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Automated Dust Detection System for Air Quality Control and Monitoring in Hafr AL-Batin University

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Abstract: Dust is one of the more worrisome manifestations of air pollution, which is a ubiquitous hazard to both our environment and health. Pollutants such as ozone, nitrogen oxides, and particulate matter combine with dust, which covers urban and highly populated areas, obstructing the skyline. This paper proposes a mobile application-based system to gather data from dust sensor hardware devices which were conveniently installed in classrooms at the University of Hafr Al-Batin and its offices premises. An Arduino-based Internet of Things (IoT) device is connected to a fine dust sensor and provides dust-level data to a mobile application in real time. This system serves as a dependable and informative indicator of dust levels present in these spaces. This application provides the students, faculty members, and employees with the tools to actively monitor and address potential dust-related concerns within their immediate surroundings. The proposed application is expected to monitor and provide early warning on the environmental health conditions of at the University of Hafr Al-Batin in real-time. Students and the staff members can then avoid places where pollution levels endanger their health.

Keywords: *Air Pollution, Dust Detection, Environmental health, Hafr Al-Batin University, Internet of Things (IoT), Mobile application, Reliability.*

1. Introduction

At present, harm to the lives of people currently posed by exposure to several contaminants. Particularly, daily activities like those at the hospital, school, and workplace contribute to air pollution. Generally speaking, exposure to contaminants from external sources tends to highlight the negative health impacts of air pollution. Dust is a common type of air pollution that has negative effects on both human health and the environment [1] Dust is composed of solid particles and liquid droplets of different sizes, origins, and compositions is a form of complex aerosol (thick mist). Dust is naturally generated from wind erosion volcanic eruptions, desert storms, and anthropogenic activities such as construction, mining, and agriculture. Dust has numerous adverse impacts on the environment and human health. According to the World Health Organization (WHO), 9 out of 10 people breathe polluted air. Air pollution costs the global economy $5 billion a year [2-5]. According to the Environmental Protection Agency (EPA), dust in the US is thought to be the cause of 200,000 premature deaths annually. According to EPA estimates, pollution contributes significantly to climate change and costs the US economy tens of billions of dollars annually in health-related expenses [6].

Indeed, there are locations for contamination in closed structures that house services like document copying, as well as in residential and commercial buildings, classrooms, and labs. People's health will be impacted by these contaminants. especially dust particles smaller than 10 PM, which have an adverse effect on pulmonary health and the general population. It also has an impact on nearby assets, people, and the surroundings. Preventive actions can be taken to mitigate potential dangers if localized levels of fine dust are found. Those who might be put in danger by noticeably large amounts of fine dust might benefit from an analysis of the factors that lead to elevated fine dust levels.

Hafar Al-Batin is one of the major cities in Saudi Arabia, located in the Eastern region. The area is characterized by its desert nature and dry environment, leading to the accumulation of large amounts of dust and dirt. Consequently, Hafar Al-Batin is considered one of the cities that frequently suffer from dust accumulation. The levels of dust and dirt in Hafar Al-Batin particularly increase during the spring and summer seasons, as the region experiences strong winds and recurrent sandstorms. These harsh weather conditions result in the movement of dust and dirt from the surrounding dry lands and deserts, spreading them throughout the local environment and increasing their levels in the air. These fluctuating weather conditions pose a challenge to the residents of Hafar Al-Batin, especially those who suffer from health issues such as respiratory allergies and asthma. By royal order, the University of Hafr Al-Batin was established. (20937) dated 06/02/1435 AH to integrate with the other Saudi institutions in order to support the educational process, be a tributary, and assist in carrying out the ambitious growth goals in the Kingdom of Saudi Arabia. The Colleges of Education for Girls in Hafr Al-Batin, Nairiyah, Qarya Ulya, and Al-Khafji had an academic

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impact from two prominent universities, the University of Dammam when they founded the University of Hafr Al-Batin. The King Fahd University of Petroleum and Minerals, which existed from its founding until the date of the university's declaration, was included under its jurisdiction, as were the Community College and University Colleges for Boys.

This paper is designed to aid individuals afflicted by dust-related ailments by furnishing precise dust level readings within classrooms, offices, and meeting spaces at Hafar Al-Batin University via mobile application. The objective is to assess the degree of risk posed by each area, thereby mitigating the likelihood of allergy reactions for these individuals.

A. Purpose of this Research

The goals of this study are as follows:

1. To keep an eye on the chemical, biological, and physical components that have an impact on atmospheric health and to develop a tool that will issue a warning signal before levels under observation cross a predetermined threshold.

2. Give your support to the study being done at Hafr Al-Batin University, specifically with the use of technological advances to enhance the health of communities.

B. Advantages of this Study:

The investigation has the potential to enable every member of the general population with an electronic device to keep an eye on the variables influencing the environment's health. Real-time results could be obtained from wherever through surveillance. People can choose either continue or go based on their knowledge of the state of the ecosystem.

The paper is organized as follows: Related works are summarized in Section 2. The proposed dust monitoring is presented in Section 3. Consequently, main interface of the proposed Android-based mobile user interface is also shown. Results and its discussion are shown in section 4. Finally, Section 5 describes conclusions and future work.

2. Literature Review

Dust may be avoided naturally in a variety of ways, including large-scale planting, the creation of green spaces in cities, the use of renewable energy sources, sustainable transportation, etc [7]. Nevertheless, a multitude of problems, such as urban sprawl, contemporary agricultural practices, industrial growth, and expense, make its implementation difficult 8]. The monitoring and mitigation of dust can be significantly aided by contemporary technologies such as the IoT and mobile based applications. IoT-based dust detection systems have the potential to revolutionize the way air quality is monitored and managed. IoTs-based dust detection systems can be used for a variety of purposes, including providing public health advisories, finding ways to prevent and track air pollution, and more [9]. IoT-based dust detection systems can offer many advantages over traditional methods of air quality monitoring such as real-time data collection, which enables the rapid detection of dust. IoTs capabilities cover large geographic areas, allowing them to identify hotspots and track trends over time. IoT technology is also relatively inexpensive to implement and maintain [10]. Physical devices are equipped with sensors, software, and other technologies that connect to other devices and systems via the Internet. These devices can range from simple everyday objects such as thermostats and light bulbs to complex industrial devices. Key IoT applications include healthcare systems, smart homes, and smart cities [11].

IoT-based dust detection systems are still in the early stages of development, but several promising systems have been implemented [12]. Air Quality Warning System (AQEWS) by India Air Quality Monitoring Institute [13], the Smart Air Quality Monitoring System (SAMS) developed by the Environmental Protection Agency (EPA) in Singapore [14], and Berkeley Air are basic monitoring systems (BAMS) developed by the University of California at Berkeley are the few examples. BAMS is expected to be completed by 2024 which will be one of the most advanced IoT-based dust detection systems in the world. All the mentioned systems AQEWS, SAMS, and BAMS use IoT-enabled air quality sensors [15]. The sensors collect data on various air pollutants such as PM 2.5, PM10, ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) and then transmit the data to a central cloud server for analysis. These systems have capabilities such as real-time data collection, dissemination, and scalability but for all the benefits and capabilities, these systems have some limitations and weaknesses such as security and privacy. For example, AQEWS [16] is computationally vulnerable to attacks. Reliability and accuracy are another hot topic in IoTs especially when using edge devices in harsh and remote environmental conditions.

IoT-based systems can be unreliable as sensors are not maintained properly or if network connectivity is compromised. Many factors can influence the accuracy of an IoT-based system, such as the sensors used, the location of the sensors, and the deployment environment [17]. Environmental factors also affect sensor calibration The calibration function consists of comparing sensor readings with known air quality concentrations and adjusting sensor readings accordingly. Installation of IoT-based dust detection sensors also plays an important role in overall system accuracy for example sensors placed too close to pollution sources can give incorrect readings, and sensors installed in enclosures may not be able to detect contamination properly [18].

A constructed ZigBee [19] mobile sensor node served as the foundation for authors in suggested forest fire surveillance system. The primary objective is to assess the levels of smoke and moisture while taking advantage of the unique benefits of low cost and energy needs [20], network creation, and data transfer safety. The entire system's hierarchical architecture is a modified cluster-tree[21-24]. A cluster-tree architecture is easier to construct and requires a smaller amount of memory for information flow than the reticular architecture. Future research must be done to enhance the chain framework, which has to be restricted in scale and secure at the exact same time. The suggested system is referred to as an initial effort and a supplement to the current approaches for tracking and avoiding forest fires.

It offers a strong physical foundation for the use of cutting-edge wireless sensor networks capabilities. It is noted that additional work on the issues of energy intake, node setting, and timing of the clocks will be necessary to maximize the system's capabilities and advance the field of forestry technology for monitoring. Until the quality of forest fire surveillance may be raised, these are some of the issues that still need to be addressed. Compared to our work, the operational method's networking characteristics are given more attention than the addition of sensors. Furthermore, temperature readings rather than actual particle size scanners are used to infer the presence of smoke, a kind of dust [25].

3. Materials & Methods

The well-being of those who spend a majority of their lives inside is seriously threatened by poor air quality. The research presented here proposes an Internet of Things (IoT)-based air quality assessment system for instantaneously, affordable, and simple installation. The suggested approach measures the dust values instantly. The ESP32 Nano WIFI circuit was used to create this fully Wi-Fi an approach which incorporates the GP2Y1014AU0F Sand Sensor into the Internet of Things architecture. Figure 1 displays the envisioned system's design. A device that tracks the quality of the air in continuous time can tell you how many dust particles are present in the air. It helps to plan initiatives that result in better air quality while offering precise and comprehensive data about the state of the air in the place where people live.

The dust sensor connected with Arduino circuit which is connected with the server. The server collect data from sensors which is distributed in the buildings (classroom and labs and offices). The users use the mobile application to access to the data via internet. The following fig 2 show the GP2Y1014AU0F Dust Sensor Inside the sensor, three key components are present: the light-emitting diode (LED) as the light source, the photodiode as the detector, and a pair of lenses. Six pins are present on the GP2Y1014AU0F Dust Sensor component: V-LED, LED-GND, LED, S-GND, VOUT, and VCC. To measure the PM in the air, we need to link this sensor's analog signal pin to a microcontroller's ADC.

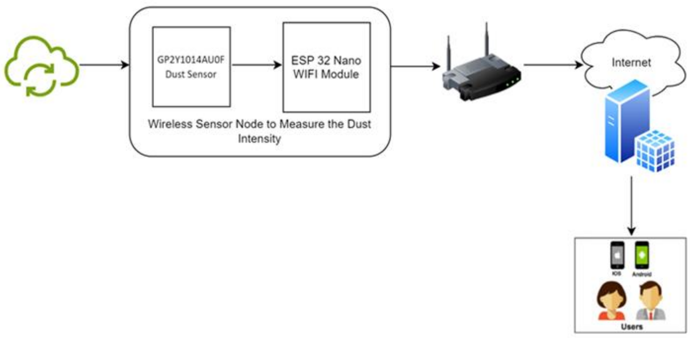

Fig 1: Proposed Model for Dust Detection

Fig 2: GP2Y1014AU0F Dust Sensor

The Pinout of the GP2Y1014AU0F Dust Sensor is shown in figure 3. The LED and photodiode are positioned within the sensor in a way that their optical axes intersect the detection area. When dust or smoke enters the sensor's detection area, it reflects the light emitted inside. Consequently, the current generated by the photodiode changes based on the amount of detected light. Through appropriate circuitry, this current is converted and amplified into a voltage value, providing the desired output from the sensor.

Inside the sensor, there are three major parts, they are the light-emitting diode (light source), the photodiode (detector), and a pair of lenses. The LED and the Photodiode inside the sensor are so placed that the two optical axis cross the detection area in the sensor. When dust or smoke enters the detection area of the sensor, the light inside the sensor gets reflected from the dust or smoke, as a result, the current generated by the photodiode varies in

Accordance with the amount of the detected light. And by converting and amplifying the current value to voltage value with proper circuitry we get the desired output from our sensor.

The fig 3 shows the pinout diagram of GP2Y1014AU0F Dust Sensor. The LED's VCC pin is denoted by V-LED. Attach this pin, together with a 150Ω current-limiting resistor that to the Arduino's 5V pin. The LED's earth pin is designated as LED-GND. Attach this pin to the Arduino's ground pin. Toggle the LED on and off using the LED pin. Attach it to any Arduino digital pin. The pulse dust sensor module's grounding pin, S-GND, needs to be linked to the Arduino's ground wire. The Sand Detector Module's Vout signal can be connected to any analog pin on the Arduino. The 5V or 3.3V pin of the Arduino is connected to the VCC Power Pin of the Dust Sensor Unit.

GP2Y1014AU0F Dust Sensor connected to the Arduino, and then we can proceed to write the code to extract data from the sensor module. The connection diagram for interfacing the GP2Y1014AU0F Dust Sensor with Arduino is illustrated in Figure 1. As discussed earlier, this sensor provides data through varying voltage output at the output pin. Therefore, we must utilize the Analog-to-Digital Converter (ADC) of the Arduino to convert and process the data into a recognizable value. Additionally, we need to link the LED enable pin of the sensor to one of the GPIO pins of the Arduino. Lastly, a 150-ohm resistor and a 220-microfarad capacitor are required. These components form an RC timer circuit, serving as a pulse driver circuit crucial for ensuring stable operation of the device. The Arduino devices and sensors connected with the server, the server collect data and stored in database system (MySQL) these data are organized and stored in the database. The users use the mobile application to access to the data via internet. The server provides the services for mobile application user all the data is stored in MySQL database and the authors used Php language to deliver the services to users. PHP backend writing sets a strong foundation and keeps working. The language performs at its best in this environment and has set the standard for development.

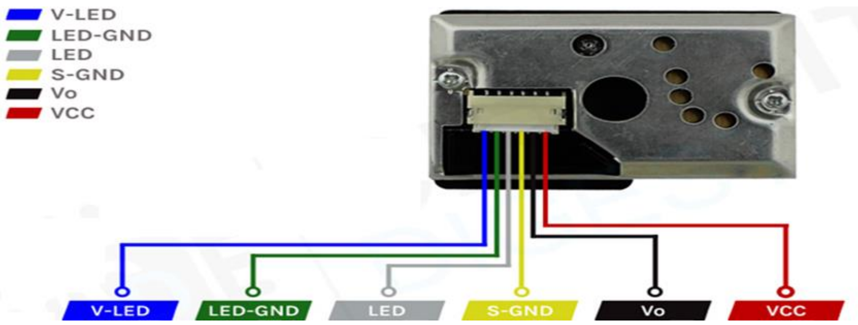

Fig 3: Pinout of the GP2Y1014AU0F Dust Sensor

PHP easily stores and manipulates data in large quantities. Once you determine and add values, PHP takes the wheel. Managing backend struggles is much easier with PHP around. It can also retrieve data and display that to users within the same keystrokes. This is especially easy with PHP in your front-end development, as there is no need for a translator. Flutter is an open-source framework developed and supported by Google. Frontend and full-stack developers use Flutter to build an application's user interface (UI) for multiple platforms with a single codebase. When Flutter launched in 2018, it mainly supported mobile app development. Flutter now supports application development on six platforms: iOS, Android, the web, Windows, MacOS, and Linux.

4. Results and Discussion

The main interface of the proposed Android-based mobile user interface is shown in Figure 3. Nowadays, various applications can be easily interacted with the Arduino based sensor. There are many free options available for Android and iOS devices. Blynk is one of these applications and it is an IoT platform developed for iOS and Android applications that enables management of different controllers such as Raspberry Pi, ESP8266, ESP32, chipKIT, Intel, LeMarker, Onion Omega, SparkFun and STM32. Using the Blynk cloud server service, digital data such as temperature, humidity, current, voltage measurements and control systems are stored and can be easily accessed at any time. The Blynk graphical components (widgets) allow real-time clock and calendar (RTCC) features to be used.

The main interface of mobile application is shown in figure no 4. It can be used by all the user of application:

- Faculty member.
- Students.
- Employees

They are using this screen to login to the application.

Figure 4 depicts the mobile user interface of the proposed system. The interface accepts the username and password of the user who is going to check the air quality of the University of Hafr Al Batin. This interface upon accepting the user credentials, will direct the user to the automated dust monitoring system towards the classrooms and laboratories.

Fig 4: Mobile user interface of the proposed system

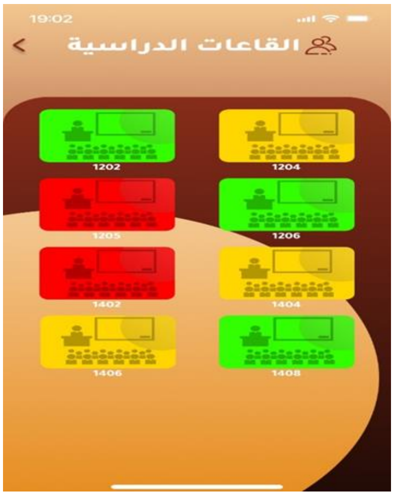

Fig 5: classrooms screen

Figure 5 shows the various classrooms present in the Hafr AL Batin University with colored representation of the Dust intensity. The various colors denote the various intensities of dusts present in the classrooms. Based on the color, the user can identify the percentage of dust particles in the classroom.

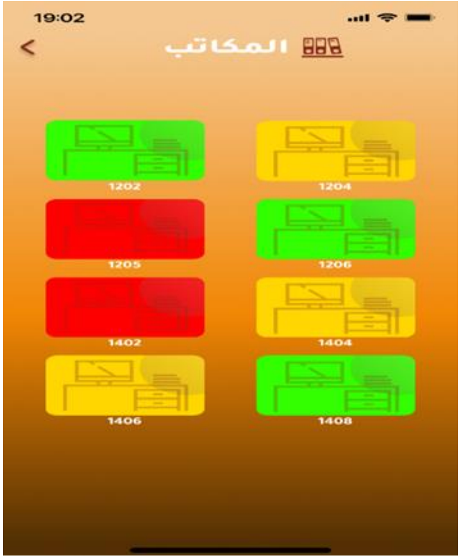

Fig 6: offices screen

Figure 6 shows the various labs present in the Hafr AL Batin University with colored representation of the Dust intensity. The various colors denote the various intensities of dusts present in the laboratories. Based on the color, the user can identify the percentage of dust particles in the laboratories. The table 1 shows the classroom number and offices number with the percentage of dust which is represented by colors the following table display the percentage of dust by color: The above figure 7 shows the output of calculations from dust Sensor connected to the Arduino, for extracting the data from the sensor module. The sensor module calculates the temperature and dust surrounding it. These calculations and values in-terms of mg/m3. The Percentage of dusts by color and its corresponding calculations is shown in table1.

It has the Level of health concern, PM 2.5 conc (mg/m3), PM 10 conc (mg/m3) along with its color representation. The Level of health concern can be of three categories such as good, moderate and unhealthy. These options denote the categories such as good which denotes the air quality ad good, moderate denotes the air quality as acceptable with precautions or it can be better avoidable. The unhealthy option denotes the category as unhealthy to inhale. Following conditions can be satisfied in order to predict the quality if air.

Table 1: Percentage of dusts by color and its corresponding calculations

Level of health concern	PM 2.5 conc (mg/m3)	PM 10 conc (mg/m3)	Color	level
Good	0 - 12	0 - 54	Green	Level 1
moderate	12.1 – 55.4	55 - 254	Yellow	Level 2
unhealthy	55.5 - Higher	255 - higher	Red	Level 3

The air quality can be considered as good, if it lies in between 0-12 PM 2.5 conc (mg/m3) or 0-54 PM 10 conc (mg/m3). It can be green in color and indicated the level 1.

The air quality can be considered as moderate, if it lies in between 12.1 – 55.4 PM 2.5 conc (mg/m3) or 55 – 254 PM 10 conc (mg/m3). It can be yellow in color and indicated the level 2.

The air quality can be considered as unhealthy, if it lies in between 55.5 - Higher PM 2.5 conc (mg/m3) or 255 - higher PM 10 conc (mg/m3). It can be red in color and indicated the level 3.

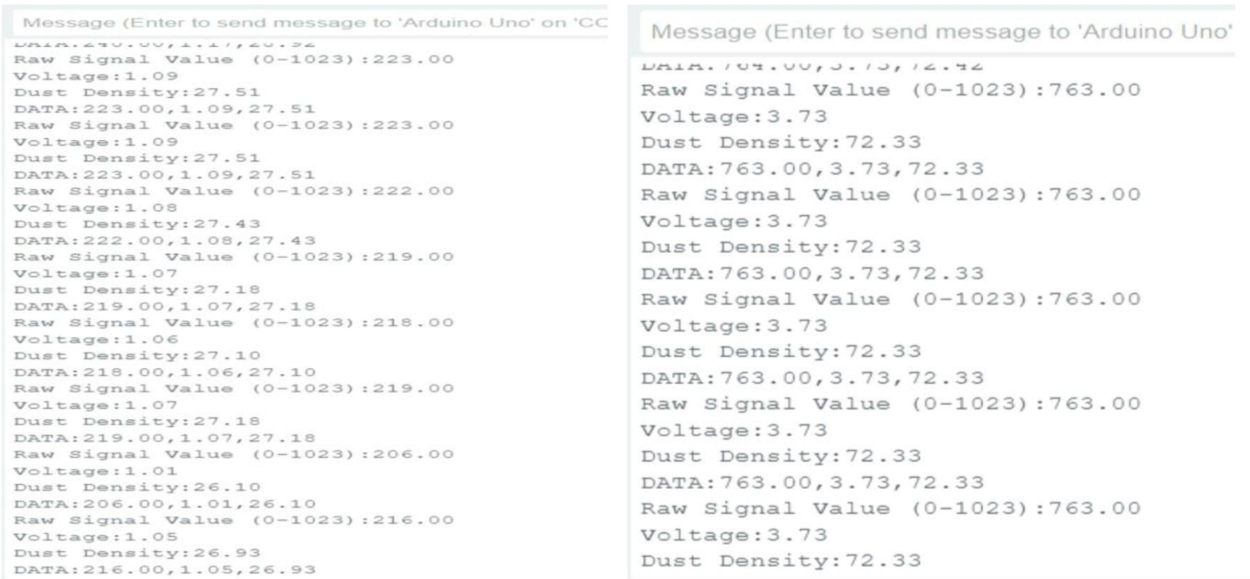

Fig 7: Output of calculations from dust Sensor connected to the Arduino

The system will calculate the data from dust sensor and proceed and send to application and representative as a colour.

Table 2: Category of Members who used this Application

Sl.No	Type of users	Total
1	Faculty members	819
2	students	23785
3	employees	688

Table 2 shows the category of Members who used this Application. A total of 24292 participants used the proposed system. Among these participants, the faculty members were 819, students were 23785 and employees were 688.

The results demonstrated that the higher than the dust detection baseline methods that were proposed model detects the dusts more effectively. The outcomes imply that the suggested paradigm works well. The proposed technique achieved the following objectives: The proposed methodology presented a novel model for dust detection that is enhanced by automated sensors.

Actual results can be obtained through the color-based indicator to increase the accuracy of dust detection services. Suggesting a user-friendly application that communicates the installed sensors readings in detecting the real-time pollution level information.

5. Conclusion

One of the more concerning effects of air pollution, which poses a constant risk to human health and the environment, is dust. Dust, which blankets cities and densely inhabited areas, combines with pollutants like ozone, nitrogen oxides, and particulate matter to obscure the skyline. In order to collect data from dust sensor hardware devices that were easily placed in classrooms at the University of Hafr Al-Batin and its offices premises, this study offers a mobile application-based solution. This technique acts as a trustworthy and useful gauge of the amount of dust in certain areas. With the use of this application, staff members, instructors, and students may keep an eye out for any dust-related issues in their immediate environment and take appropriate action. Real-time monitoring and early warning of the environmental health conditions at the University of Hafr Al-Batin are anticipated by the suggested application. Then, faculty and staff can steer clear of areas where air pollution poses a health risk.

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