Design and development of autonomous ground-level weather monitoring station

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ABSTRACT Weather is one of the important factors influencing human daily activities. Not only that, weather also influence societal progress and industries such as agriculture. In general, traditional weather station relied on manual equipment to measure weather parameter. However, the modernization of technologies has introduced personal and professional weather station. Nonetheless, recent technological advancements have introduced long-range personal weather station, but the reliance on Wi-Fi limits the access to weather data in areas with poor internet coverage. In addition to this limitation, some of these weather stations may require manual data storage, such as using memory cards, which can prevent users to have access to weather data remotely. Furthermore, certain weather stations may utilize bluetooth as an alternative communication method. However, bluetooth short-range nature can restrict remote access to weather data, presenting challenges in scenarios where users need data from a distance. Meanwhile, for extended data collection in remote, unattended locations or small areas like a greenhouse, professional weather station may introduce inherent inaccuracies due to the fixed locality limitation whereby the location of the professional weather station may be located far away from the user location of interest. Thus, installing multiple automatic weather stations to increase accuracy can be costly. In this paper, an autonomous ground-level weather monitoring station has been built integrating sensors, microcontrollers and software to provide a real-time and reliable weather data as well as the location of the weather station for users. This prototype integrates LoRa technology as the communication medium between the transmitter and receiver. Additionally, this prototype also uses a custom monitoring software to complement the weather station for data processing and visualization thus, catering to both personal and professional needs. Hence, the test was conducted to verify the workability of the overall system. It was found that the transmitter of the weather station was able to transmit weather data wirelessly to the receiver. Simultaneously a custom monitoring software were able to visualize and log the real time data thus providing users with an insight of the current and past weather condition.

KEYWORDS: Weather monitoring; Weather; LoRa technology; Real-time weather data; Data visualization

Received 27 October 2023 **Revised** 24 December 2023 **Accepted** 27 December 2023 **Online** 31 December 2023

Original Article

INTRODUCTION

Before the rise of cutting-edge technology, the only approach to collect information on outdoor activities is by direct observation (Brasser *et al*., 2018). Correspondingly, this approach is also applied to monitoring environmental condition such as the weather. Weather is referred to as the current state of the atmosphere at a given time and location (Torres Puentes, 2019). Whereby, the ever-changing conditions of the weather is mainly influenced by the sun, water and wind which in return has an enormous influence on human activities (Murdyantoro *et al*., 2019). Weather also serves as one of the important key determinants of how a community progresses at a given geographical location. With that in mind, it is worth emphasizing that weather also plays an essential role in facilitating the growth of industries (Pauzi & Hasan, 2020) such as agriculture. This, in turn can indirectly contributes to meeting the rising demand for agricultural product caused by the increasing world population.

In the context of monitoring the weather condition, a device such as a weather station that can gather information related to the weather condition is necessary (Murdyantoro *et al*., 2019). In the earlier times, weather stations utilized manual weather equipment to obtain weather information which according to Trivedi & Mistry (2012) a manual or men monitored weather station would be kept at a location and then utilized for weather analysis and forecasting purposes. However, given that weather is very influential towards human activities therefore, there are numerous existing weather stations that are currently available which can be categorized into personal weather stations which is commonly used by public users for personal purposes such as planning their outdoor activities and professional weather station such as the weather station owned by the Malaysian Meteorological Department which were used to forecast and provide weather information to airlines and other various sectors such as construction and agriculture.

In recent times, the remarkable strides in technology have introduced wireless personal weather station, that allows users to access weather data away from the weather station itself (Brasser et al., 2018). However, these types of weather station mostly depend on Wi-Fi as their communication medium to provide weather information to users. This dependency can lead to complication when utilized in a remote area with limited to no internet coverage, potentially caused accessibility problem to users without reliable internet connection. Additionally, the reliance of the weather station on the internet coverage to record and display weather data could face disruption when there is no internet coverage available at the receiving end, preventing the collection of data. Apart from that, this type of weather station may also require an additional data storing medium such as a memory card that requires users to manually download the weather data from the memory card before they can view it, also preventing users to have access to weather data remotely.

In addition to that, some personal weather stations also employ bluetooth as a communication medium. However, bluetooth technology typically operates within a relatively short-range (Đorđević & Danković, 2019), making it suitable for local connections but impractical for remote access to weather data. This limitation means that users must be in close proximity to the weather station for data retrieval, and it may not be a viable solution for remote or unattended locations where users require access to weather information from a distance. Hence, relying solely on Wi-Fi and bluetooth can pose challenges and limitations that needs to be addressed to ensure effective weather data logging processes and reliable access to weather data.

Furthermore, in situation where weather data is required for extended period of time in a remote unattended location or small areas such as the greenhouse or an off-grid renewable energy power plant. Utilizing weather information reported using a professional weather station can introduce inherent inaccuracies and this is because professional weather station can only collect large amount of useful data from one particular locality but precision remains limited at that particular location. Often, this type of weather station may be positioned far from user's location of interest, potentially causing the weather data in that area to be different from the data reported by the meteorological department. Not only that, but in order to install multiple automatic weather station (AWS) such as the AWS owned by the Malaysian Meteorological Department with the aim of increasing the accuracy of the weather data can be very costly whereby the cost may increase with the number of parameters that can be measured. Hence, this type of weather station is uneconomical for application in small or specific area.

In this paper, an automated weather monitoring station was developed and tested to verify the workability of the overall system in measuring weather condition at ground level as well as the functionality of the monitoring software prioritizing navigational convenience for end users. In short, the transmitter contains multiple sensor which responsible to measure weather parameter. These sensors are connected to a microcontroller which responsible to collect and send the data wirelessly to the receiver. Thus, the data will then be stored and displayed by using the monitoring software. Hence, this project enables users to have access to real time, cost effective and reliable weather data away from the weather station.

METHODOLOGY

The prototype described in this paper aims to provide real-time and reliable weather data while simultaneously upholding its cost-effectiveness and self-sufficiency. The prototype basic operation can be summarized as shown in Figure 1 whereby the weather data that was measured and sent by the transmitter to the receiver wirelessly includes the wind speed and direction, surrounding temperature and humidity, sunlight intensity, atmospheric pressure, amount of rain as well as the location of the transmitter. Meanwhile, at the receiver the data received was parsed and display at the monitoring software. Further elaborations regarding the transmitter module, receiver module and the monitoring software are presented in the subsequent section of this paper.

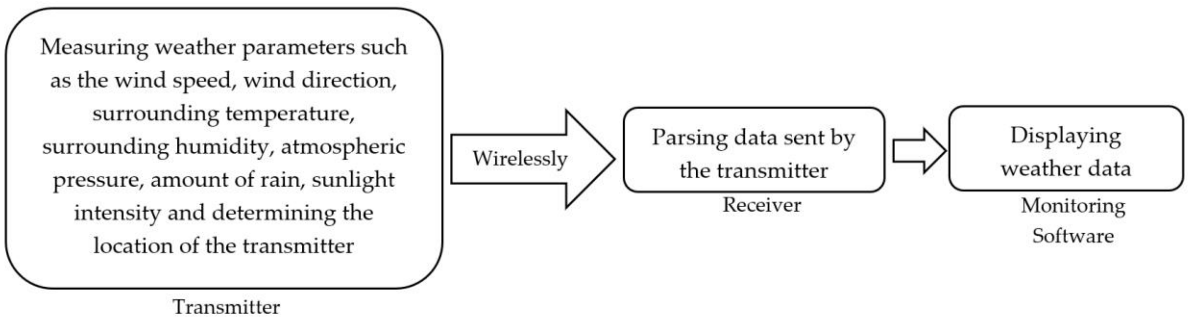
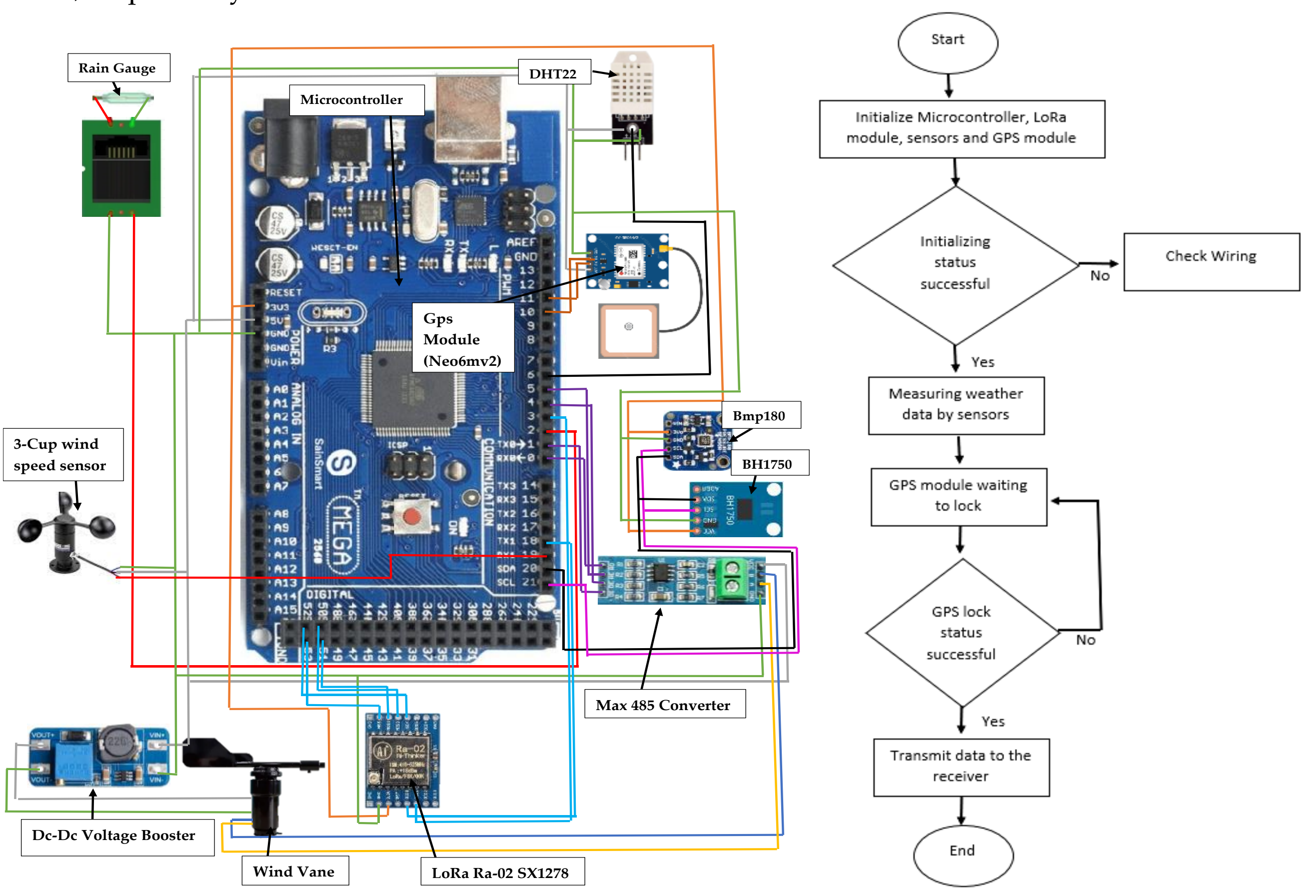


Figure 1. Flowchart showing the prototype basic operation

The Transmitter Module

The primary task of the transmitter module is to collect weather data measured by the sensors, and the schematic diagram together with its algorithm, and the actual photo is shown in Figure 2 and 3, respectively.



(a) Circuitry design (b) Microcontroller algorithm

Figure 2. Illustration of the design overview of the transmitter

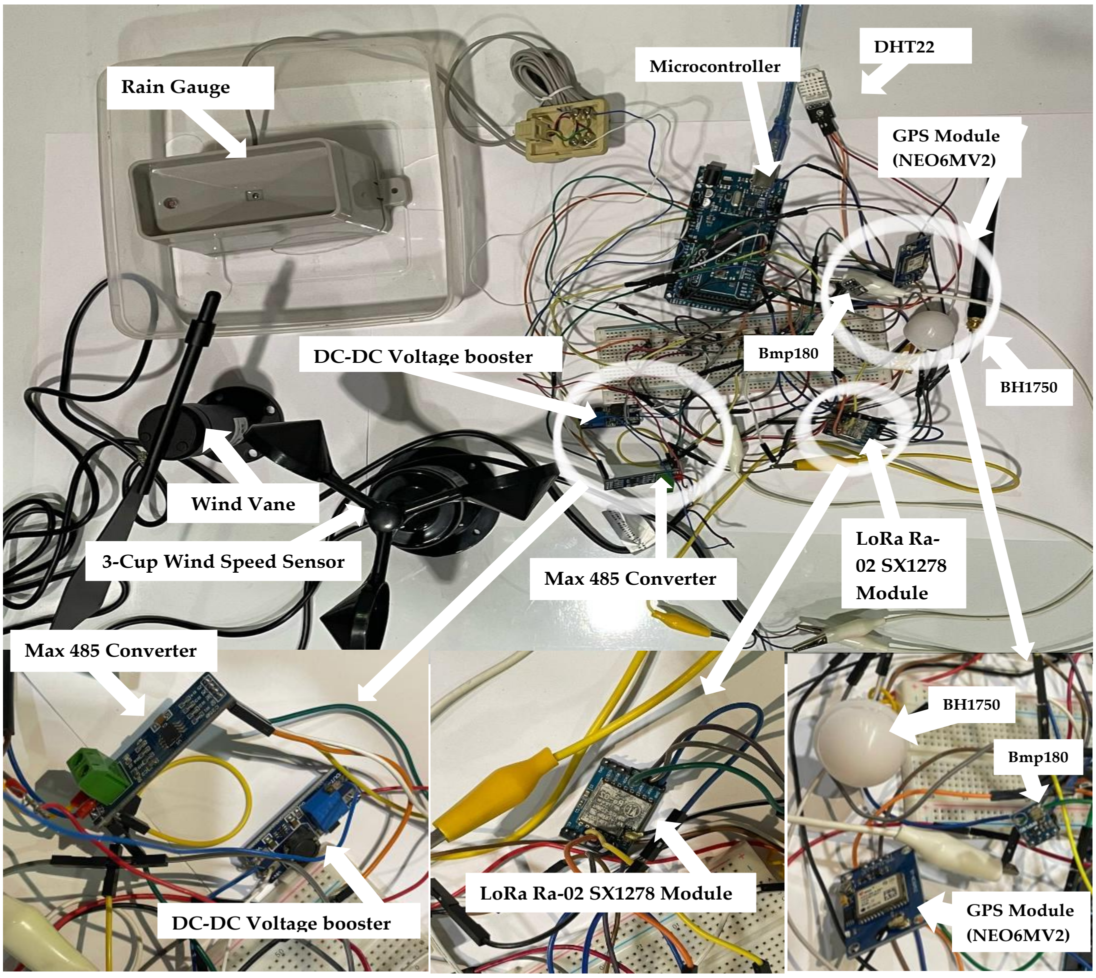
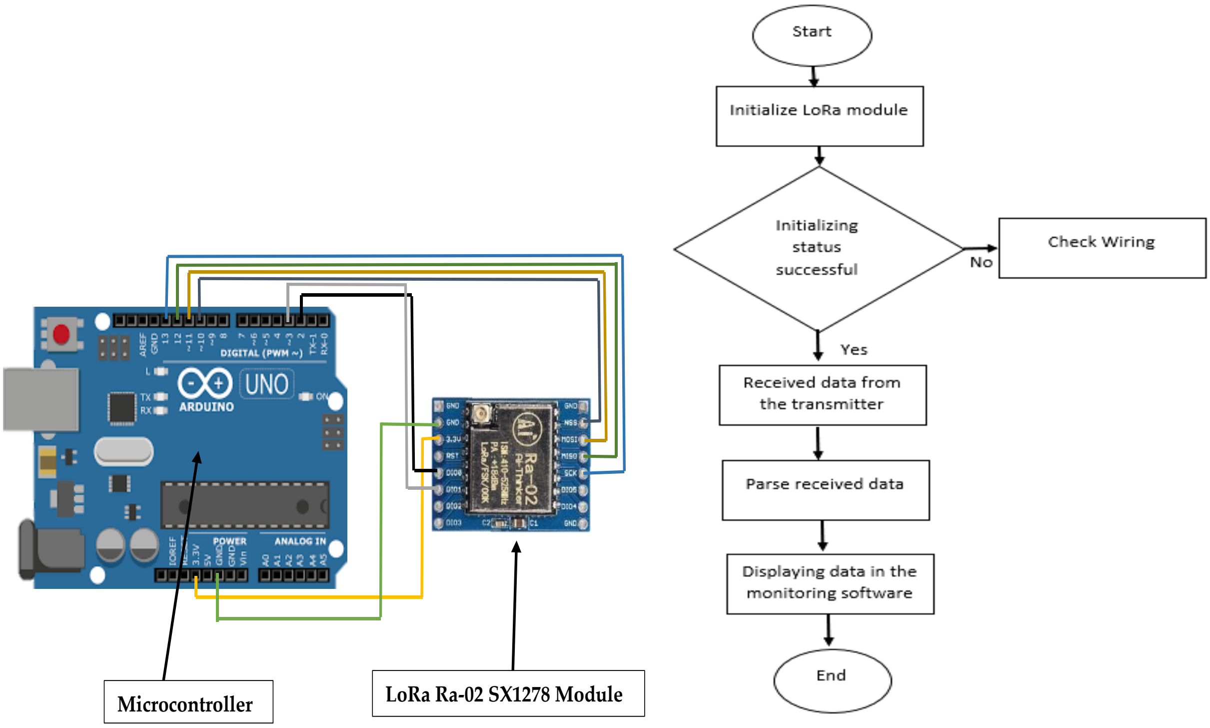


Figure 3. Photo showing the actual circuit configuration of the transmitter including all associated sensors and modules

DHT22 is used to measure surrounding temperature and humidity whereas a 3-cup wind speed sensor is used to measure wind speed and a wind vane determines the wind direction. The system is further equipped with a rain gauge to quantify rainfall, a BMP180 sensor for atmospheric pressure, and a BH1750 sensor for sunlight intensity. A GPS module is used to identify the location of the transmitter. All of the sensors and the GPS module are connected to Arduino Mega microcontroller. The weather data collected by the Arduino Mega is transmitted to the receiver through a LoRa module which is also connected to the Arduino Mega. Prior to transmission, a computer algorithm is used to arrange all the data into a format that allows the monitoring software to interpret the data and an ID was assigned to enable the receiver to receive and parse the data followed by displaying it in the monitoring software.

The Receiver Module

At the receiving end, a LoRa module was connected to a microcontroller namely Arduino UNO. This LoRa module function to receive the data from the transmitter. The microcontroller was programmed to assigned the LoRa with an ID that matches the ID of the data sent by the transmitter. This allows the receiver to detect the transmitted data. Upon receiving the data from the transmitter, the data was parsed to enable the monitoring software to display the received data thus, allowing it to function accordingly. Figure 4 illustrates the design overview of the receiver which consist of the circuitry design of the receiver (Figure 4(a)) and Figure 4(b) shows the computer algorithm within the microcontroller of the receiver as well as Figure 5 the actual circuit configuration of the receiver.



(a) Circuitry design (b) Computer algorithm

Figure 4. Figure showing the schematic diagram and computer algorithm of the receiver

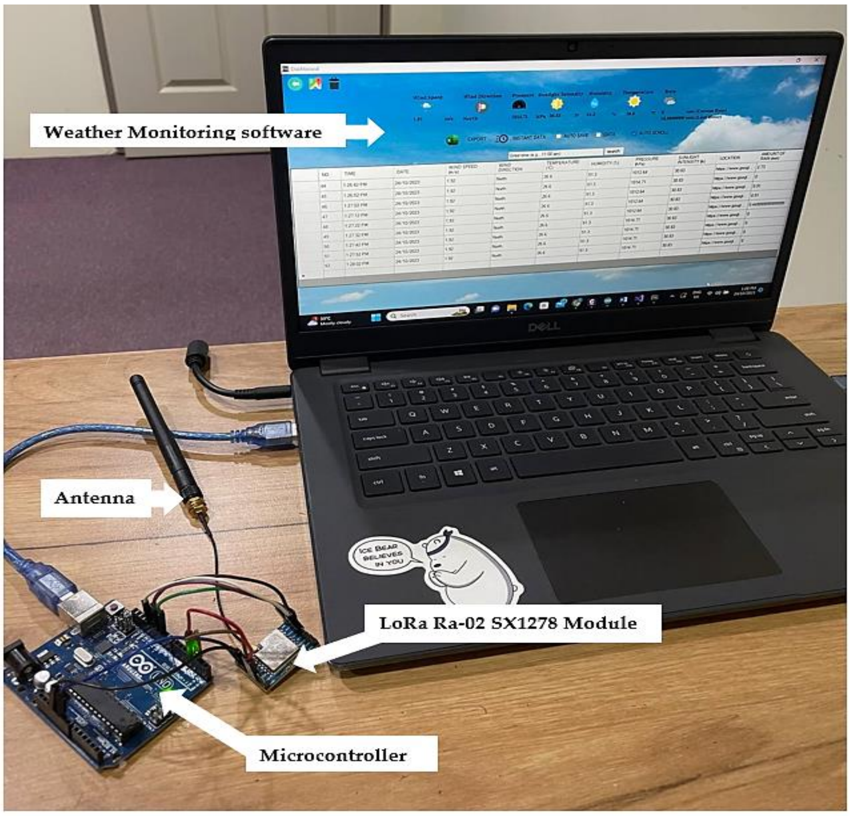


Figure 5. Photo showcasing the actual circuit configuration of the receiver

The Weather Monitoring Software

The prototype presented in this paper introduces a standalone monitoring software, customized to complement the weather surveillance system. As part of the system set up, the receiver is interfaced to a laptop that hosted the monitoring software via a USB port. The monitoring software was designed using a VB.NET programming language. This custom software integrate feature to enhance the weather monitoring experience.

Upon successfully receiving the data from the transmitter, the monitoring software captures and interprets the data. The software converts the raw data into a visual representation that provides real-time insight of the current weather condition utilizing its user interface design. Simultaneously, the software also performs the logging process for the weather data. This feature ensures the immediate availability of a real time weather data for user while also enabling user to access previous weather data through its data archive.

Not only that, the monitoring software also equip with feature that enable users to export the data to a Microsoft Excel file. In line with that, feature to enable faster export of large data was also programmed in to the software. Other than that, automatic saving feature was also introduced to enable data to be automatically exported. Additionally, to prevent overload of weather data, this software also incorporates an alternative logging mechanism. The mentioned mechanism allows approximately 20 minutes between logging which allows the software to regulate the volume of data per day.

This software is integrated with Google Maps feature, which can provide users the location of the transmitter. However, in cases where internet coverage is unavailable, the Google Maps link can be retrieved by using the software even in an offline state. This link can be used to locate the transmitter by using a mobile phone or when the internet coverage is restored.

RESULT AND DISCUSSION

As previously mentioned, a test was conducted to verify the workability of the overall system and the functionality of the monitoring software that aims to provide users with navigational convenience. In this context, the transmitter was placed outdoor at Penampang, Sabah (coordinates: 5.9271, 116.0760) to measure the weather condition in real-time. The measured data was transmitted wirelessly to a receiver located indoor alongside a laptop which hosted the monitoring software. Upon successful execution of the software, users will be presented with the home page, as shown in Figure 6.

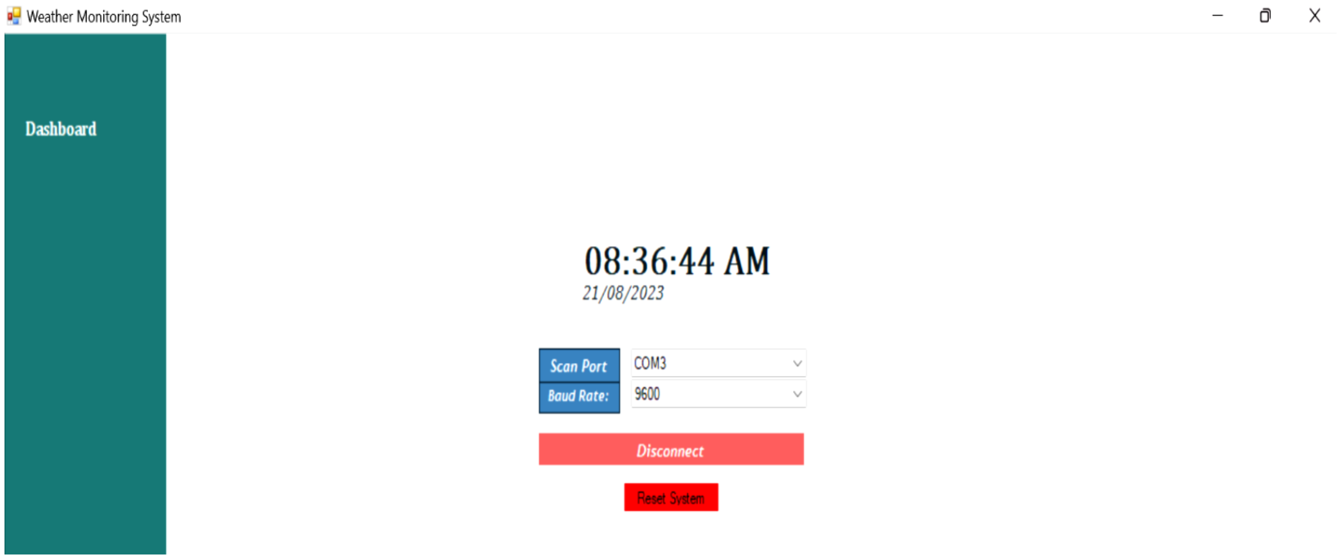


Figure 6. Front page of the weather monitoring software.

Upon successful transmission, real-time data are displayed in the monitoring software as shown in Figure 7. As shown, the time and date stamps shown in Figure 7 are correctly displayed and all the weather data fall within acceptable limits in reference to the actual weather condition. Furthermore, it is important to note that simulated rainfall was employed to demonstrate the functionality of the rain gauge.

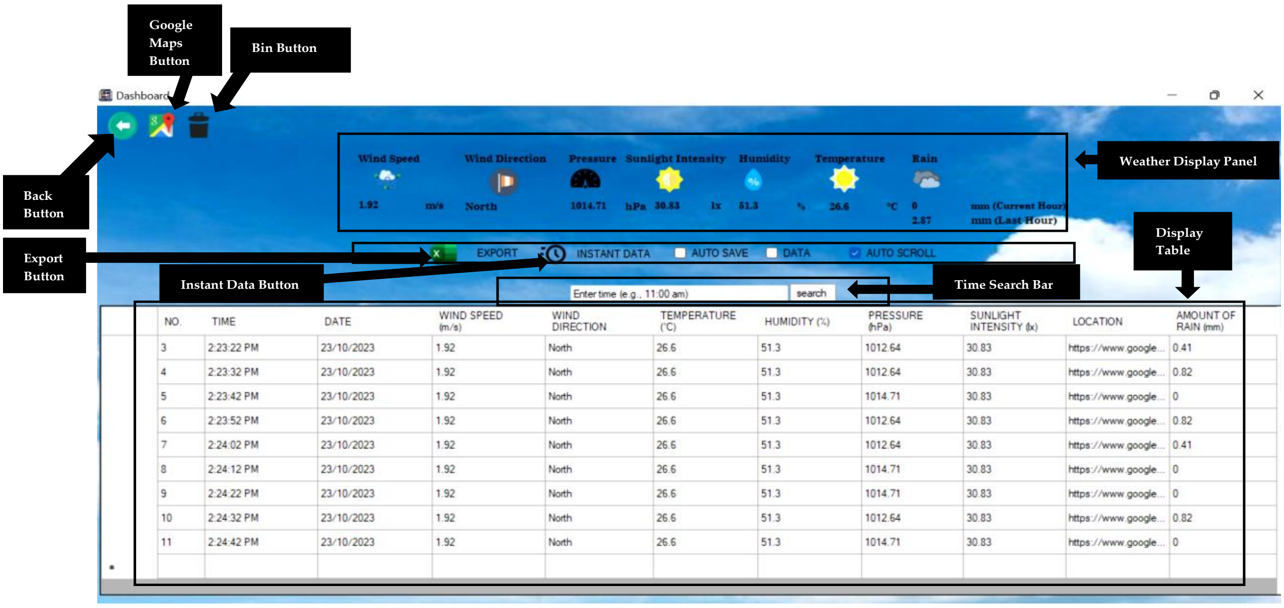


Figure 7. The dashboard view with a real time weather data of the monitoring software upon successful transmission

Figure 7 also shows a number of button and each was assigned with a specific function. Notably, the back button allows the dashboard to return to the home page and Google Maps button allows Google Maps to display the location of the transmitter via an internet browser as shown in Figure 8. Meanwhile, the bin button functions to clear the display table. In line with that, there are buttons designated for data export, namely the export data button and the instant data button. The export data button facilitates the export of log data to Microsoft Excel, while the instant data button allows users to export large amount of data instantly to Microsoft Excel.

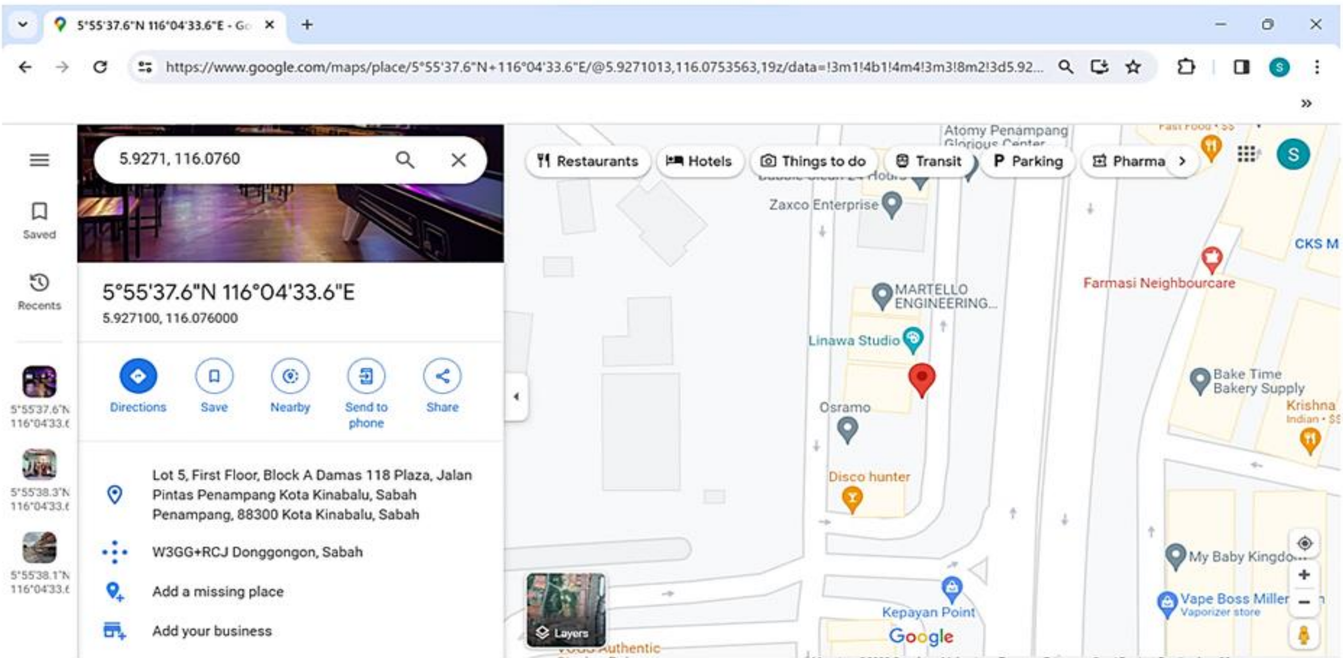


Figure 8. Figure showing the location of the transmitter with Google Maps via a web browser

CONCLUSION

In this paper, an autonomous ground level weather monitoring station was designed, fabricated and tested. This prototype utilizes various sensors and modules to collect data and wirelessly transmitted the data to a receiver which is then displayed in a monitoring software. This paper has shown the workability of the overall system upon successful transmission of the weather data to the receiver via LoRa. Also, it shown that the monitoring software developed in this project has enhance the value of the weather monitoring station beyond its role as a mere data presentation tool. The monitoring software not only convert complex data into user friendly visualization benefiting the end users but also providing an insight of the past weather condition which can be utilized for research purposes.

ACKNOWLEDGEMENTS

This research was funded by Universiti Malaysia Sabah Post Graduate Research Grant Scheme (UMSGreat) Number GUG0552-1/2022.

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