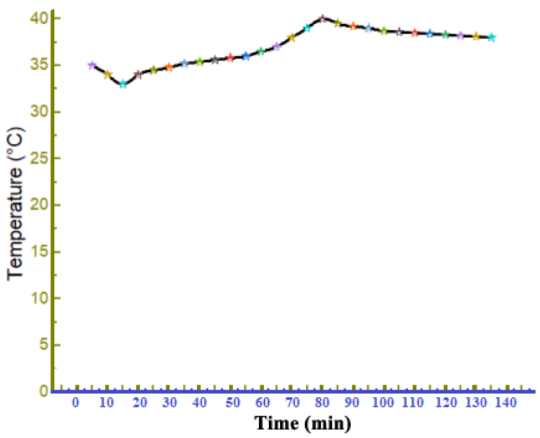
(3) Nitrogen dioxide sensor experiment

The tests were carried out to verify the usefulness of the nitrogen detector in identifying the degree of NO_2 gas perceptible all around, as shown in Fig. 6.

To confirm its activity, the sensor was presented with NO_2 taken from a small vial. The vial is associated with a cone-shaped measurement object where a substance response occurred to frame the gaseous NO_2. To form gaseous NO_2, a limited amount of sodium nitrite was mixed with 1 mol/L corrosive hydrochloride to create



(a) Humidity



(b) Temperature

Fig. 4 Experimental result of humidity and temperature level in air.

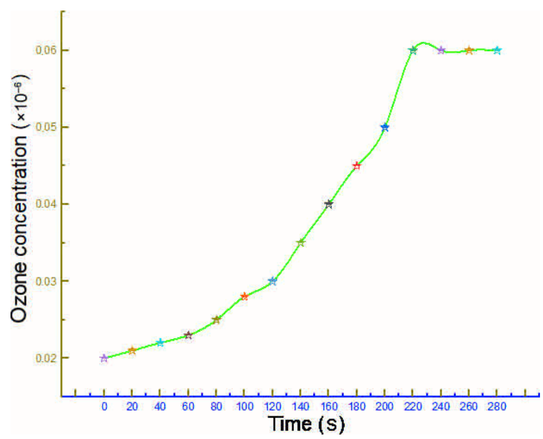


Fig. 5 Experimental result of ozone concentration in air.

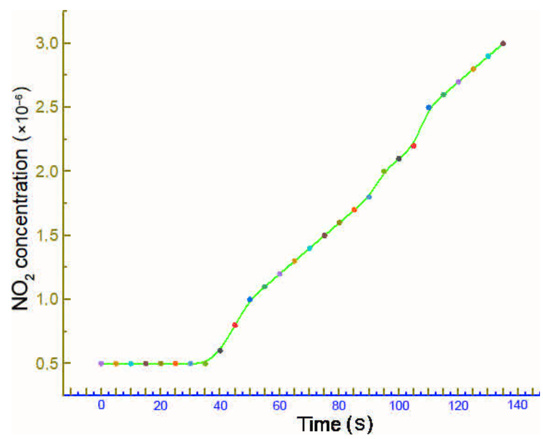


Fig. 6 Experimental result of NO_2 concentration in air.

gaseous NO_2 with an earthy coloration.

$$NaNO_2 + HCl \longrightarrow NaCl + HNO_2 \quad (1)$$

$$2HNO_2 \longrightarrow NO + NO_2 + H_2O \quad (2)$$

$$2NO + O_2 \longrightarrow 2NO_2 \quad (3)$$

In this situation, HNO_2 was not stable and was quickly replaced by nitric oxide (NO), which on seeing oxygen, framed the earth-coloured NO_2 gas, as shown in Fig. 6. The response of the preparation was at 0 s. As the NO_2 gas reaches the tank containing the sensor through the association channel, the reading begins to advance steadily by 55 s until the end of the test. In this way, the sensor has the opportunity to determine the degree of NO_2 and is functioning accurately.

(4) Sulfur dioxide sensor experiment

The usefulness of the MQ-136 sensor for estimating the degree of SO_2 in air was validated by a basic test where the sensor was presented directly to the gas in a small container as shown in Fig. 7. Sulphur dioxide was manufactured by mixing a portion of the sodium bisulphite with a small volume of 1 mol/L corrosive hydrochloride. This step resulted in the rapid release of dry SO_2 into the kettle:

$$NaHSO_{3(s)}+HCl_{(aq)} \longrightarrow SO_{2(g)}+NaCl_{(aq)}+H_2O_{(l)} \quad (4)$$

As a result of the SO_2, the MQ-136 sensor was slowly expanded within 20 s after its introduction from 0 to 70×10^{-6}. Since the synthetic response was constantly rejecting SO_2 gas, the sensor reading rate remained high until the end of the test, as shown in Fig. 7. This type of estimation showed that the MQ-136 sensor filled as planned.

(5) Carbon monoxide sensor experiment

Figure 8 shows the scanning device for judging the usefulness of the MQ-7 sensor in recognizing the degree of CO gas in the air. The sensor cables have been

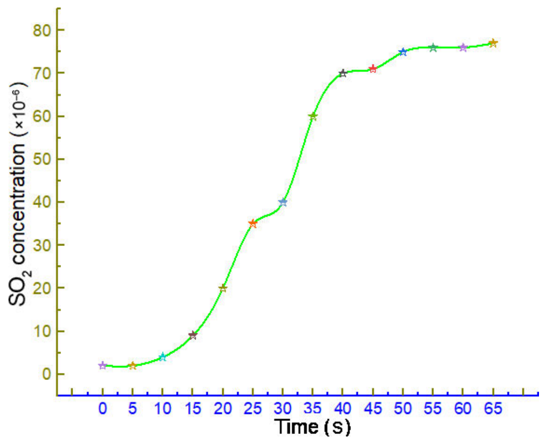


Fig. 7 Experimental result of SO_2 concentration in air.

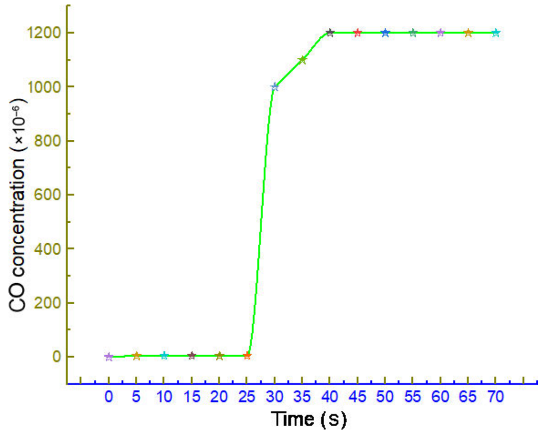


Fig. 8 Experimental result of CO concentration in air.

extended to allow the sensor to be placed in a small housing attached to the outside air. The container is associated with a measurement object where a compound response occurs to produce CO gas. This has been placed on a heater to preheat the response of the substance inside.

The visualization of the detector was made on a screen and filmed in the frame. To create CO gas, a small volume of formic corrosive was integrated with a small volume of sulfuric corrosive in a basin that released dry and unscented CO after heating, so that the accompanying recipe would specify the marvel.

$$H_2SO_4 + HCOOH_{(l)} \longrightarrow CO_{(g)} + H_2SO_4 \cdot H_2O_{(l)} \quad (5)$$

The response command was given in a matter of moments. The drawing shows a perfect trough from the earliest starting point of the test to 30 s where a radical rise in the CO level occurred up to 37 s when the heated gas reached the pot containing the detector. The sweep was then set at a significant threshold until the end of the test, as shown in Fig. 8. From this perspective, the detector was able to recognize the CO level and operate accurately.

(6) Experiment in the field

To demonstrate the functionality of the system, a field experiment was conducted to measure pollutant concentrations at the three sites with different traffic volumes. The system was positioned near a low-traffic (Site 1) and high-traffic (Site 3) road. Table 1 presents the results of the experimental installation for obtaining sub-Application Programming Interface (API) values in low-traffic and high-traffic areas. The experiment was conducted along a roadside near a housing and other area next to the industrial area. Measurements were taken every 30 times for one day. The measurements were recorded and saved in the system. Similarly, another

Table 1 Measurement results of pollutant concentrations at the terrain.

Site	Temperature (℃)	Humidity (%)	Pollutant concentration ($\times10^{-6}$)			
			O_3	SO_2	CO	NO_2
1	24	65	0.03	62	1245	0.7
2	28	60	0.05	72	1324	2.0
3	22	71	0.03	65	1420	1.2

experiment was set up to obtain sub-API readings in a high-traffic area.

The results of these experiments showed that the levels of each pollutant in the two zones differed considerably, except for Site 3 as shown in Table 1. O_3, SO_2, CO, and NO_2 concentrations were all relatively low in the low area, but higher when traffic was high. This observation can be explained by the higher amount of gas accumulated in the high-traffic industrial area. It is interesting to note that PM10 levels were higher in the low-traffic area than in the high-traffic area. This can be explained by the dynamic movement of dust particles in the area due to the heavy traffic that keeps dust particles away from the roadside. The system seemed to be working as expected, judging by the ability of its sensors to differentiate between different levels of pollution in low and high traffic areas.

5 Conclusion

The implementation of a system for monitoring environmental parameters using the IoT has been tentatively tested to verify air and weather parameters. The system provides a low energy consumption solution for the establishment of a station weather system. The system is tested in an indoor environment and it successfully updated the environment and weather conditions from sensor data. It is also a less expensive solution thanks to the use of low power consumption wireless sensors and System-on-Chip (SoC) contains a Wi-Fi module. This information will be useful for future review and tend to be shared effectively with various users. This model can also be extended to the observation of contamination in new and modern urban areas. To protect the general well-being from contamination, this model provides an effective and minimal effort response for continuous observation.

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