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Performance Analysis of Low Cost Mobile Weather Station

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***Abstract*—Climate monitoring is crucial for agriculture and research but often the data we have is not that accurate and there are gaps which reduce the efficiency of climate monitoring. This project aims to reduce the gap of the disparities between the data collected from the satellites and real time data for parameters such as temperature, rainfall, humidity, air index and pressure. Multiple sensors have been incorporated in this cost efficient, portable weather station while keeping in mind that this project is specifically catered towards remote areas with limited infrastructure.**

***Index Terms*—BMP - 180, Cost Efficient, DHT - 22, ESP - 32, MQ - 2, Sensors, weather station.**

I. INTRODUCTION

In India, the practice of weather monitoring date back to the Vedic period, where ancient texts discussed seasonal cycles resulting from the Earth's movement around the Sun, as well as cloud formation and rainfall. Weather changes greatly influence human activities such as agriculture, fishing, shipping, and military operations. Agriculture remains the backbone of the Indian economy, supporting the livelihoods of numerous farmers from various regions. However, many of them lack the necessary resources to assess unpredictable weather patterns. Understanding weather conditions is also vital for healthcare, as it aids in disease prevention and management

This project creates an innovative solution which is designed to be portable and functional, designed to help farmers and researchers with real time and accurate weather data. In a world where climate monitoring has become so crucial, and where there is a constant change in the weather, monitoring and recording weather parameters had become a need that cannot be ignored. Traditional weather stations are often very expensive and stationary which makes it inaccessible for the common people. This project addresses this problem and aims to make weather monitoring more affordable and accessible especially in remote areas where range is often a problem.

Now, weather satellites play a crucial role in weather monitoring and help provide important data on various atmospheric parameters. They provide with global coverage and advanced imaging but even with all these features, on ground weather monitoring is highly crucial. With on ground weather monitoring, we can have access to localized data and detailed measurements. To resolve this exact issue, we have tried to create a portable weather station. Now, the question arises, what exactly is a weather station? A weather station is a device that is designed to measure weather parameters such temperature, humidity, pressure and air index with the help of various kinds of sensors.

The concept of weather station can be traced back to ancient times but the most modern date that we have is the 17th century. This was thanks to the invention of barometer by Italian scientist Evangelista Torricelli in 1643.This was a simple device which consisted of a glass tube filed with mercury. Fast forward to the 18th century, Danish astronomer Ole Rømer developed the first mercury-in-glass thermometer which enabled somewhat accurate readings. Around this time, English meteorologist Thomas Romney Robinson introduced the cup anemometer in the mid-18th century, which was capable of measuring wind speed. In the 19th century, Telegraph was popularized which revolutionized weather data transmission, allowing meteorologists to gather and share data more quickly. In the 20th century, thanks to digital revolution, the advent of digital technology transformed weather stations from analog devices to sophisticated digital systems which made use of advanced sensors and data loggers to provide better readings while also making data transmission easily possible.

This project incorporates multiple sensors, an Arduino Uno, ESP-32, LCD screen to bring together a weather station that is both portable and affordable while delivering accurate readings and being easy to use.

II. LITERATURE REVIEW

Traditional weather stations are usually fixed in one place and rely on complex infrastructure, which limits their use in remote or mobile settings. To address this, one of the prominent studies [1] has developed a portable weather station that uses Wi-Fi to ensure connectivity to monitor various weather parameters

and send data wirelessly. This makes data transmission much more convenient and also their system also makes use of the NodeMCU Wi-Fi module, which enables easy data transmission.

Adding to this, research [2], created an Arduino-based weather station, which was affordable and easy to use. Their system efficiently captured temperature and humidity data, proving reliable for remote areas. The scope was further expanded by [3] with the use of a Raspberry Pi-powered station, adding pressure monitoring but then affordability took a back seat as the cost of the project was quite high.

Another study [4] introduced a microcontroller-based model, which provided data accessibility but this system compromised on adaptability. One of the key research[5] designed an IoT- based weather station that could connect multiple sensors to a network. Similarly, another study [6] introduced a low-cost, mobile Arduino-based weather station which could monitor parameters in mobile areas. Together, these studies highlight the impact of IoT and embedded systems in meteorological data collection.

High-performance computing (HPC) is important weather monitoring. Many researchers have been trying to find ways to make HPC more efficient. One research [7], developed a portable Raspberry Pi-based HPC cluster, offering cost efficient replacement to usual supercomputers. Meanwhile, [8] introduced a cloud-based HPC model, which was a scalable and low-cost solution. One research [9], introduced a hybrid HPC model, that combined cloud storage to weather monitoring which was a great solution. The hybrid approach improved the scalability of the system.

Another study [10] created a budget-friendly local weather station, made to improve environmental data collection using affordable sensors. Not like the models before, their system provided measurements that were better and supported real-
time data sharing, addressing limitations found in solar-powered stations such as those by [4]. Similarly [5] developed a weather station, that combined low-cost sensors to measure a wide range of parameters, including temperature, humidity, pressure, wind speed, precipitation.

III. METHODOLOGY/EXPERIMENTAL

1. COMPONENTS AND MATERIALS:

- DHT-22: The DHT-22 sensor helps measure temperature and humidity. It is easy to connect to a microcontroller and can measure temperature from -40 Celsius to 80 Celsius. It needs less amount of power and provides proper readings.
- MQ-2: The MQ-2 sensor helps detect a different type of gases such as methane, hydrogen and carbon monoxide. This sensor is highly sensitive because it contains tin oxide that reacts fast with gases.
- BMP-180: The BMP-180 sensor measures atmospheric pressure, temperature, and altitude. Because of its accurate readings, it is a popular choice for various electronic projects. It is very often used in projects based on weather monitoring and environmental research.
- ESP-32: The ESP-32 is a microcontroller that has a built-in Wi-Fi and Bluetooth module, making it great for a vast range of wireless applications. This micro-controller is known for its low power consumption and ease of use as it allows wireless Wi-Fi connections.
- LCD screen: An LCD screen is a widely used 16 x 2 display which works on low power and can be controlled by a parallel I2C module.
- Additional components: Aside from all these materials, this project makes use jumper wires and a breadboard along with a physical model to protect the weather station from any external damage.

Fig. 1.

2. Circuit Diagram and Software

1. Circuit Diagram:

To bring all these sensors together, we took help of

Tinkercad to help create a circuit diagram and test whether it could actually work.

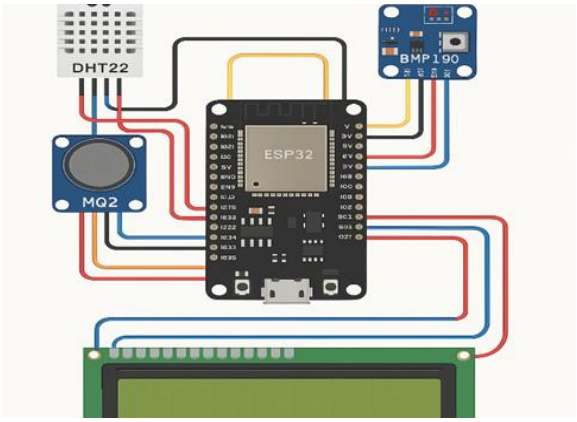

Fig. 2.

As the above diagram suggests, all the sensors have been individually connected to the ESP-32 and then have been put together. All the individual codes for the sensors have to be calibrated together for the weather station to actual function. As we can see from the above circuit diagram, we require multiple sensors to incorporate this weather station.

2. SOFTWARE:

This project combines the use of the ESP-32 microcontroller with the robust data analysis capabilities of the Thing Speak module to create a mobile weather station. The Arduino IDE helps with, programming and managing a wide range of sensors, allowing the users to gather accurate data on temperature, humidity, pressure, and other weather conditions. By integrating Thing Speak, it widens the scope of the project because of the system's capabilities to track and log real-time data visualization, analysis, and cloud storage. The combination of Arduino IDE and Thing Speak creates an affordable weather station which helps deliver valuable insights and data for monitoring the environment and forecasting weather.

Thid Thing Speak model makes weather data accessible from anywhere in the world. Such accessibility makes the system highly useful for practical applications and educational purposes alike. Additionally, we have ensured that the real-time sensor data is automatically recorded into a worksheet, facilitating easy tracking and further analysis.

IV. RESULTS AND DISCUSSIONS

This portable weather station was successful in measuring various weather parameters and the results were further integrated on Thing Speak IOT platform.

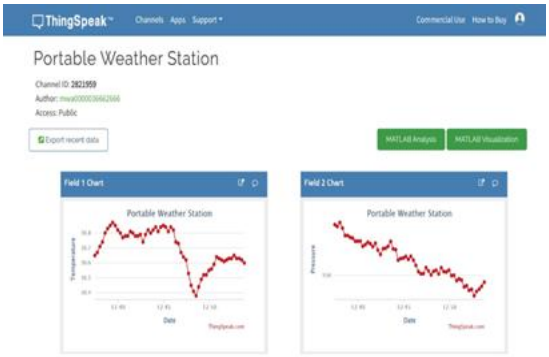

Fig. 3.

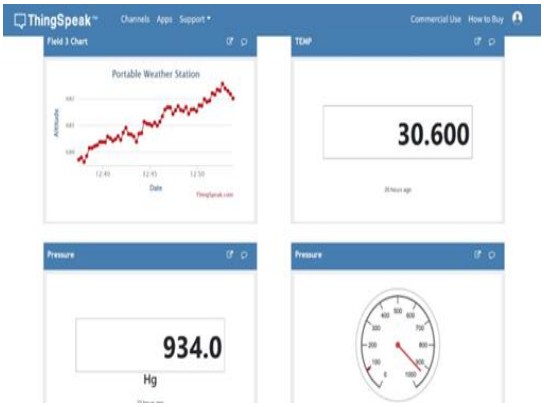

Fig. 4.

Temperature Calculations:

DHT22 provides temperature in °C, but we need to convert it to Fahrenheit:

$T\_F = (T\_C \times 9/5) + 32$

Relative Humidity:

Dew Point Calculation (Approximate formula):

$DP = T - (100 - RH)/5$

$DP = (b \cdot \alpha)/(a - \alpha)$

$\alpha = (a \cdot T)/(b + T) + \ln(RH/100)$

Pressure:

BMP sensor provides pressure in Pascals (Pa), conversion required:

$P\_hPa = P\_Pa / 100$

$P\_mmHg = P\_Pa \times 0.00750062$

Altitude Calculation:

Given pressure P at current altitude:

$h = ((P_0 - P) \times T) / (g \times M)$

$h = 44330 \times (1 - (P/P_0)^{0.1903})$

The below table shows that readings from this weather station are more accurate than the conventional ones.

TABLE I

Parameter	This Weather Station	Actual Weather Station
Temperature (°C)	28.8	29.1
Humidity (%)	62	64
Air Quality (ppm)	180	175
Pressure (hPa)	1008	1010

V. FUTURE SCOPE

The future of portable weather stations is full of possibilities, shaping the way we track, predict, and respond to weather conditions in everyday life and across various industries. As technology evolves, these compact devices will become even more essential, making weather data more accessible, accurate, and impactful.

In environmental monitoring, improvements in sensor technology and connectivity will help provide real-time insights into climate patterns, air quality, and pollution levels. This is important for researchers studying climate change, as well as communities looking to improve their local environment. Farmers, for example, will benefit from more reliable weather forecasts, helping them make informed decisions about planting, irrigation, and harvesting, ultimately improving crop yields and reducing weather-related risks.

Weather stations will also play a vital role in disaster management, providing live updates during hurricanes, floods, and storms, which can help authorities make faster and more effective decisions, potentially saving lives and minimizing damage. In industries like construction and energy, access to real-time weather data will help teams plan better, ensuring safety and efficiency while working in unpredictable weather conditions.

With the boom in AI and ML, it is possible that future models will integrate these which will take weather monitoring to the next level. Portable weather stations are now becoming a necessity thanks to their ability to provide localized data. Continued advancements will play an important role in ensuring safety, efficiency, and climate awareness all around the world.

VI. CONCLUSION

This project was successful in developing low-cost mobile weather station that shows proper readings of temperature, humidity, pressure and air quality. Through testing, the device showed performance comparable to existing weather stations on the market. Adding to that, its affordability and portability make it a practical solution for a wide range of applications, especially in remote areas

This research was important as it helped understand the gap between localized weather and the weather that is usually detected. Weather is very unpredictable and therefore there is a need for proper resources to keep track of it. By making weather data more accessible and available, this device encourages research and development.

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