Evaluation of Environmental Monitoring and Data Visualization

Akari Myint Soe
NETsys Research Lab
University of Information Technology
Yangon, Myanmar
akarimyintsoe@uit.edu.mm

Shwe Sin Myat Than
NETsys Research Lab
University of Information Technology
Yangon, Myanmar
shwesinmyatthan@uit.edu.mm

Aung Htein Maw
NETsys Research Lab
University of Information Technology
Yangon, Myanmar
ahmaw@uit.edu.mm

***Abstract*—Real-time IoT-based environmental monitoring and data visualization refer to the use of Internet of Things (IoT) devices and technologies to collect, analyze, and visualize real-time data related to environmental parameters. This approach enables a better understanding of environmental conditions, facilitates proactive decision-making, and supports sustainable practices. This paper mainly focuses on automating air quality, temperature, and humidity from the simple IoT monitoring testbed. The overall evaluation performs fast and convenient with the ETS (AAA) Microsoft Power BI tool and then visualizes the data showing the next 10 days of environmental monitoring.**

Keywords—IoT, Real-Time data, ETS (AAA) Microsoft Power BI tool

I. Introduction

Air quality has emerged as a prominent global concern, with the World Air Quality Report 2021 highlighting the alarming situation in South Asia, including Myanmar [1]. The detrimental effects of air pollution are widely acknowledged, as it contributes to the development of severe respiratory diseases, both acute and chronic, affecting people worldwide. Rising levels of air pollution can have environmental impacts, including climate change, acid rain and depletion of the ozone layer. In addition, there is a correlation between air pollution and temperature. Emissions of greenhouse gases through air pollution can exacerbate global warming, thereby exacerbating the effects of climate change [2].

The impact of temperature on our health can lead to a series of illnesses, such as heat cramps, heat exhaustion, heatstroke, and hyperthermia, creating a domino effect of health complications. Air pollution possesses the ability to influence relative humidity, while humidity, in turn, can impact air pollution. When the air is dry, it facilitates the airborne movement of viruses and can compromise our immune defenses, rendering us more susceptible to respiratory infections like the flu, common cold, and Covid-19. High and prolonged indoor humidity levels create favorable conditions for the rapid growth of microorganisms such as mold, fungi, and bacteria on surfaces. Contact with these microorganisms can trigger allergic reactions in individuals with asthma or allergies to mold [2]. Exposure to carbon dioxide (CO_2) can give rise to a range of health effects, which encompass symptoms like headaches, dizziness, restlessness, breathing difficulties, sweating, fatigue, elevated heart rate, high blood pressure, coma, asphyxia, and convulsions. Amongst these, children are particularly vulnerable due to their delicate physiology. Additionally, since CO_2 is 1.5 times denser than air, its concentrations increase as you approach ground level, further adding to the potential risks [3].

People can use the Air Quality information to protect themselves from unhealthy air pollution. So, it is importance for us to forecast air quality, promote public awareness of environmental protection, and enhance the quality of public life. Therefore, it is essential to precisely forecast how the air quality will vary over a short period of time in the future utilizing information gathered from sensor devices.

In this paper, the IoT station generates sensor data in real-time, which is then sent to the ThingSpeak cloud. The evaluation focuses on the real-time data collection, transmission, and forecasting of data. Importantly, the direct import of data from a web URL in Power BI eliminates the requirement to download and store data locally before making predictions. This approach can significantly save both time and storage resources.

The remainder of the paper is structured as follows: Section II provides background theory with an overview of IoT and different types of forecasting methods. Section III, conducts an experimental evaluation and provide a comprehensive explanation of the system. Finally, the conclusions are outlined in Section IV.

II. Background Theory

This section provides an overview of the importance of environmental monitoring and data visualization, discusses the implementation of an IoT-based monitoring system, and evaluates the collected data using Microsoft Power BI.

A. IoT

The Internet of Things (IoT) is a network of physical objects, referred to as "things", that are equipped with sensors, software, and other technologies. These enable them to connect and exchange data with other devices and systems through the Internet. In this ecosystem, web-enabled smart devices use embedded systems, such as processors, sensors, and communication hardware, to collect, transmit, and react to data gathered from their environment. These IoT devices collaborate by sharing the sensor data they collect, either by connecting to an IoT gateway or another edge device, where the data is then analyzed locally or sent to the cloud for further analysis.

B. ThingSpeak Cloud Platform

ThingSpeak is an open-source IoT application and API that enables storing and retrieving sensor data over the internet using HTTP. It serves as an analytics platform, allowing users to aggregate, visualize, and analyze real-time data in the cloud [7]. ThingSpeak facilitates continuous data updating through APIs for sensor data collection and application data retrieval.

C. Exponential Smoothing Method

Forecasting methods can be categorized into two main types: ***qualitative techniques*** and ***quantitative techniques***.

Qualitative research focuses on words and meanings, while quantitative research deals with numbers and statistics. Each method has its own techniques and can address different types of research questions. Qualitative data collection methods involve interviews and focus groups, while quantitative data collection methods utilize surveys and polls. Qualitative data analysis involves identifying commonalities and patterns, whereas quantitative data analysis relies on statistical analysis and hypothesis testing. It is important to consider the operation of variables when collecting quantitative data.

Exponential smoothing method is a forecasting method that involves weighted averages of previous values to predict future values. It combines the components of error, trend, and seasonality to provide accurate forecasts. This technique is commonly referred to as ETS (Error, Trend, Seasonality) modeling [5]. To analyze the data using exponential smoothing, the following components are considered:

1. Level: The average value of the time series during the period under study.
2. Trend: The direction in which the level is changing, whether it is increasing, decreasing, or constant.
3. Seasonality: The pattern or type of periodicity in the data, such as monthly or annual variations.

The error component is calculated by subtracting the actual values from the level, trend, and seasonality. ETS encompasses various models, including:

- ETS (AAA): This model assumes additive error, additive trend, and additive seasonality. It is suitable when the time series has a linear trend and exhibits seasonality. It is commonly known as Holt Winter's triple exponential smoothing model [6].
- ETS (AAN): This model assumes additive error, additive trend, and no seasonality. It is used when the time series does not exhibit seasonality, and both the error and trend components are additive. It can also be applied when there is no trend in the data, known as the linear Holt model.

D. Microsoft Power BI

Microsoft Power BI is a comprehensive business intelligence platform created by Microsoft, which incorporates a variety of mathematical and statistical techniques, as well as artificial intelligence and machine learning algorithms. This powerful tool seamlessly integrates advanced analytics with a user-friendly interface, enabling businesses to gain valuable insights and make accurate predictions.

In terms of prediction models, Power BI utilizes the ETS (AAA) and ETS (AAN) models, as described by data analysis and data science specialist Sandeep Pawar [4]. These models are specifically designed to handle seasonal and non-seasonal data in time series forecasting. Power BI automatically selects and applies the appropriate model based on the characteristics of the time series data being analyzed.

III. Experiemental Evaluation

The experimental evaluation performs on a simple IoT-based environmental monitoring testbed as shown in Fig. 1. The testbed provides to verify the effectiveness of the overall system in real-world scenarios. This includes three experimental tasks:

Firstly, data is collected from sensors (DHT11, MQ135) and connected to the NodeMCUESP8266 Wi-Fi module to verify its proper functioning.

Secondly, the sensor data are transmitted from the ESP8266 Wi-Fi module to the ThingSpeak cloud through a Wi-Fi gateway.

Finally, the time series forecasting method in Power BI is applied to give accurate forecast data value.

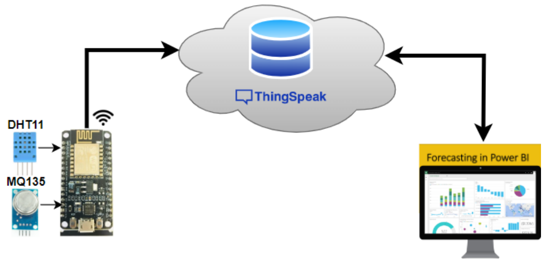

Fig.1. Simple IoT-based Environmental Monitoring Testbed

A. Data Collection

Data was collected from temperature values, measured in Celsius degrees (C°), humidity values, measured in percentage (%) and Air Quality values, measured in parts per million (ppm) captured every 15s shown in Fig. 2.

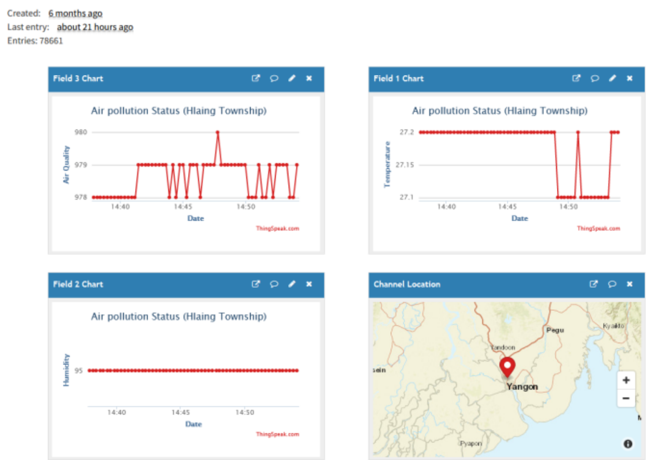

Fig.2. Environmental condition on ThingSpeak cloud data logger

B. Data Transmission

Power BI data tools get real-time ThingSpeak cloud data using API requests from the web. The historical time series data are extracted from ThingSpeak cloud that are manipulate in Microsoft Power BI. Fig. 3 represent based on the data collected for the past 6 months, forecasted the maximum possible temperature, humidity and air quality for the next 10 days.

C. Mean Absolute Percentage Error (MAPE)

In the field of forecasting, it is important to acknowledge that uncertainty is inherent in the process. Forecasts are not perfect and there will always be a difference between the forecasted value and the actual value. The MAPE provides a measure of the average percentage error across all observations in the time series. In general, MAPE value below 20% is considered to indicate good performance in time series forecasting [8]. Table I. shows MAPE data for the actual and forecast values on a given sensor data. The MAPE can be calculated using the Equation (1).

$$MAPE = (1/n) \sum |(Actual - Forecast)/Actual| \times 100 \quad (1)$$

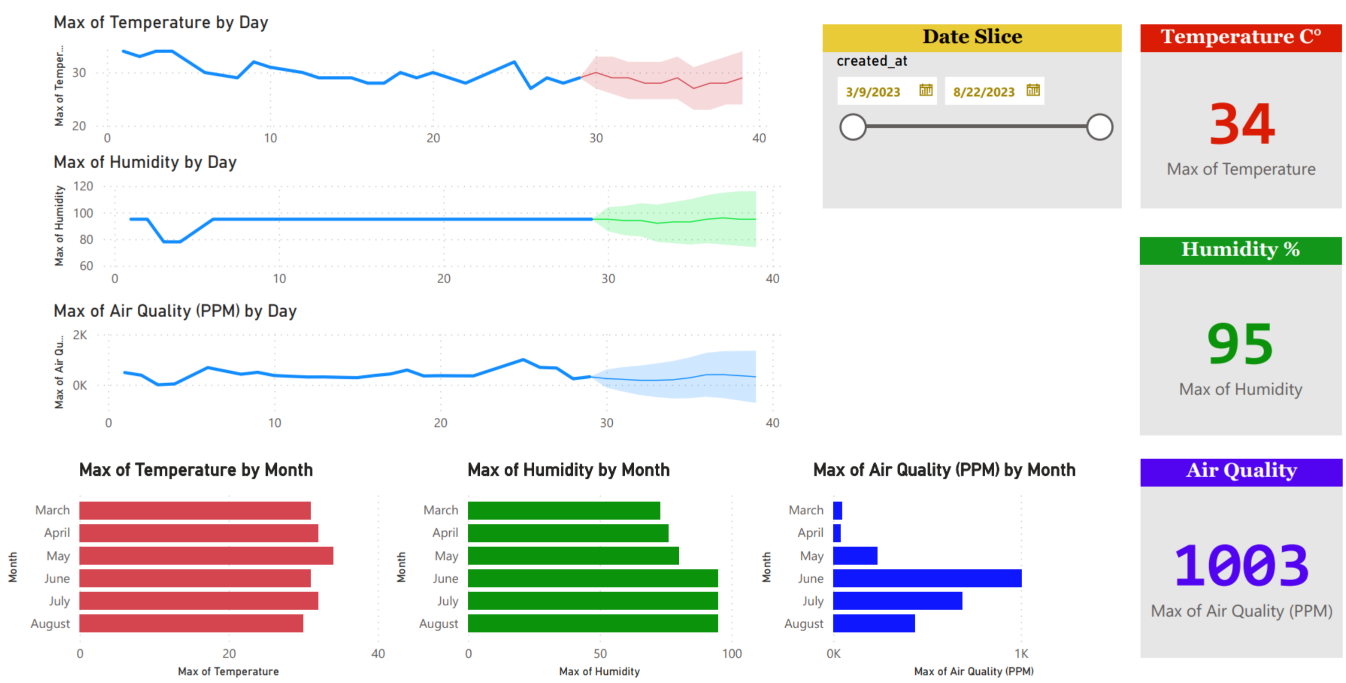

Fig.3. The actual and forecast data record from the environment

TABLE I. CALCULATION OF MAPE FOR NEXT 10 DAYS

No.	Date	Maximum Actual(A)			Maximum Forecast(F)			Diff (| A-F |)			Abs of error by Actual (A-F) / A		
		T (°C)	H (%)	AQ (ppm)	T (°C)	H (%)	AQ (ppm)	T (°C)	H (%)	AQ (ppm)	T (°C)	H (%)	AQ (ppm)
1	23.08.2023	28.1	95	350	30	95	344	1.9	0	6	0.07	0.00	0.02
2	24.08.2023	28	95	327	29	94	332	1	1	5	0.04	0.01	0.02
3	25.08.2023	29.5	95	508	29	94	507	0.5	1	1	0.02	0.01	0.00
4	26.08.2023	27.8	95	419	28	92	408	0.2	3	11	0.01	0.03	0.03
5	27.08.2023	28.2	95	376	28	93	433	0.2	2	57	0.01	0.02	0.15
6	28.08.2023	27.8	95	366	29	93	431	1.2	2	65	0.04	0.02	0.18
7	29.08.2023	28.2	95	382	27	95	387	1.2	0	5	0.04	0.00	0.01
8	30.08.2023	27.6	95	362	28	95	533	0.4	0	171	0.01	0.00	0.47
9	31.08.2023	29	95	373	28	95	578	1	0	205	0.03	0.00	0.55
10	01.09.2023	28.9	95	577	29	95	660	0.1	0	83	0.00	0.00	0.14
		MAPE									2.73	0.95	15.69

IV. CONCLUTION

The overall evaluation of the system performs the accuracy of temperature is 97.27%, closely resembling the actual values, while humidity is 99.05% accurate. Furthermore, the forecasted air quality value is 84.31% similar to the actual value. Therefore, this system offers a complete solution for real-time data processing and analysis in the context of IoT. In terms of future prospects, there is potential for expanding the current investigation to incorporate additional datasets, specifically utilizing IoT-based pollution data, to enable real-time assessment and forecasting of air quality.

REFERENCES

[1] Nayan Das, Asaduzzaman, "An IoT-based System for Air Pollution Data Analysis and Visualization" 2021 5th International Conference on Electrical Engineering and Information Communication Technology (ICEEICT)

[2] Daria Luschkova, Claudia Traidl-Hoffmann, Alika Ludwig, "Climate change and allergies".2022.

[3] F.M.Kodirova ,"Technology for Processing Carbon Dioxide Exhausted from the Mixture of ExHaust Gas Flows", INTERNATIONAL SCIENTIFIC JOURNAL ,VOLUME 1- ISSUE 7, 2022

[4] Laifa Assala, Hadouga Hassiba, "Using Microsoft Power BI for sales forecasting as a data mining technique," HAL open science, International Journal of Economic Performance, Volume:06 Issue:01 P:368, Published:04/06/2023.

[5] Franco, D. "Exponential smoothing methods for Time Series Forecasting", (2022), Retrieved from encora: https://www.encora.com/

[6] Sandeep , P. "*Time series Forecasting in Power BI",* (2020). Retrieved from pawarbi.github: https://pawarbi.github.io/

[7] Mohd Amirul Asyraf Razali, Murizah Kassim, Norakmar Arbain Sulaiman,Shuria Saaidin "A ThingSpeak IoT on real-time room condition monitoring system," Faculty of Electrical Engineering, Universiti Teknologi MARA, IEEE International Conference on Automatic Control and Intelligent Systems, 20 June 2020.

[8] Lewis, C.D., Industrial and business forecasting methods", London, Butterworths.1982