Home-Based and Portable Smart Weather Station

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Abstract:

Weather is the state of the atmosphere to the degree that it is hot or cold, wet or dry, sunny or cloudy, or rainy. Weather generally refers to day-to-day temperature, relative humidity, and illuminance. Temperature, relative humidity, and illuminance are measured using the appropriate microcontroller sensor and monitoring them locally and remotely. The system uses Arduino (or other microcontroller) and compatible sensors to collect real-time data in indoor and outdoor environments. Its compact size and portable design allow for convenient deployment in various settings, such as laboratories and open fields, making it an ideal tool for scientific research that requires continuous monitoring of essential parameters. Researchers can maintain controlled surroundings for experiments or analyse changes in ambient circumstances with the help of the weather station, which offers valuable insights into environmental conditions. For researchers and students who need accurate environmental data, its user-friendly interface and versatility across various applications make it an essential tool. Furthermore, the system has been tested under different conditions to evaluate its effectiveness.

Keywords: Portable Weather Station, Arduino, Temperature Sensor, Humidity Sensor, Light Sensor, Sensor Calibration

1. Introduction:

Weather forecasting is the application of science and technology to predict the state of the atmosphere for a given location (Kumar, Singh, Ghosh, & Anand, 2012)[1] . People have tried, both professionally since the nineteenth century and informally for millennia, to forecast the temperature. The process of generating weather forecasts involves collecting quantitative data regarding the current state of the atmosphere in a specific location, and applying a scientific understanding of atmospheric processes to predict the future evolution of the atmosphere in that location. Others have approached this project differently (Krishnamurthi, Thapa, Kothari, & Prakash, 2015)[2]. Our method for this project stands out in several ways. The device we have created serves multiple purposes, including environmental studies, agricultural research, and

[1] Kumar, A., Singh, M. P., Ghosh, S., & Anand, A. (2012). Weather Forecasting Model using Artificial Neural Network. *Procedia Technology, 4*, 311-318. doi:https://doi.org/10.1016/j.protcy.2012.05.047

[2] Krishnamurthi, K., Thapa, S., Kothari, L., & Prakash, A. (2015). Arduino Based Weather Monitoring System. *International Journal of Engineering Research and General Science, 3*(2).

primarily educational applications. Highly sophisticated instruments require protection from external weather conditions, and we can achieve this with an innovative and portable weather/environmental monitoring system. Such monitoring systems are also highly recommended for medical purposes, although they often have a high price tag. Nowadays, electronic components are available at very low costs, allowing us to build our affordable weather monitoring system. All we need is a basic understanding of each component and fundamental knowledge of electrical principles, computer programming and the science surrounding us.

2. Literature Review:

The Internet of Things (IoT) is a system of linked computing devices, machines or objects with distinct identities and data communication capabilities across a network or Internet free from human involvement. The Internet of Things offers many applications today that help make life easier. Making an IoT product connects any physical object to the Internet or local network to collect and share data and performs some physical act according to available data. Preparing the prototype is the first step in building an Internet of Things (IoT) product (Aamer, Mumtaz, Hirra, & Poslad, 2018)[3]. An IoT prototype comprises user interface, hardware devices including sensors, actuators and processors (Mukta, Islam, Khan, & Ahmed, 2019)[4], backend software and connectivity. NodeMCU firmware comes with ESP8266 Development board/kit. Many research studies have been done using NodeNCU, and a few works are listed below.

(i) Environment Dynamic Monitoring and Remote Control of Greenhouse (Perangin-angin & Simanjuntak, 2021) (Wan, Song, & Cao, 2019)[5] designed with ESP8266 NodeMCU.

(ii) An IoT based Smart Garbage Alert System designed (Paavan, Sai, & Naga, 2019)[6] using NodeMCU.

(iii) A Very Low Cost, Open, Wireless, Internet of Things (IoT) (Kairuz-Cabrera, et al., 2024)[7] Air Quality Monitoring Platform has been designed using NodeMCU.

(iv) IOT based Smart Water Quality Monitoring System (Mukta, Islam, Khan, & Ahmed, 2019)[8] monitoring system.

[3] Aamer, H., Mumtaz, R., Hirra, A., & Poslad, S. (2018). A Very Low Cost, Open, Wireless, Internet of Things (IoT) Air Quality Monitoring Platform.

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[7] Kairuz-Cabrera, D., Hernandez-Rodriguez, V., Schalm, O., Martinez, A., Laso, P. M., & Alejo-Sánchez, D. (2024). Development of a Unified IoT Platform for Assessing Meteorological and Air Quality Data in a Tropical Environment

[8] Mukta, M., Islam, S., Khan, M. H., & Ahmed, A. W. (2019). Iot based Smart Water Quality Monitoring System

3. Research Methodology:

Environmental conditions change from time to time and vary from place to place; if we see cloudy weather, we predict it must be rainy, but after a couple of hours, it changes to sunny. In this case, we build a weather station to monitor the weather conditions from inside without leaving a couch or bed. We can train an AI model by collecting sensor data from the weather station. AI helps to tell us, visually or verbally, what real-time weather conditions are. For instance, in sunny weather, we usually use umbrellas and suncreams for strong sunny days, which have heavy amounts of solar particles like UV, which can damage human body cells. In that case, AI will strongly suggest not to go outside in the sun. In the winter season, the weather station will give the temperature and relative humidity of the weather; if it is foggy weather, we will have low temperature and high relative humidity; in that case, AI will suggest turning on the heater and fireplace or putting on some clothes.

Also, by comparing the indoor and outdoor temperature and relative humidity, we can control the lab or room's air conditioner or HVAC devices where sophisticated items are present to prevent damage. By measuring the light intensity using a light sensor, we can determine the location of the portable weather station, if it is outside in the sun or inside simultaneously, by monitoring the real-time data.

In our project, we are not forecasting the weather; we are simply monitoring the real-time weather or environmental conditions data. As we can monitor and record the real-time data, we can process and analyze those real-time and recorded data and calculate various parameters. We have also used Python to access and analyze those data.

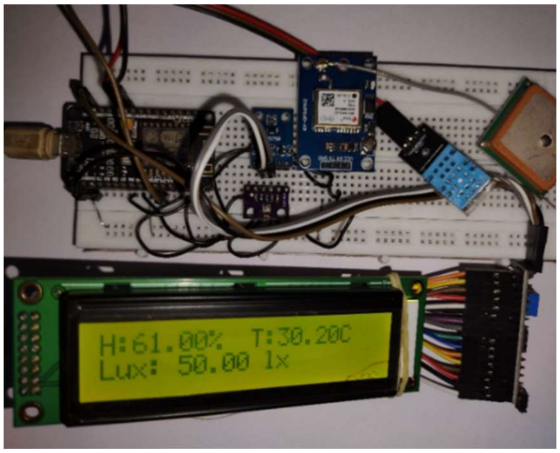
4. Research Gap:

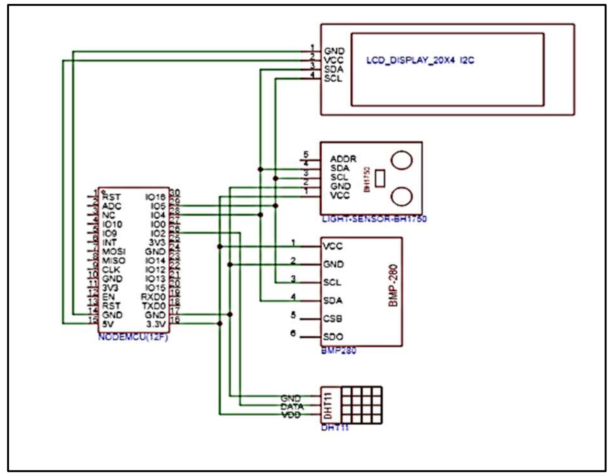
In this experiment, we have implemented Edge Computing with cloud and IOT. All the data collected from sensors and sent to the cloud (Google Firebase (Google, 2011)[9]) for further processing and relevant data is displayed on the device screen. All things are happening in real-time.

5. Experimental Setup:

We have shown the experimental setup and Schematic Diagram in Figure 1. We have given the Working Principle and data visualization with location in Figure 2 and Figure 3. After that, we have to describe the overall working of the instrument.

[9] (Google, 2011)





Experimental setup **Schematic Diagram**

Figure 1: Experimental setup and Schematic Diagram

5.1 Components:

i) NODEMCU ESP8266: The NodeMCU is an open-source development environment based on the ESP8266 chip by Espressif Systems (Espressif Systems, 2024).[10] It features the ESP-12E module with a Tensilica Xtensa 32-bit microprocessor, operating at 80-160 MHz, with 128 KB RAM and 4 MB Flash memory.

ii) DHT11 SENSOR: The DHT11 is a temperature and humidity sensor that outputs calibrated digital signals. It combines a resistive humidity sensor and an NTC temperature sensor, ensuring reliability and stability with fast response and anti-interference capabilities.

iii) BH1750 LIGHT SENSOR: The BH1750 is a 16-bit ambient light sensor that measures light in lux, ranging from 0 to over 65,000 lux. It can be calibrated for higher measurements, making it suitable for various light-sensing applications.

iv) BMP280: The BMP280 is a barometric pressure sensor ideal for mobile applications, featuring low power consumption and high accuracy. It supports I²C and SPI interfaces and operates in normal or forced modes for flexible measurement options.

v) 16X2 LCD DISPLAY: This LCD, controlled by the HD44780, shows 16 characters across two lines. With an I2C adapter, it easily connects to microcontrollers for clear output in various projects.

vi) GPS MODULE (Optional): The GY-GPS6MV2 module integrates GPS functionality, acquiring satellite signals for position, speed, and time data. It communicates via UART, facilitating

[10] Espressif Systems. (2024). *Espressif*. (Espressif Systems)

easy integration with platforms like Arduino and Raspberry Pi.

vii) Google Firebase RTDB: Firebase (Google, 2011) is a cloud-based platform by Google that provides tools for app development, including databases, authentication, and analytics, streamlining the creation of high-quality applications.

5.2 Working Principle:

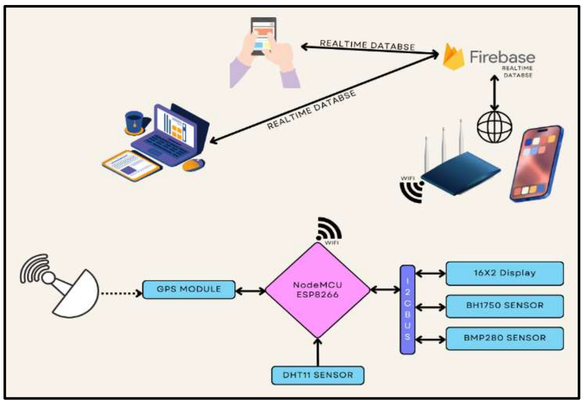


Figure 2: Working Principal

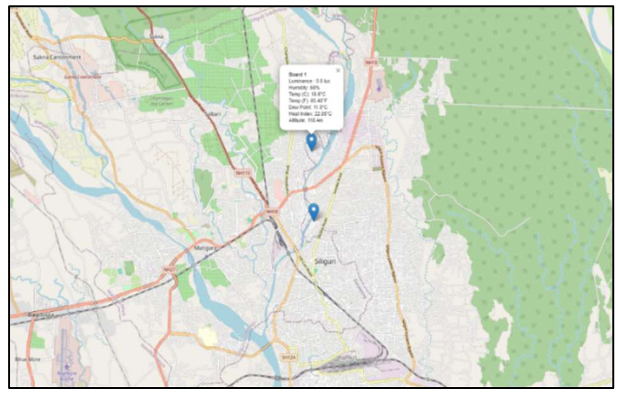


Figure 3: Data visualisation with location Leafmap via folium (Python Library)

This project utilises the NodeMCU ESP8266 (Espressif Systems, 2024)[11] to communicate with Google Firebase Real-time Database (Google, 2011) via Wi-Fi and read data from various sensors. The ESP8266 collects temperature and humidity from a DHT11 sensor, light illuminance levels from a BH1750 sensor, and air pressure from a BMP280 sensor. These readings are displayed on a 16x2 LCD screen.

The BMP280, BH1750, and LCD are connected to the ESP8266 using the I2C communication protocol. The DHT11 and other sensor data are sent to the Google Firebase database, allowing for global access to real-time data. An optional GPS module can be added to track the device's location and altitude, enabling calibration by comparing data from different sensors.

Programming is done using the Arduino IDE (Arduino, 2020)[12], which simplifies code writing and uploading to the ESP8266. After setting up Google Firebase (Google, 2011) and configuring the ESP8266 for communication, all sensor data is sent to the database. A CRUD Android app built with MIT App Inventor (Massachusetts Institute of Technology, 2012-2024)[13], fetches and displays this data in real time. Additionally, Python can be used to access the data. Built-in

[11] (Espressif Systems, 2024)
[12] (Arduino, 2020)
[13] (Massachusetts Institute of Technology, 2012-2024)

libraries are utilized to streamline programming. Experimental results from various scenarios are summarized in Tables 1-2, showcasing data collected through Arduino, Google Firebase.

6. Experimental Result (Some Data Points)

6.1 Arduino IDE serial output:

Table 1: Serial Output in Arduino IDE (GPS module Time not accurate)

Morning	After Noon	Evening
LAT: **.***** LONG: **.***** SPEED (km/h) = 0.09 ALT (min)= 114.5 HDOP = 0.81 Satellites = 8 Time in UTC: 2024/11/15,12:10:18 DHT-11 || Temp_C: 24.80°C, Temp_F: 76.64°F, Humidity: 71.00% BMP280 || Temp_C: 25.23°C, Temp_F: 81.01°F, Pressure: 1001.69 mb, Altitude: 96.86 M BH1750 || Lux: 5517.5 lx	LAT: **.***** LONG: **.***** SPEED (km/h) = 0.33 ALT (min)= 100.00 HDOP = 1.76 Satellites = 7 Time in UTC: 2024/11/16,9:20:39 DHT-11 || Temp_C: 28.90°C, Temp_F: 84.02°F, Humidity: 59.00% BMP280 || Temp_C: 29.42°C, Temp_F: 84.96°F, Pressure: 997.08 mb, Altitude: 135.49 M BH1750 || Lux: 1014.17 lx	LAT: **.*****56 LONG: **.***** SPEED (km/h) = 0.87 ALT (min)= 114.80 HDOP = 0.81 Satellites = 9 Time in UTC: 2024/11/15,12:10:18 DHT-11 || Temp_C: 28.00°C, Temp_F: 82.40°F, Humidity: 68.00% BMP280 || Temp_C: 28.36°C, Temp_F: 83.05°F, Pressure: 998.27 mb, Altitude: 125.54 M BH1750 || Lux: 59.17 lx

6.2 Retrieve the data from the Google Firebase Real-time Database using Python:

Table 2: Retrieve the data from the Google Firebase Real-time Database using Python

Morning	After Noon	Evening
Time: 2024-11-16 08:58:18.217774 Illuminance: 5517.5 lux Temperature: 24.8°C || 76.64°F Humidity: 71 % Pressure: 1001.69 MB Dew Point: 19.0° Heat Index or feel like: 25.98°C Altitude: 114.5m Location: **. ***** || **.***** No. of Satellites: 8 Speed: 0.0926	Time: 2024-11-16 14:58:47.937490 Illuminance: 1160 lux Temperature: 28.5°C || 83.3°F Humidity: 62 % Pressure: 997.07 MB Dew Point: 20.9° Heat Index or feel like: 30.83°C Altitude: 116.7m Location: **. ***** || **.***** No. of Satellites: 7 Speed: 0.03704	Time: 2024-11-15 17:44:28.154347 Illuminance: 59.17 lux Temperature: 28°C || 82.4°F Humidity: 68 % Pressure: 998.33 MB Dew Point: 21.6 Heat Index or feel like: 30.79°C Altitude: 126.4 m Location: **. ***** || **.***** No. of Satellites: 9 Speed: 0.6482

*Note: Due to security reasons, we are not showing the precise GPS locations of the place of the experiment.

Here we can see two extra parameters in Table 2, Dew Point and Heat index (Feel Like), are calculated using the formula visible in the Python terminal.

A. Dew Point: The temperature at which air must be cooled to reach 100% relative humidity and become saturated with water vapour. The dew point can be calculated from eq(I).

$$\text{Dew Point (°C)} = \text{Temperature(°C)} - ((100 - \text{Relative Humidity (\%)}) / 5) \text{ ---------(I)}$$

B. Heat Index: (Wikipedia, 2024)[14] The Heat Index (HI) is an equation combining air temperature and relative humidity to determine the (Pradhan, et al., 2013)[15] equivalent temperature experienced by humans. The heat index is a thermodynamic value that relates humidity and to air temperature. The heat index can be calculated from eq (II).

$$HI= c_1+c_2T + c_3R + c_4TR + c_5T^2 + c_6R^2 + c_7T^2R + c_8TR^2 + c_9T^2R^2 \text{ -----------------(II)}$$

Here, T = Temperature(°C), R= Relative Humidity (%), co-efficient in figure 4

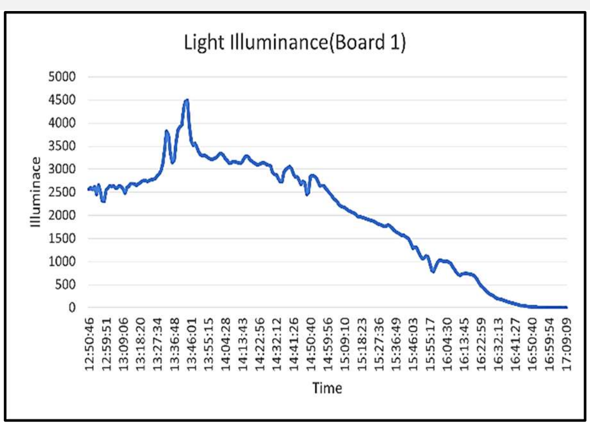
$c_1 = -8.784\,694\,755\,56,$	$c_2 = 1.611\,394\,11,$	$c_3 = 2.338\,548\,838\,89,$
$c_4 = -0.146\,116\,05,$	$c_5 = -0.012\,308\,094,$	$c_6 = -0.016\,424\,827\,7778,$
$c_7 = 2.211\,732 \times 10^{-3},$	$c_8 = 7.2546 \times 10^{-4},$	$c_9 = -3.582 \times 10^{-6}.$

Figure 4: Heat Index calculating co-efficient

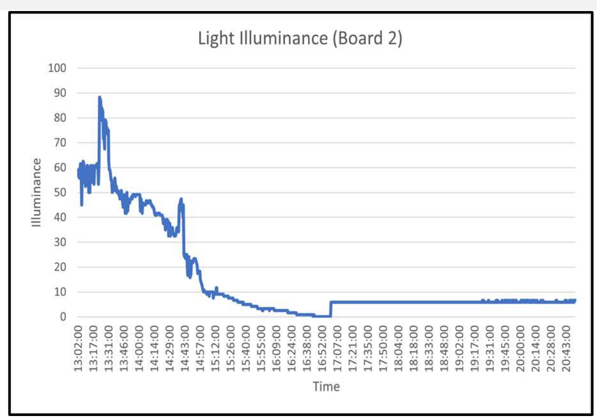
C. **Study the variation of weather parameters with time:**

Based on our collected data from the prototype boards, which have been deployed in multiple places. Also, we confined some of the relationships between light illuminance (L), temperature (T), and relative humidity (H%). In Figure 5, we show the variation of the three weather parameters with time (morning to evening). The plots clearing indicates a trend that the temperature increases as illuminance increases, but humidity decreases as illuminance increases and increases as illuminance decreases.

Board 1



Board 2



14 (Wikipedia, 2024)

15 Pradhan, B., Shrestha, S., Sthresthan , R., Pradhanang , S., Kayastha , B., & Pradhan, P. (2013). Assessing Climate Change and Heat Stress Responses in the Tarai Region of Nepal. *Industrial Health, 51*(1), 101-112.

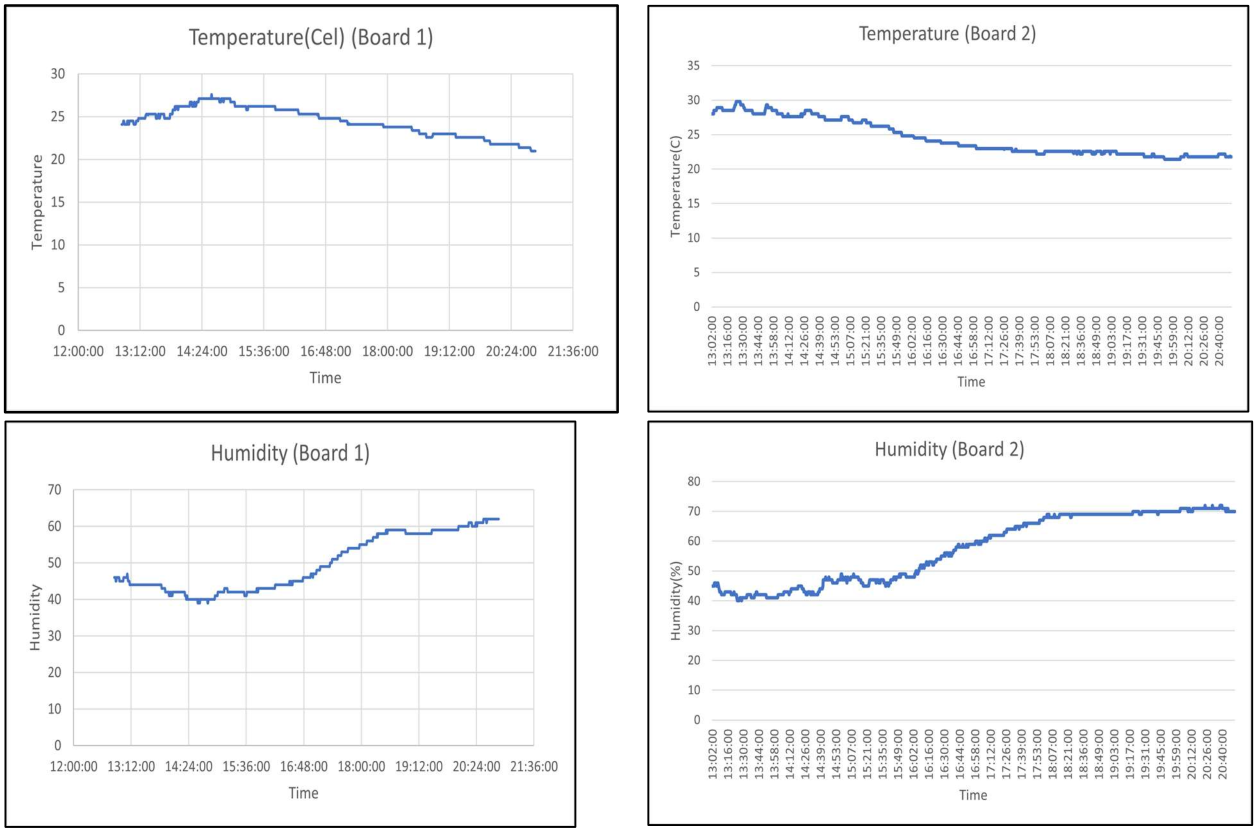


Figure 5: Variation of three Weather Parameter (date: 30/11/24) (L, T and H% with Time))

7. Conclusion and Future Scope:

In this project, we just collected real-time data from the sensor and monitored weather conditions via local display and remotely via mobile app or laptop. Still, the results are not recorded; we can only view the results.

We plan to record the weather data in different locations. Moreover, AI (artificial intelligence) can be trained to predict the weather. The first simple AI would be the following: Do we need an umbrella or shade based on weather conditions? Here are some examples:

7.1 Depending on the Sun light exposures:

i) We might need shade Between 10K – 20k lux (Shorter Exposures).

ii) Above 20k lux means strong direct sunlight and an umbrella is required.

7.2 Humidity alone does not guarantee rain, but some high relative conditions:

(i) Above 70% -80% relative humidity suggests the air holds significant moisture, making rain more likely if other conditions, like low pressure or cooling, occur.

(ii) 90% or Higher Relative Humidity: suggests rain, significantly when temperatures drop or a front move in, increasing the chances of condensation and cloud formation.

7.3 Humidity and temperature together can create some scenarios:

High 70%-80% relative humidity and low temperatures (below 14 degrees) can suggest wintertime or foggy weather; it is cold outside.

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