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Real-Time Weather Monitoring System

Adithya K S[1], Adithya V[1], Anand Harikrishnan C[1], SharunRagh K[1], Elezebeth Skaria[2], Meenu Gibi[2]

[1]*Student, Department of Electrical and Electronics Engineering, Kothamangalam, India*

[2]*Assistant Professor, Department of Electrical and Electronics Engineering, Kothamangalam, India*

Corresponding Author: adithyav905@gmail.com

***Abstract*: A real-time weather monitoring system gathers weather data at regular intervals to improve crop yield. Rainfall is measured by a rain gauge, temperature and humidity with a DHT11 sensor, wind speed using an anemometer, and air pressure with a BMP180 sensor. The ESP32 reads data from these sensors at a constant time interval, processes it, and can either send it out or store it for future Users are able to access weather trends on a website, which makes it easier to read the data. The system is cheap, easy to install, and provides correct weather information from that location, making it suitable for agriculture, which enhances crop yield. Yet, the system gives information only from a single point, and cheap sensors are prone to require regular calibration, particularly in instances of extreme weather. All in all, this system allows farmers to base their decisions on local weather.**

***Keywords*: BMP 180, DHT11, Tipping Bucket Rain Gauge, Cup Anemometer, Data Monitoring.**

1. Introduction

In the modern world, precise and up-to-the-minute weather data is essential to numerous industries such as agriculture, transport, and disaster management. To meet this demand, we created a cost-effective and effective weather monitoring system with a miniature ESP32 microcontroller and an array of sensors. It gauges major environmental factors like precipitation (through the use of a rain gauge), temperature and moisture (through the utilization of a DHT11 sensor), air velocity (utilizing an anemometer), and atmospheric pressure (utilizing a BMP180 sensor). This data is retrieved at regular cycles, processed, and transmitted forthwith or warehoused to be accessed for later processing.

The system also makes it available via an easy-to-use website. Users are able to see the data as graphs and trends, allowing them to make decisions based on noted weather patterns. However, although the system is simple and inexpensive to install, it is only for single-location monitoring and its low-cost sensors might need to be calibrated regularly, particularly during harsh weather conditions. In general, this weather monitoring system is a worthwhile resource for farmers and other people concerned, as it maximizes productivity and allows effective response to changes in the environment.

A. BMP 180

The BMP180, one of the Bosch's sensors, which is used for the purpose of measurement of barameter and temperature in an extremely high accurate way. The basic part of the sensor is a piezoresistive sensor which is a device that is made of a semiconductor material that is very sensitive to changes in air pressure like, for example, silicon. These resistors change their electrical resistance because air pressure changes. It will be the air pressure in your current location and the atmospheric pressure at that point to find the real altitude where you are situated.

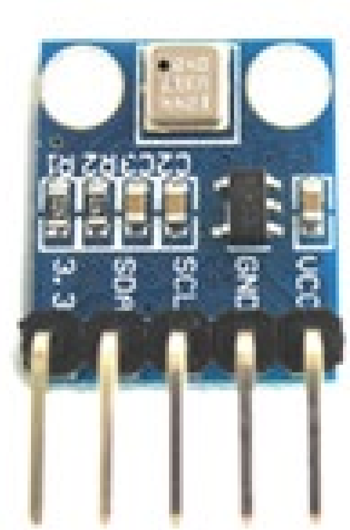

Fig. 1. Pressure Sensor

The sensor's PCB is quite small and includes a 3.3V voltage regulator, as well as an I2C level shifter, and pull-up resistors. These are needed for I2C communication pins. As a result, the sensor is easy to connect to different electronic projects. The BMP180 is capable of processing the pressures of 300 to 1100 hPa which can be further converted to the altitude from -500m land to 9000m sky. For example, the sensor is capable of working correctly at the temperature of -40°C to +85°C, displaying a temperature accuracy of ±2°C. The high accuracy, flexibility, and the fact that the system is extremely small, make it the best option for the environmental monitoring (weather), altitude and the other environmental sensor applications.

B. DHT11

The DHT11 is a sensor that is found to be very popular in various fields when the calculation of temperature and humidity demands on their necessity. It is mainly a material of the kind that has gas in the water, the material that undergoes a form change is what causes the change in the sensor. Apart from a thermometer (TM) that can sense heat the material used in the

Thermistor that changes its resistance with the temperature is also involved.

The DHT11 contains a small chip which reads the changes and transforms them into digital data. It can feel the temperature 0°C to 50°C (with an accuracy of ±1°C) and humidity 20%-90% (with an accuracy of ±1%). The sensor includes three pins: one for power (VCC), one for data, and one for ground (GND). It's simple, affordable and is perfect for basic weather projects.up or down.

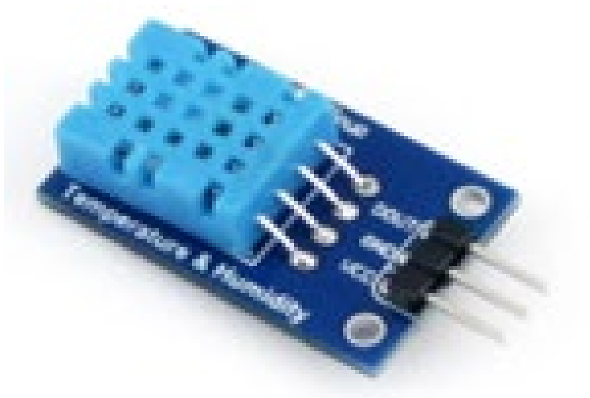

Fig. 2. DHT Sensor

C. Tipping Bucket Rain Gauge

The tipping bucket rain gauge is the most automated means of measuring rain. It is made up of a funnel, two little buckets on either side of a pivot, and a system that records the data. When rain comes, water flows through the funnel and one of the buckets gets filled. A specific amount of water, such as 0.2 mm or 0.5 mm of rain, is required to make the bucket tip over and drain out the collected water. The first bucket is then relased and the weight moves and the empty second bucket rolls the belt to make the new collection. Every time a bucket tips, it sends an electrical signal that gets recorded, allowing the system to calculate the total rainfall.

Fig. 3. Tipping bucket rain gauge

D. Cup Anemometer

A cup anemometer is a tool that is used to measure the wind speed. This anemometer has a set of cups fixed to arms which spin when the wind blows. The faster the wind, the faster the cups rotate. The machine works out wind speed by the time it takes for the cups to complete a certain number of spins. This information is then transformed into wind speed, usually in meters per second (m/s).

Fig. 4. Cup anemometer

System Design:

The ESP32 microcontroller is utilized in the weather monitoring system so as to be in charge of the sensors and gather data. The DHT11 senor, place on a digital pin of the microcontroller, gives the temperature and humidity data, meanwhile the tipping bucket rain gauge and cup anemometer are interfaced to interrupt pins for the proper recording of events. Via the I2C protocol, the BMP180 sensor shares data with the microcontroller.

Each sensor undergoes periodic polling for the purpose of gathering data:

- The DHT11 sensor is read every 2 seconds for temperature and humidity.
- The tipping bucket rain gauge is read on every bucket tip event to calculate rainfall.
- The cup anemometer is being measured every second in order to know the speed of the wind.
- The BMP180 sensor gives pressure data, the data is collected every 10 sec.

1) Data Processing

Data from all sensors are processed and converted into usable units:

- Temperature (°C) and humidity (%) are directly displayed.
- Rainfall is calculated in mm/hr based on the number of tips and the volume per tip.
- Wind speed is calculated in meters per second (m/s) based on the rotation rate.

- Atmospheric pressure is presented in Pa (pascal).

2) Display and Communication

An LCD screen that is capable of displaying real-time data is what the system uses and data can be transmitted to a remote server or cloud-based platform using a Wi-Fi or GSM module. In this way, the data is being recorded for historical analysis and visualization is being done to improve user interaction.

3) Hardware

The hardware implementation of the real-time weather monitoring system is illustrated in Figures 2 and 3. At the core of the system is the ESP32 microcontroller, which effectively gathers and transmits environmental data thanks to its dual-core processing power and integrated Wi-Fi. Several sensors are integrated into the system: an anemometer for wind speed, a BMP180 sensor for barometric pressure, and a DHT11 sensor for temperature and humidity. Wind speed is converted by the anemometer into an analog signal that the ESP32's ADC pin can read. The BMP180 connects to the ESP32 using the I2C protocol, and the DHT11 connects via a GPIO pin.

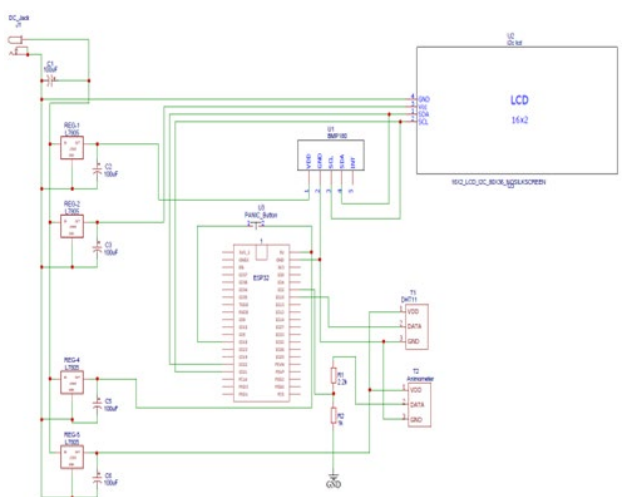

Fig. 5. Schematic diagram of real-time weather monitoring system

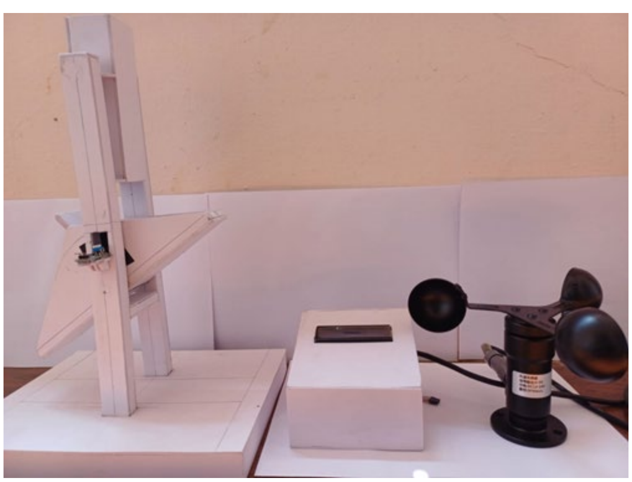

Fig. 6. Hardware implemented for the weather monitoring system

A custom voltage regulation circuit was created to supply the ESP32 and sensors with a steady 3.3V supply in order to guarantee stable and dependable operation. This circuit guarantees smooth operation and shields the parts from voltage variations. The Arduino IDE, which includes libraries for sensor communication and Firebase integration, is used to program the ESP32. After it is up and running, the system sets up the sensors, gathers data periodically, processes it, and uses Wi-Fi to upload it to a Firebase real-time database. This allows users to use web or mobile applications to remotely monitor weather conditions.

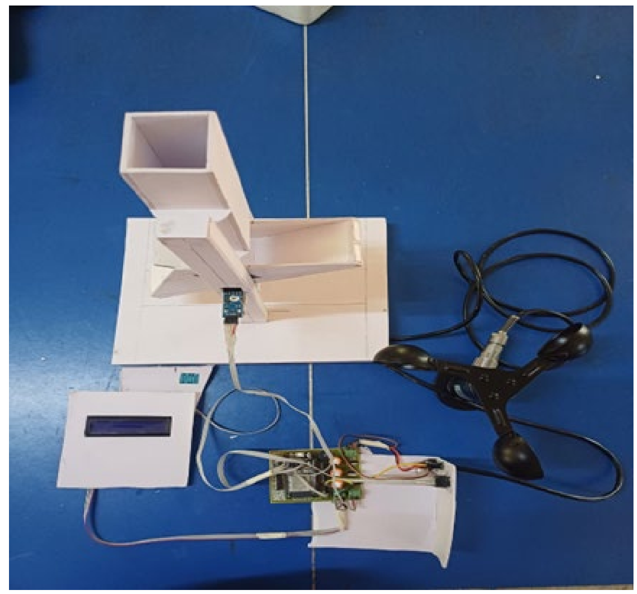

Fig. 7. Hardware implemented for the weather monitoring system

The system is very adaptable due to its modular design, accurate data collection, and effective power management. Applications like IoT-based weather stations, smart agriculture, renewable energy management, and environmental monitoring are a good fit for it.

2. Results and Discussion

The system provides up-to-date information on temperature, humidity, precipitation, wind speed, and atmospheric pressure in real time. The sensor data is shown on a screen in numerical formats. With each touch of the rain gauge bucket, the intensity of the rainfall is instantly updated, guaranteeing accurate precipitation tracking. While the BMP180 sensor provides real-time atmospheric pressure readings, the cup anemometer's rotation data is used to calculate wind speed. This system's affordability and ease of setup are among its greatest advantages. It offers comprehensive weather data by integrating several sensors, which is useful for observing conditions in both urban and rural regions. Because of its modular design, the system can easily be upgraded or expanded to accommodate new sensors and future developments.

3. Conclusion

The system is an effective and affordable solution for real-time environmental data collection. By combining the DHT11 sensor, tipping bucket rain gauge, cup anemometer, and BMP180 sensor, the system offers valuable insights into weather conditions. The design demonstrates how readily available components can be used to build a robust and reliable weather monitoring platform for a wide range of applications which include an increase in the crop productivity. Future improvements could include incorporating additional sensors, improving data processing algorithms, and extending the system's connectivity for remote monitoring.

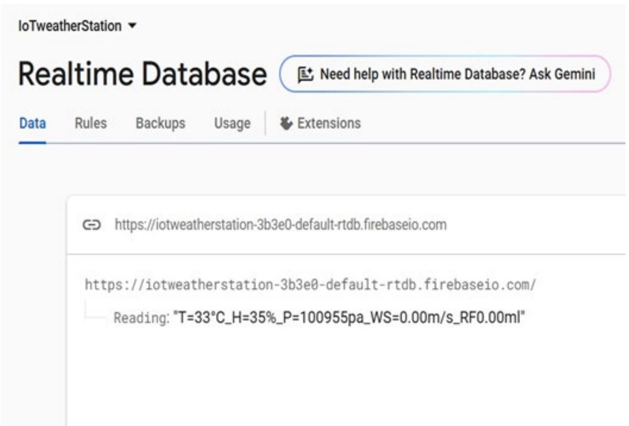

Fig. 8.

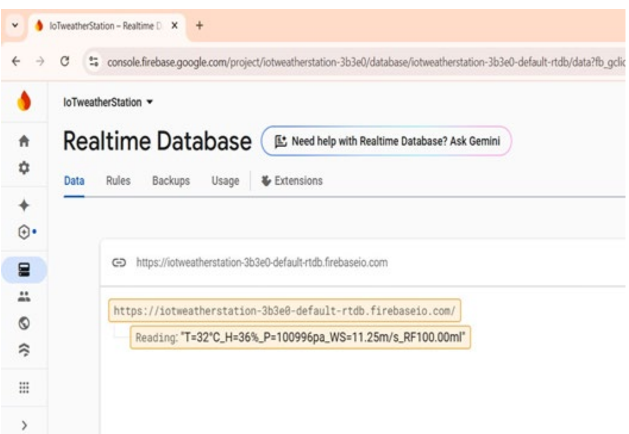

Fig. 9. Hardware result of weather monitoring system in a real-time database

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