Investigation of the Production and Acquisition of Data in an Automated Weather Observation Station

Students: **<u>Ho,Tsung-Han</u>**

Teacher: <u>Shih,Feng-Hsi</u>

School: Mingdao High School, Taichung

Country/Religion: Taiwan Relationship

6th, March, 2024

Abstract

In our school's GLOBE Program, the weather observers usually have to go to the weather station for observations and manually record the data. However, the location of the weather station on campus is remote, and the observation time is limited. Therefore, creating a low-cost automated weather observation station can improve the continuity of data collection and eliminate the need for manual record-keeping. This study utilized a DHT11 temperature and humidity sensor connected to an ESP32 microcontroller, which transmitted the data over the internet. The results of the study showed consistency in the temperature and humidity data between the MDSH Site and the Wuri Site of the Central Weather Bureau, while also explaining possible reasons for the differences observed. In the future, the device used in this study will continue to be used for observing the microclimate on the campus.

Research Motivation

The weather observers on our campus usually have to travel to a distant weather station in the campus area to record environmental weather data and manually upload the data. Moreover, the observation is limited to a one-hour window from 12 PM to 1 PM. Although the observation time is only one hour, the inconsistencies in observation times can introduce errors when using this data for long-term research. Additionally, due to the small number of campus observers and no classes on holidays, observations may not be conducted every day, resulting in a lack of data for research and an excessive number of variables.

Research Objectives

The objective of this study is to create an automated weather observation station and place it in a fixed experimental location. The aim is to achieve automation, improve data accuracy, and address error correction, improvements, and reviews.

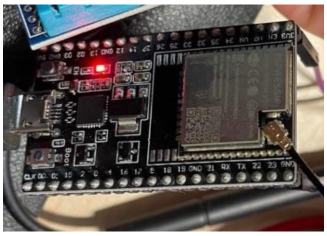
The automated weather observation station developed in this study aims to minimize costs by requiring only a portable power source, an internet microcontroller, and a temperature and humidity sensor module. The process involves programming the microcontroller, configuring the remote observation website, and setting up the station with the campus GLOBE PROGRAM and wireless network. The automated weather observation station will regularly upload data to the internet, generating a timeline table of temperature and humidity changes. This will enable remote observation and automatic recording of a large amount of data.

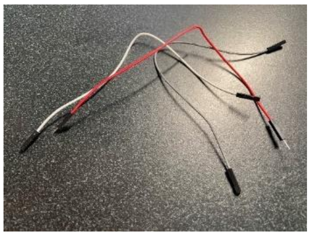
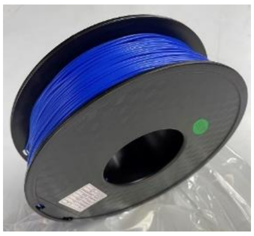
The following tasks are expected to be completed in this study:
A. Automatic scheduled data recording
B. Automatic data upload to the internet
C. Remote observation of campus temperature and humidity changes

Research Equipment

The hardware used in this study consists of readily available devices in the Taiwanese market. The models, features, and appearances of these devices are described below (Table 1).

Table 1:Hardware Equipment

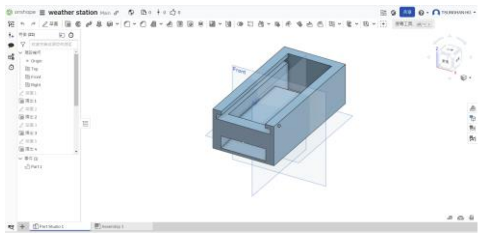
model	feature	picture
ESP32 System-on-Chip (SoC)*1	The ESP32 is a low-power and cost-effective microcontroller that integrates networking and Bluetooth capabilities. It is highly suitable for projects involving wireless devices or	

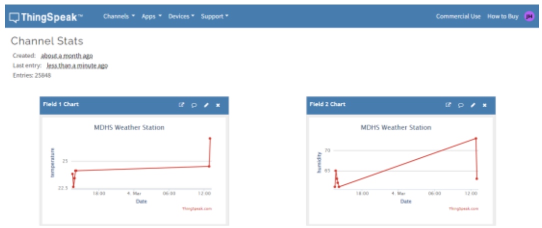
	internet connectivity due to its low cost and convenience.	
DHT11 Digital Temperature and Humidity Sensor*1	The DHT11 digital temperature and humidity sensor is a composite sensor with calibrated digital signal output. It can directly output data in digital format and is compatible with applications using Arduino UNO and ESP32 microcontrollers.	
Jump wire*3	The connecting wires for these devices do not require the removal of their outer insulation, and their specifications are generally similar. This makes them suitable for project development and research purposes, as it saves costs and time associated with wire preparation.	
3D printing filament 1kg*1	The main materials used in 3D printing	
Meteorological observation box	The meteorological observation box can be printed using 3D printing filament.	
Acrylic sheet	Upcycling surplus teaching materials from the school's instructional sessions.	

Power bank	Originally intended for powering the GLOBE weather observation station.	
Gigastone R101 Router*1	Portable mini router that is highly compact and convenient. It features a high-performance Qualcomm networking chipset, ensuring stable and reliable connections. It is ideal for on-the-go and regular internet usage.	
5 Volt USB Charger *2	Providing sufficient power for both the router and ESP32 microcontroller.	
Micro USB Charging Cable *2	Cables for charging and data transmission.	

The website and software used in this study (as shown in Table 2) are all free versions, with advanced features requiring payment. Since this research only requires basic functionality, there is no financial investment involved in the use of the website and software.

Table 2: Internet Resources Utilized in this Study

Onshape 3D cad	CAD website for creating meteorological observation boxes	
Arduino IDE	Compiling and uploading programs to the ESP32 microcontroller application	

IoT Analytics - ThingSpeak	ThingSpeak is an IoT platform that allows users to collect and organize real-time data. By setting up different channels, it enables statistical analysis and visualization of data in various categories, facilitating data analysis.	
Codis climate data service system	The Wuri Site obtains its temperature and humidity data from the website of the Central Weather Bureau, which is the weather data website provided by the Central Weather Bureau of Taiwan for the general public.	

Research Method

This study is based on the knowledge acquired in school regarding information technology and life technology. The DHT11 temperature and humidity sensor is connected to the ESP32 microcontroller. The device is powered by a portable power bank. Since the ESP32 is a low-power chip, it does not consume excessive power. Testing has shown that with a 10000mAh power bank, uploading data every 15 seconds, the device can operate continuously for at least 24 hours without charging, consuming only 15% of the power (from 100% to 85%). The observer will also remove the original power bank and replace it with a fully charged one when visiting the GLOBE PROGRAM weather station on campus during noon.

Finally, the assembled device (ESP32) is connected to a computer and the program is uploaded. The program initiates the DHT11 sensor to measure temperature and humidity. The data is then transmitted from the data pin to the ESP32 microcontroller via jump wires. Once the ESP32 successfully connects to the wireless network, it utilizes its features to upload the data to the ThingSpeak platform. The platform then generates temperature and humidity graphs based on the data, eliminating the need for additional wiring and reducing costs while achieving the convenience of positioning and installation for the weather station.

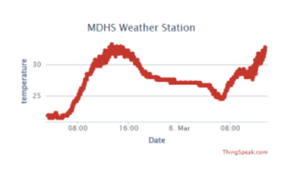
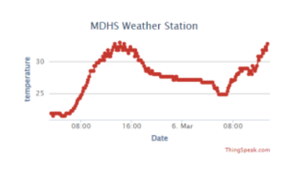
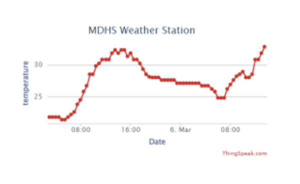
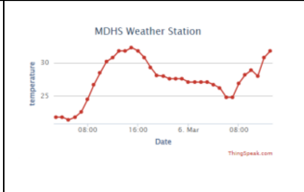
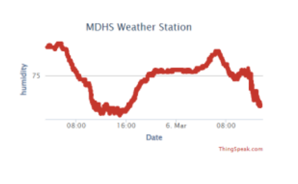
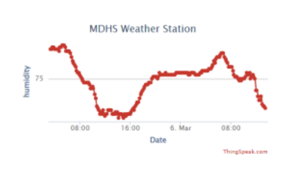
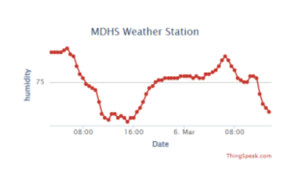
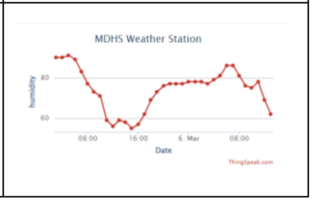
After completing all the materials, the device is placed inside the printed box, and the lid is closed. The fully assembled device is then placed in the louver box of the Mingdao High School GLOBE PROGRAM weather observation station, connected to the campus Wi-Fi network, and achieves the goal of automatically uploading temperature and humidity data to the internet at regular intervals. However, due to limitations in the campus network signal strength, the plan had to be modified, and the device was relocated to the corridor outside the Natural Science Office on the fourth floor of the teaching building (MDSH Site).

Research Results

The automated weather observation station in this study started measuring temperature and humidity data on March 1, 2024. However, due to a campus-wide power outage on March 3, 2024, the data, which was originally being uploaded every 15 seconds, stopped at 14:17 and did not update further. It was necessary to reset the network settings at the school the next day. Therefore, for data analysis in this study, only the data from March 1 to March 3 was used, and it was compared with the data measured by the nearby Central Weather Bureau's Wuri Site to verify if the device could accurately measure temperature and humidity changes.

Regarding the recorded temperature and humidity data, initially, the display was set to show data from March 2, 2024, 04:25:08 to March 3, 2024, 14:17:08, with automatic observations every 15 seconds. It can be observed that there were no significant discrepancies between any two consecutive data points. Later, within the same time frame, I changed the setting to automatically observe every 10 minutes, and there was almost no noticeable difference compared to the previous setting. In subsequent observations, I changed the time intervals to every 30 minutes and 60 minutes, and there was no significant difference compared to the initial 15-second interval. The graphs also became more aesthetically pleasing and easier to analyze. This demonstrates that even if observations are made every 60 minutes, it does not have a significant impact on the overall results, proving that if we want to study changes over approximately one day, less frequent observations are sufficient.

Table 3: Resolution of Temperature and Humidity Records at MDSH Site (3/5 13:30-3/6 13:30)

	15s	10mins	30mins	60mins
Temperature				
Humidity				

Questions and Discussions

Next, a comparison will be made between the data from the campus weather station and the data from the Central Weather Bureau's Wuri automatic station, along with a description of the geographical locations of both sites.

The coordinates (Table 4) for the Wuri Site are (120.624103°E, 24.107058°N), with an elevation of 43m. The station is located in an open grassland next to the main entrance of Wuri Elementary School. The coordinates (Table 4) for the MDSH Site are (120.636874°E, 24.106054°N), with an elevation of 46m. The station is located in the corridor of the teaching building of Mingdao High School. The straight-line distance between the two stations is 1.26km (Figure 1). There is a river, called Mayuantou Stream, between the two stations. The temperature and humidity data captured by both stations covers the time range from 3/1 17:00 to 3/3 14:00. The temporal resolution for the data is 1 hour per temperature and humidity record.

Table 4: Elevation and Coordinates of the Station

	Wuri Site	**MDSH Site**
Elevation	43.0m	46.0m
Coordinates	(120.624103°E, 24.107058°N)	(120.636874°E, 24.106054°N)

Figure 1: Straight-line Distance between Wuri Site and MDSH Site

When comparing the temperature between the two sites (Figure 2), it is observed that there is a consistent overall temperature trend, but there are discrepancies between them. The temperature at Wuri Site is consistently lower than at Mingdao High School, with a minimum difference of 1°C and a maximum difference of 5°C. There are no instances where the temperature at Wuri Site is higher than at Mingdao High School. This difference could possibly be attributed to the placement of the station in the corridor on the 4th floor of the teaching building at Mingdao High School, which is relatively narrow compared to Wuri Site. The narrower setting may result in poorer ventilation, leading to higher temperatures compared to Wuri Site.

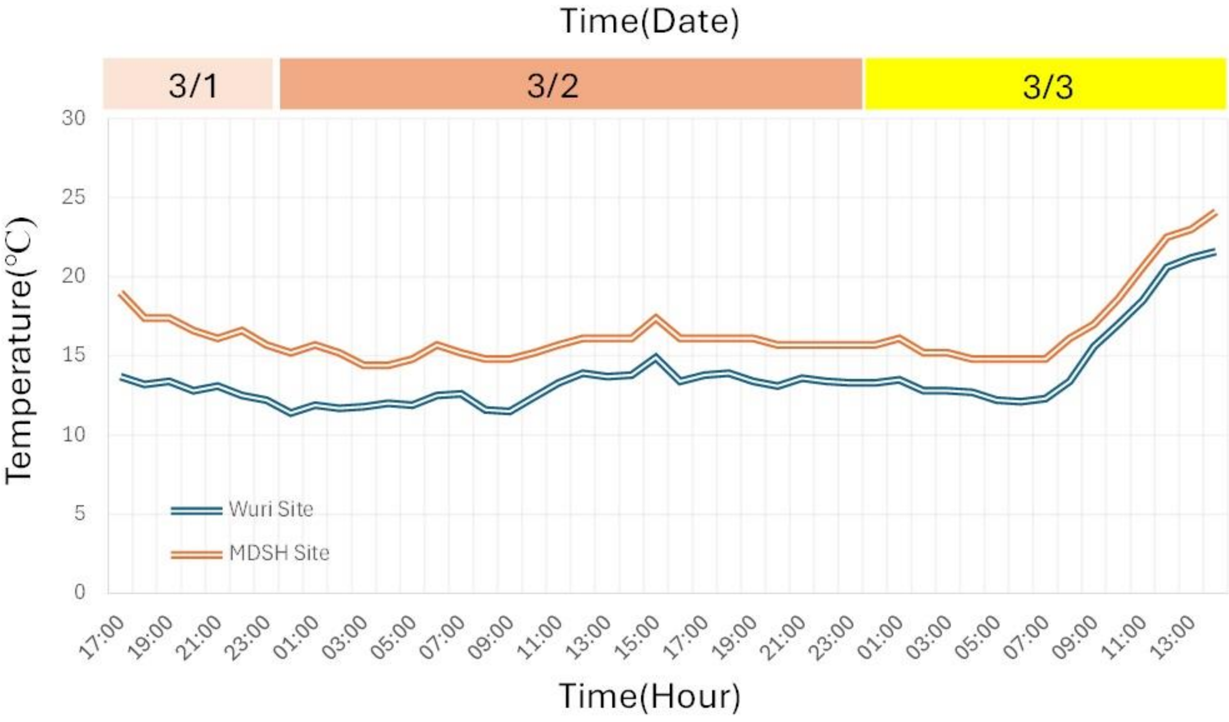


Figure 2: Comparison of Temperature between MDSH Site and Wuri Site

When comparing the relative humidity between the two sites (Figure 3), it is observed that initially, the relative humidity at MDSH Site is lower than the relative humidity at Wuri Site, continuing until 4:00 on 3/2. The minimum difference is 1%, and the maximum difference is 6%. From 4:00 to 10:00, the relative humidity values at both sites are very similar. From 10:00 to 19:00, the relative humidity at MDSH Site is consistently higher than at Wuri Site, with a minimum difference of 1% and a maximum difference of 5%. During this period, both sites experience a simultaneous decrease in relative humidity, showing a similar trend.

Starting from 19:00, the relative humidity at Wuri Site begins to exceed the relative humidity at MDSH Site. Eventually, at 6:00 on 3/3, Wuri Site reaches its highest relative humidity, surpassing MDSH Site by 2%. This high relative humidity at Wuri Site continues until 9:00, where the relative humidity values resemble the situation at 10:00 on 3/2, with MDSH Site having higher relative humidity than Wuri Site. Both sites experience a simultaneous decrease in relative humidity, showing a similar trend.

At 9:00 on both days, the relative humidity at MDSH Site is higher than the relative humidity at Wuri Site, and both sites experience a decrease in relative humidity together. This may be due to geographical factors, as the relative humidity near MDSH Site tends to be higher during the daytime hours of approximately 9:00-19:00.

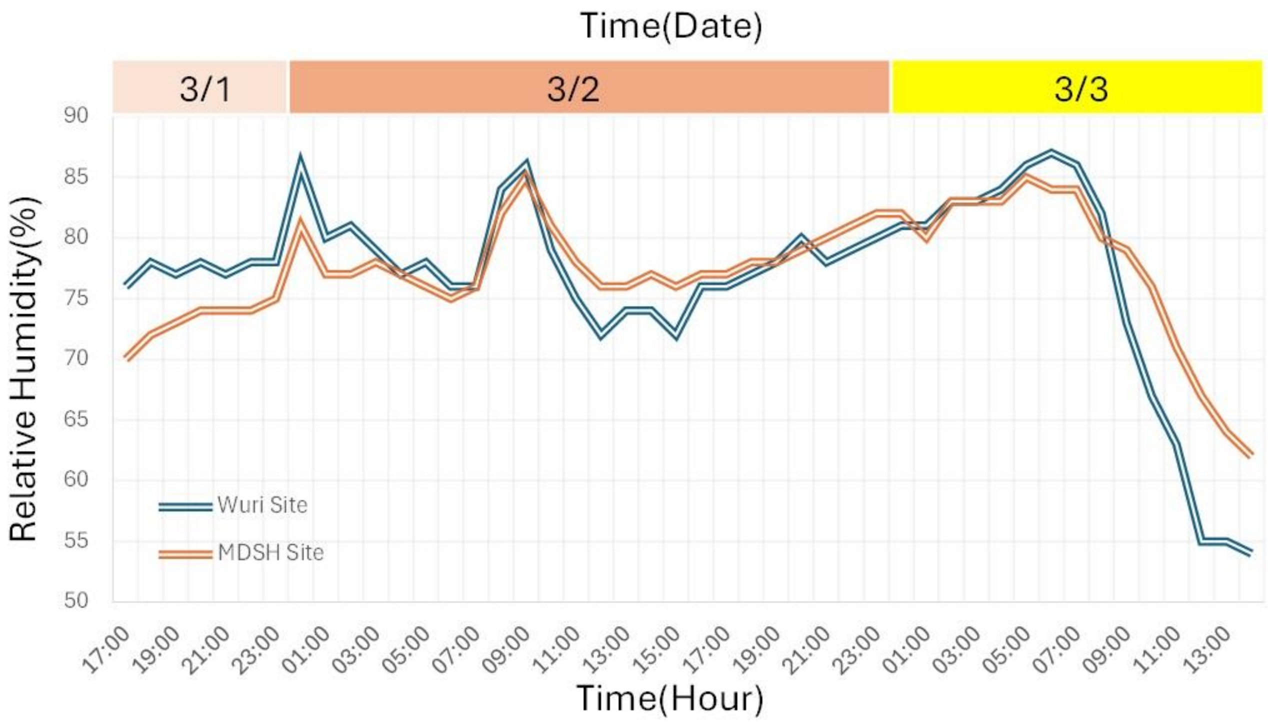


Figure 3: Comparison of Humidity between MDSH Site and Wuri Site

From the above data, it is evident that the automated weather station developed for this study is highly accurate in measuring temperature and humidity. Most of the differences observed between the station and Wuri Site can be attributed to geographical factors. This homemade automated weather station is suitable for long-term recording and research purposes. It will also be further improved by adding more observation parameters and conducting comparisons with Wuri Site to enhance the accuracy of the data.

Conclusion

In the process of constructing the automated weather station, I encountered various challenges related to computer programming and design. This research project pushed me to learn many new things from scratch. I constantly searched for information online and consulted with my school mentors. Many challenges arose right from the beginning, such as programming and hardware issues with Arduino, as well as problems with acquiring the necessary materials for 3D printing. There were also unexpected issues that arose during the setup of the complete automated station, such as wireless network and power supply voltage problems, which I had not initially considered. However, I persevered and solved each problem one by one, gradually completing each component and detail.

Analyzing the data from the observed data table, it is evident that both temperature and humidity values and waveforms are very similar, with extremely low error values. This indicates that the automated weather station I constructed provides highly reliable observation results and can be used for long-term monitoring or research purposes.

Currently, the automated weather station cannot directly connect to the internet through the ESP32 module, as the campus network infrastructure has not been updated. It requires a router to act as a relay for proper functioning. Additionally, routers consume a significant amount of power, and if powered by a portable power bank, it may run out of battery within a day, making it unsuitable for long-term use. This also means that the station needs to be plugged into a power outlet to achieve the goal of continuous automated observations. In the event of a power outage or maintenance of the electrical system on campus, the device would be unable to function without a power source, resulting in a loss of data during those periods. Therefore, resolving this power supply issue will be a key focus for future research work.

References and Websites

On shape (https://www.onshape.com/en/)
Google Map (https://www.google.com/maps?authuser=0)
Think Speak (https://thingspeak.com/)
Codis climate data service system (https://codis.cwa.gov.tw/)