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Central Jakarta Rainfall Intensity Forecast using Single Exponential Smoothing

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Abstract: Rainfall is the precipitation amount that is falling from clouds. In extreme conditions, rainfall could arise many problems. It is the leading cause of landslides and flood disasters. In D.K.I. Jakarta, the capital city of Indonesia, rainfall intensity plays a very vital role since it could easily be puddled and caused floods in many areas. Therefore, in this study, we try to make a rainfall intensity prediction in Central Jakarta using a very popular forecasting method, i.e., the Single Exponential Smoothing (SES). Based on the experiments conducted using Phatsa, it can be concluded that the SES method has been successfully used to predict rainfall intensity. However, it cannot give a very good prediction result due to its high forecast error values.

Index Terms: Central Jakarta, Flood, Prediction, Rainfall intensity, SES.

I. INTRODUCTION

Merriam-Webster e-dictionary gives rainfall definition as the amount of precipitation, usually measured by the depth in inches [1]. Precipitation itself is a general term for rainfall, snowfall, and other forms of frozen or liquid water, which was falling from clouds [2]. It is intermittent and varies from year to year. The character of precipitation when it occurs depends significantly on the weather condition and temperature situation [2].

Rainfall in extreme conditions can arise many disasters. One typical example of extreme rainfall is landslides. Another disaster that can happen due to heavy rainfall is the flood. Fig. 1 described a situation when the flooding happened in a region of Jakarta, the capital city of Indonesia.

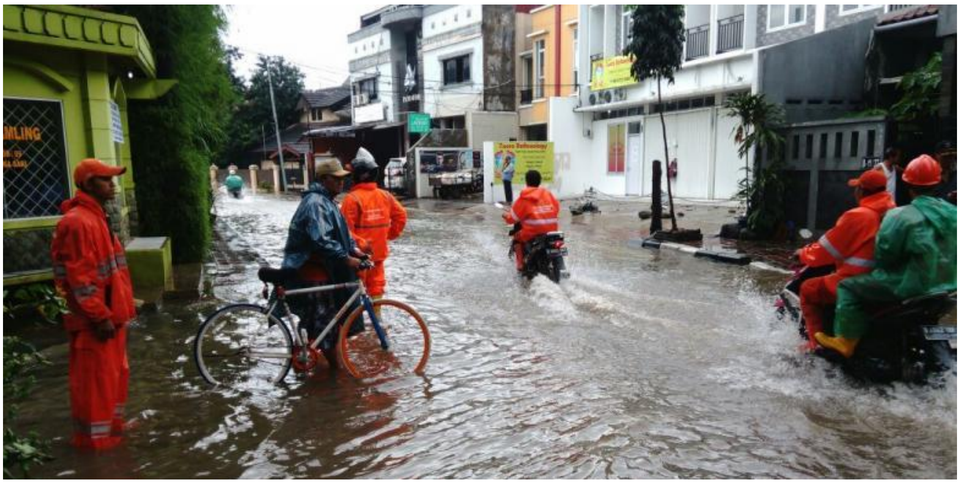

Figure 1. Flood condition in East Jakarta in February 2017 [3]

Jakarta, as a capital city of Indonesia, can be classified as a city with the most flooding disaster that happened every year. The main factor for the disaster to happen is the rainfall. Therefore, a method or tool to predict rainfall intensity is needed, so that proper decisions to prevent such disaster can be taken by the authority, in this case, the local government of D.K.I. Jakarta.

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Several types of research related to the rainfall intensity prediction had been done by notable researchers. Staley *et al.* [4] had proposed a fully predictive method for calculating site-specific rainfall thresholds. Cramer *et al.*

[5] had made an extensive evaluation of some popular machine learning methods for rainfall prediction, including extended Markov Chain model, k-Nearest Neighbors, Radial Basis Neural Network, Genetic Programming, Support Vector Regression, M5 Rules, and M5 Trees. Nhat *et al.* [6] had researched to construct Intensity-Duration-Frequency (IDF) curves for seven stations in the monsoon area of Vietnam. They also had proposed a generalized IDF formula that using base rainfall depth and base return period for Red River Delta (RRD) of Vietnam. Several other types of research focus on the landslide rate changes induced by rainfall, as we can find in the works of Bernardie *et al.* [7] and Zhuang *et al.* [8].

In this research, we will use a popular technical technique, i.e., Single Exponential Smoothing (SES), to predict the rainfall intensity of a region in Indonesia. SES, also known as EWMA, has been used by many researchers

and practitioners to forecast the future value of a given time series data. For instances, Murray *et al*. [9] had used Exponentially Weighted Moving Averages to calculate the acute:chronic workload ratio that gives a better injury likelihood than rolling averages method, Hansun and Kristanda [10] had analyzed the performance of different conventional moving averages methods, including SES, in Forex Forecasting, and they also had applied SES to predict Indonesia's Human Development Index [11].

SES actually is a unique type of Moving Average (MA) that uses the exponential function in forming the weighting factors. It can smooth out random fluctuations where the declining weight is put on older data, extremely easy to compute, and minimum data is required [12]. Thus, it can be used to predict rainfall intensity. To calculate the forecast error, we will use the Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE) criteria.

In the next section, further discussion on SES, the forecasting method used will be given. We also explain MSE and MAPE forecast error measurements in section 2. Section 3 will be started with an explanation of the data pre-processing phase in this study, followed by the prediction results of rainfall intensity in Central Jakarta region and evaluation of the results using MSE and MAPE. Using the experimental result we have, we analyze and conclude the research's findings in the last section.

II. Single Exponential Smoothing

SES is a family of Moving Average (MA) forecasting method. It is also known as Exponentially Weighted Moving Average, which came from Brown's work [13]. It will put a higher weight on recent data than old data. As can be seen in Hansun and Subanar [14], SES for a time series Y can be calculated as

$$S_1 = Y_1, \tag{1}$$

$$for\ t > 1, S_t = \alpha \cdot Y_t + (1-\alpha) \cdot S_{t-1} \tag{2}$$

where

Y_t : data value at a time period t

S_t : SES value at time t

α : a constant smoothing factor between 0 and 1.

As proposed in [15], α can be estimated as:

$$\alpha = \frac{2}{n+1} \tag{3}$$

but in this study, we will use a brute force technique to find the best α value so that it can minimize the error rate of the predicted results.

III. Error Measurements

Mean Square Error (MSE) is a very popular forecast error measurement tool commonly used by researchers in the time series domain. It can be obtained by averaging the square of the error sum. The formula for MSE can be seen as [16],

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(A_t - F_t)^2 \tag{4}$$

where

n : total data of time series

A_t : the real value of data

F_t : forecasted data

Another popular tool to measure forecast error of time series data is the Mean Absolute Percentage Error (MAPE). The equation for MAPE can be written as [17],

$$MAPE = \left(\frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right|\right) \cdot 100\% \tag{5}$$

IV. RESULTS

We start this section by describing the data collection and pre-processing phase to predict rainfall intensity in the Central Jakarta region. After that, using the data collected, a forecasting results graph will be depicted and explained. The final analysis of forecasting accuracy using MSE and MAPE criteria will be given later to finish this section.

A. Pre-processing Phase

In this study, we try to predict the rainfall intensity of a region in Indonesia, i.e., D.K.I. Jakarta, the capital city of Indonesia. Therefore, the data needed was collected from Meteorological, Climatological, and Geophysical Agency (BMKG). The agency has provided the data needed for research in its online database [18]. After registering ourselves, we can download the data we need for each region in Indonesia. In this case, we choose the Central Jakarta region because it has more complete data than other regions have. The data given was collected from Kemayoran Meteorology Station for January 1st, 2017, to December 14th, 2017. There is a total of 346 recorded data, but some of them will be omitted due to not measurable and missing data. There are 18 data counted as not measurable and 1 data counted as missing, so there is a total 327 data that can be used in this study. Another pre-processing step taken is to change the value of "0" data to the average value of data used in forecasting, to avoid division by zero error when calculating MAPE criteria.

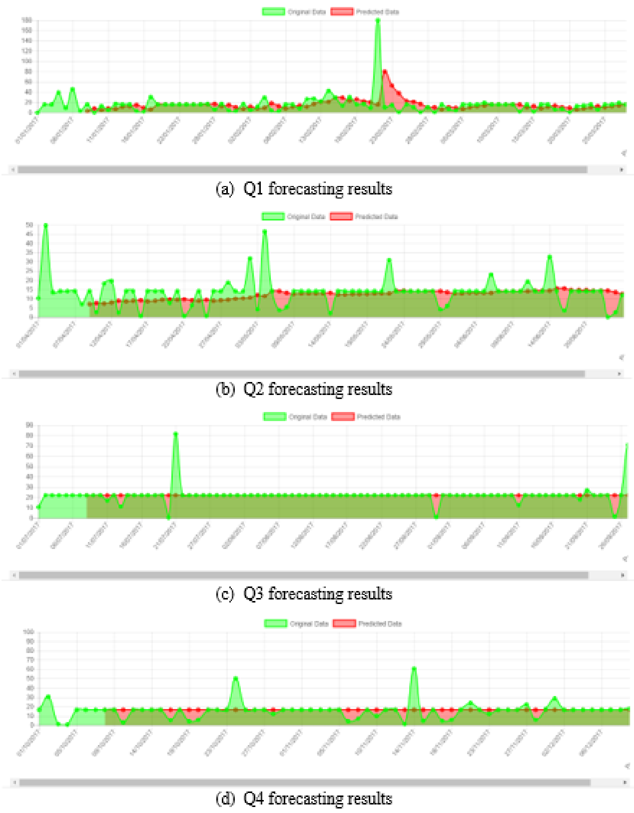
Table 1 shows the data collection and scenario for the prediction phase. The prediction will be done for all data in 2017, started from January 2017 to December 2017, which will be divided into four (4) quarters. For December 2017, we only have 12 data that can be used in rainfall prediction.

Table 1. Data Collection and Scenario

Prediction Interval	Data Used Count	Data Omitted Count	Total Data
Q1	87	3	90
Q2	84	7	91
Q3	90	2	92
Q4	66	7	73
Total	**327**	**19**	**346**

B. Forecasting Results

The rainfall prediction results using SES can be seen in Figure 2. There are four graphs that represent each quarter's forecasting results. We used Phatsa (PHP application for time series analysis) framework which can be used for free on http://phatsa.com. Phatsa is free to use web application with the primary purpose to help researchers, practitioners, and ordinary people to forecast future values of given time series data or any data they have. It was built by Hansun and Kristanda in 2017 and still be developed and maintained until now. For further information on Phatsa, interested readers are encouraged to see [19].



(a) Q1 forecasting results
(b) Q2 forecasting results
(c) Q3 forecasting results
(d) Q4 forecasting results

Figure 2. Q1-Q4 forecasting results of rainfall intensity in Central Jakarta

C. Analysis

The rainfall intensity prediction results have been successfully calculated using the SES method. By dividing one-year data collected from BMKG into four quarters, we get quite good forecasting results. Moreover, using MSE and MAPE, we could know the accuracy level of the SES method in rainfall prediction. Table 2 shows the MSE and MAPE results for each quarter and overall data of rainfall intensity in Central Jakarta.

Table 2. Central Jakarta Rainfall Prediction Error Measurement

Prediction Interval	MSE	MAPE
Q1	496.7062814	252.2980836
Q2	71.42816139	313.83
Q3	93.33337349	186.379348
Q4	181.0784746	92.64674712
Total	**210.6365727**	**211.2885435**
Overall (Q1-Q4)	**194.9185108**	**216.7821203**

From Table 2, it's clearly seen that the MSE and MAPE values for each quarter are quite high. It seems that the SES method not suitable in rainfall intensity prediction. One main cause of the result is because there are too many zero data values in the dataset. Although we have used the average value to cover such data, the time series data pattern has been changed. Thus, the forecasting results of rainfall intensity in Central Jakarta are not too good.

V. CONCLUSION

In this study, we try to predict rainfall intensity in the Central Jakarta region, the capital city of the Republic of Indonesia. We use Single Exponential Smoothing (SES) method to predict the rainfall intensity of January 2017 to December 2017 dataset, which was taken from Meteorological, Climatological, and Geophysical Agency (BMKG). The dataset was divided into four quarters, and the forecasting results had been presented in the paper. Although SES method can be applied to predict rainfall intensity in Central Jakarta, the accuracy level of prediction results is not too good. It can be concluded from the value of MSE and MAPE which are quite high. Therefore, SES method is not suitable to forecast rainfall intensity in Central Jakarta region.

For further study, we need to make sure and identify what factors affect the forecasting results. A more significant dataset range also can be considered to achieve a better forecasting result.

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Seng Hansun had finished his Bachelor and Master's degree from Universitas Gadjah Mada, majoring Mathematics and Computer Science program. Since 2011, he has been a lecturer and researcher at Universitas Multimedia Nusantara and published more than 75 papers both nationally and internationally. His research interests mainly in time series analysis and machine learning domain where he has successfully granted some research grants from the government and UMN institution.

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