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AQI Measurement and Prediction using B-WEMA Method

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Abstract

Air is one of the main key factors for all living beings in the world. Despite its importance, air can be easily polluted by many pollutants that can pose a great threat to human health. Therefore, the air quality index became a crucial tool to measure the air quality in one area and regaining its popularity among researchers. In this study, we focus on the AQI measurement and prediction based on historical data for the Central Jakarta region. PM2.5 as one of the most commonly used elements in AQI measurement was used in this study. With a total of 744 data records of PM2.5, which was pre-processed to 723 records, B-WEMA method was implemented to predict the future value. Based on the experimental results, B-WEMA had successfully predicted the future values of Central Jakarta AQI. It had the highest accuracy level compare with Weighted Moving Average, Exponential Moving Average, and Brown's Double Exponential Smoothing methods.

Keywords: Air Quality Index, B-WEMA, Central Jakarta, DES, Prediction.

I. INTRODUCTION

Air is one of the main key factors for all living beings in the world. Without enough amount of it, living beings can't survive. Despite its importance, air can be easily polluted by many pollutants [1] that can pose a threat to human health. In fact, as reported by the World Health Organization in 2009, urban outdoor air pollution was listed as one of the biggest risk factors for global deaths in 2004 [2].

Given the increasing air pollution problems, the air quality index (AQI) has received increasing attention recently. It is used to measure how much the air in one area is free from pollution [3]. It consists of six groups with different coloring for each group and has range values from 0 to 500, as shown in Fig.1.

AQI	Air Pollution Level	Health Implications	Cautionary Statement (for PM2.5)
0 - 50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	None
51 -100	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects	Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.
300+	Hazardous	Health alert: everyone may experience more serious health effects	Everyone should avoid all outdoor exertion

Fig. 1. AQI and its levels [4]

Some of the major pollutants for the air are the ground-level ozone, the particle pollution, the carbon monoxide, the sulfur dioxide, and the nitrogen dioxide [5]. All of those pollutants are used as the key indicators in calculating the air quality index in a region. One of the most commonly used criteria is PM2.5, which is the measurement of particulate matter with less than 2.5μ in diameter [6-9], although some other criteria can be used such as O3, CO, SO2, and NO2 [10-14].

Other research focuses on the air quality index are the evaluation of the air pollution in a region using AQI and the prediction of AQI in one or some regions. Monforte and Ragusa [3] for example, highlighted the importance of evaluating air pollution in a Mediterranean region by using the air quality index. They analyzed the AQI's trend from 2013 to 2015 to get the air quality status and then prepare an overall scenario to protect human health and the ecosystems. Moreover, Yang et al. [15] also designed and developed a mobile AQI monitoring system on unmanned-aerial-vehicles, called ARMS. Its main purpose is to efficiently build a fine-grained AQI map in real-time. Zhu et al. [16] also stated the importance to have an accurate and stable AQI forecasting model. They proposed an optimal-combined model based on CEEMD (Complementary Ensemble Empirical Mode Decomposition), PSOGSA (Particle Swarm Optimization and Gravitational Search Algorithm), PSO, and combined forecasting method. The forecasting model was tested to five cities in North China and gave a promising result. Okonkwo, Ijioma, and Onwuamaezea [17] also had investigated the pollutants emissions of three different filling stations in Umuahia and their impacts on the air quality of the region. Different pollutants were recorded, and they found that the filling stations tend to pollute the air and constitute health hazard risk.

In this study, we try to measure and predict the Central Jakarta AQI using a relatively new forecasting method, known as B-WEMA (Brown's Weighted Exponential Moving Average). B-WEMA is a hybrid variant of double exponential smoothing family and was first introduced in 2016 [18]. It was claimed that the hybrid method excels other moving average methods, such as weighted moving average, exponential moving average, and Brown's double exponential smoothing [19]. However, the method is not tested in many different real-cases yet. Furthermore, we also use the two most common error measurement criteria, i.e., the mean square error and the mean absolute percentage error in this study.

II. RESEARCH METHOD

There are three conventional moving average methods being used in this study, i.e., weighted moving average, exponential moving average, and Brown's double exponential smoothing. B-WEMA as the hybrid moving average method will also be used to predict the air quality index of Central Jakarta region.

II.I Conventional Moving Average Methods

The weighted moving average (WMA) is one of the simplest moving average methods. It gives greater weight for the more recent data in a sequential manner and is formulated as [20]:

$$WMA_n = \frac{\sum_{t=k-n+1}^{k} w_t A_t}{\sum_{t=k-n+1}^{k} w_t} \tag{1}$$

The later version of WMA is exponential moving average (EMA). It also gives greater weight to more recent data, but in an exponential manner. EMA calculation is running recursively, as explained in [21].

$$S_1 = Y_1, \tag{2}$$

$$for\ t > 1, S_t = \alpha \cdot Y_t + (1-\alpha) \cdot S_{t-1} \tag{3}$$

Brown's double exponential smoothing (B-DES) is another improved version of EMA. In B-DES, there are two different smoothed series with procedures as follows [22]:

1. Find the single-smoothed series by applying EMA to time series Y, as

$$S'_t = \alpha Y_t + (1-\alpha) S'_{t-1} \tag{4}$$

2. Find the double-smoothed series by applying EMA to S',

$$S''_t = \alpha S'_t + (1-\alpha) S''_{t-1} \tag{5}$$

3. Get the forecast value F_{t+k}, for any $k \geq 1$, by

$$F_{t+k} = L_t + kT_t, \tag{6}$$

   L_t refers to the predicted level at time t and T_t refers to the predicted trend at time t, that can be found using

$$L_t = 2S'_t - S''_{t-1} \tag{7}$$

$$T_t = \frac{\alpha}{1-\alpha}(S'_t - S''_{t-1}) \tag{8}$$

II.II Hybrid Moving Average Method

Brown's weighted exponential moving average (B-WEMA) is a hybrid version of B-DES. It combines the weighting factor calculation in WMA with B-DES procedures. It can be used to predict future values of time series data with a trend pattern spotted.

As described in [19], B-WEMA method follows three steps:

1. Calculate the base value, B_t, using equation (1)
2. Calculate the prediction value by implementing equation (4) – (8), but we start the model by introducing

$$S'_{t-1} = S''_{t-1} = B_t \tag{9}$$

3. Return to Step 1) until all data point in the time series data given have rounded.

III. RESULTS AND ANALYSIS

We start this section by explaining the data pre-processing step being done in this study. Then the prediction results on Central Jakarta AQI using different forecasting methods will be given. Lastly, we evaluate all the applied methods using MSE and MAPE.

III.I Central Jakarta AQI Pre-processing

We aim to predict the future values of Central Jakarta AQI by using the historical data we got from AirNow [23]. In this study, we used the JakartaCentral_PM2.5_2019_12_MTD data that records Central Jakarta AQI from December 1, 2018 to January 1, 2019. There are 744 data recorded in the dataset, but some have missing values. Therefore, the data preprocessing step was conducted where we found and omitted 21 zero data. As a result of the preprocessing step, we have 723 data of Central Jakarta AQI.

III.II Prediction Results

Fig.2 shows the prediction result of Central Jakarta AQI using WMA method, Fig.3 shows the result using EMA method, Fig.4 shows the result using B-DES method, and Fig.5 shows the result using B-WEMA method.

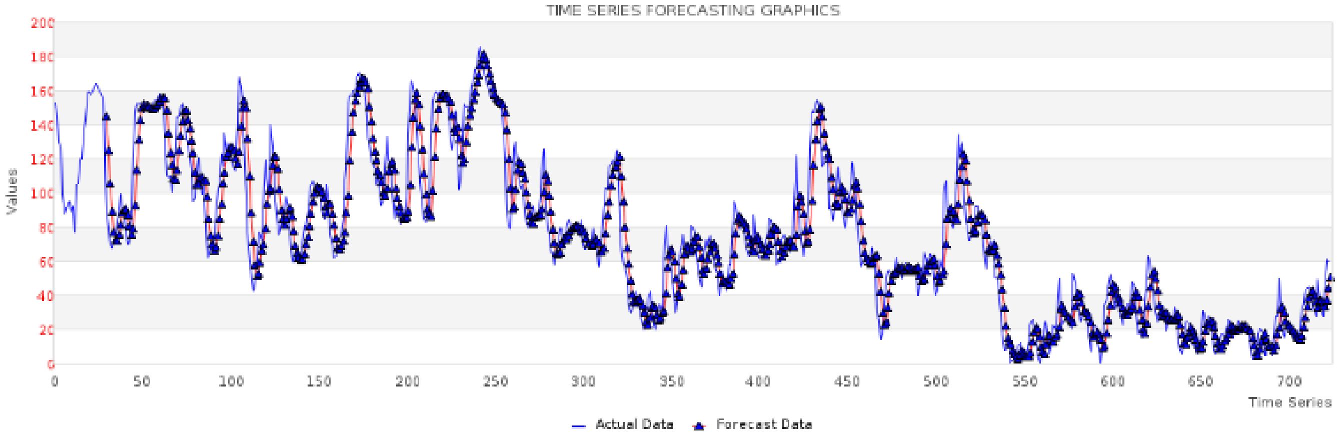

Fig. 2. AQI Prediction using WMA

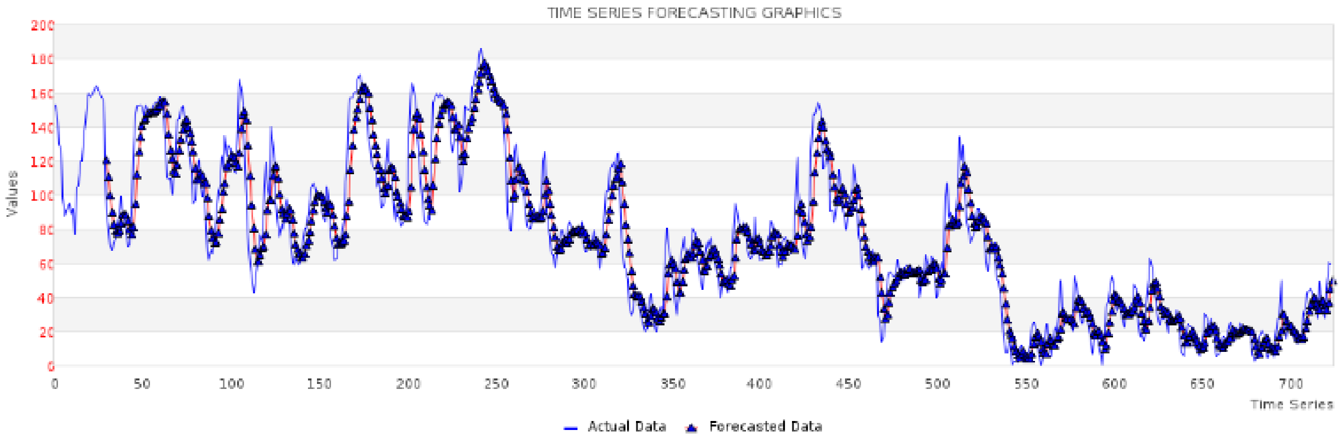

Fig. 3. AQI Prediction using EMA

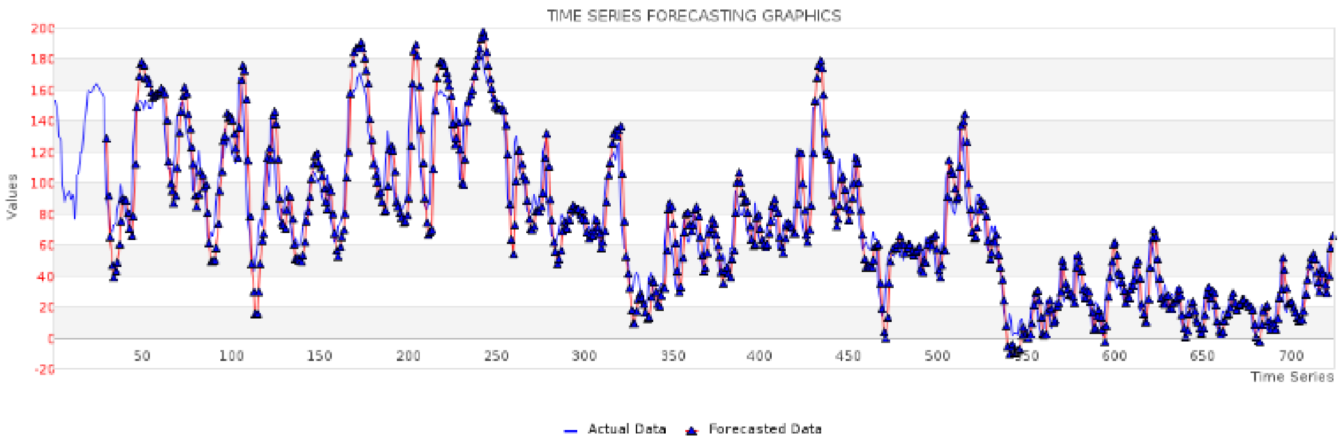

Fig. 4. AQI Prediction using B-DES

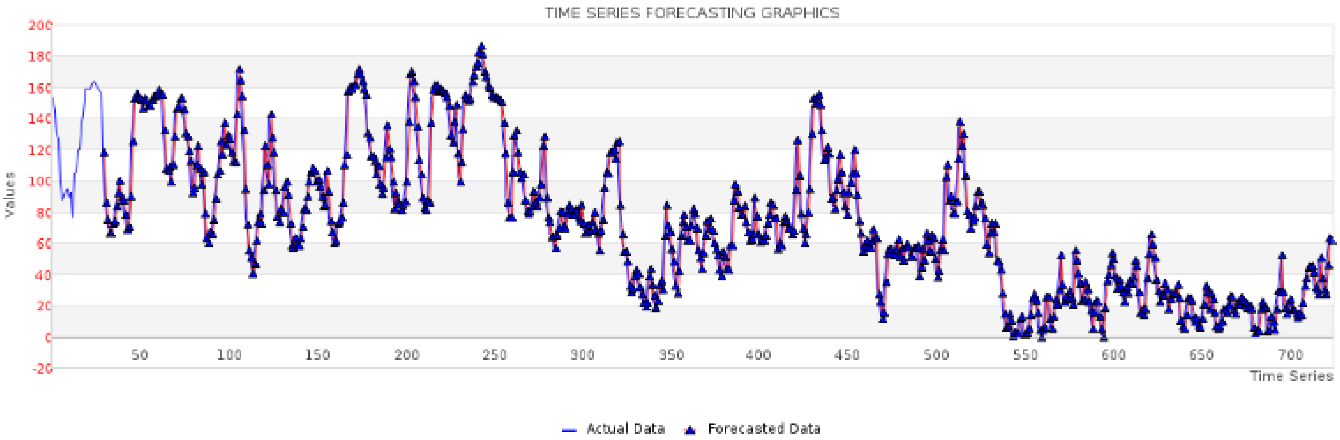

Fig. 5. AQI Prediction using B-WEMA

III.III Evaluation Results

Based on the experimental results and the graphs shown above, it is clearly seen that B-WEMA excels all other methods in Central Jakarta AQI prediction. Table 1 shows the Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE) for all incorporated methods in this study.

Table 1. MSE and MAPE values

Forecasting Method	MSE	MAPE
Weighted Moving Average	268.79985270573	32.165310281335
Exponential Moving Average	262.70112883315	32.932531303964
Brown's Double Exponential Smoothing	282.2126916475	31.096563985867
Brown's Weighted Exponential Moving Average	114.32627786206	20.062284792033

B-WEMA has the smallest MSE and MAPE values compare with WMA, EMA, and B-DES. It means that B-WEMA gives the smallest error in predicting future values for Central Jakarta AQI, which in return means that it has the highest accuracy level compare with other moving average methods implemented in this study.

IV. CONCLUSION

In this study, we have successfully predicted the Central Jakarta Air Quality Index (AQI) using three conventional moving average methods and one hybrid method. B-WEMA as the hybrid approach being implemented in this study, has excelled all other moving average methods, both in MSE and MAPE values. It has the smallest MSE value at 114.3263 and the smallest MAPE value at 20.0623. So, B-WEMA is the most suggested method in Central Jakarta AQI prediction case. Another research to implement other hybrid variants of B-WEMA, i.e. H-WEMA, can be done using the same procedure introduced in this study.

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