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Brown's Weighted Exponential Moving Average Implementation in Forex Forecasting

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Abstract

In 2016, a time series forecasting technique which combined the weighting factor calculation formula found in weighted moving average with Brown's double exponential smoothing procedures had been introduced. The technique is known as Brown's weighted exponential moving average (B-WEMA), as a new variant of double exponential smoothing method which does the exponential filter processes twice. In this research, we will try to implement the new method to forecast some foreign exchange, or known as forex data, including EUR/USD, AUD/USD, GBP/USD, USD/JPY, and EUR/JPY data. The time series data forecasting results using B-WEMA then be compared with other conventional and hybrid moving average methods, such as weighted moving average (WMA), exponential moving average (EMA), and Brown's double exponential smoothing (B-DES). The comparison results show that B-WEMA has a better accuracy level than other forecasting methods used in this research.

Keywords*: Brown's double exponential smoothing, B-WEMA, exponential moving average, foreign exchange, time series forecasting, weighted moving average*

1. Introduction

Time series is a time-oriented or chronological sequence of observations on a variable of interest [1]. There are two types of time series data, i.e. continuous time series where observations recorded continuously over some time intervals, and discrete time series where observations are made at fixed time intervals [2]. According to Dufour [2], the discrete time series data is more commonly used than the continuous time series data, especially in economic related field.

In order to understand the characteristics of time series data, there are so many time series analysis methods that have been developed [3, 4]. One of their goal is to forecast or predict the future values from a given time series data [5]. To achieve that goal, many researchers had conducted and developed, not only conventional methods as we can find in the works of Wang [6], Klinker [7], and Papailias and Thomakos [8], but also the soft computing methods such as fuzzy, neural networks, or their hybrid methods [9-15].

In mid-2016, a new technique to forecast future data in time series analysis had been introduced. The technique is called as Brown's Weighted Exponential Moving Average (B-WEMA) since it is a hybrid method which combined the weighting factor calculation formula found in weighted moving average with Brown's double exponential smoothing method. Based on the research's results as presented in [16], B-WEMA has a better accuracy value compare to other conventional moving average methods.

In this study, we will try to implement B-WEMA in a real financial time series data, i.e. the foreign exchange (forex/ FX). Forex is the exchange of one currency into another currency [17] and the market is said to be the largest and most liquid market in the whole world [18]. So the prediction of forex time series data by using its historical transaction is very important, that the decision of selling or buying the forex can be taken more precisely.

This study is the extended version of the research that had been published in late 2016 [19]. If on that research, the author only used one forex time series data (i.e. the EUR/USD closing data) and compared the B-WEMA forecasting results' with weighted moving average (WMA) and Brown's double exponential smoothing (B-DES), in this research we will try

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to implement B-WEMA in five major currency pairs in forex transactions (i.e. EUR/USD, AUD/USD, GBP/USD, USD/JPY, and EUR/JPY closing data). Furthermore, exponential moving average (EMA) will also be used as a comparison method in spite of WMA and B-DES methods. To calculate the accuracy level of all forecasting methods, we will use mean square error (MSE) and mean absolute percentage error (MAPE). The next section will describe in detail the three moving average methods used in this research, i.e. WMA, EMA, and B-DES; and the hybrid moving average method, i.e. B-WEMA. Furthermore, MSE and MAPE forecast error measurements will be explained on the same section, while the forecasting results will be graphed and explained on Section 3. Section 4 will conclude the research's results and other findings which can be used as future research's topics.

2. Research Method

This chapter is begun with the discussion of weighted moving average, exponential moving average, and Brown's double exponential smoothing methods. The hybrid Brown's weighted exponential moving average method will be described later. The explanation of mean square error and mean absolute percentage error as the forecast error measurements will end this section.

2.1. Weighted Moving Average (WMA)

Weighted moving average is designed to put more weight on recent data and less weight on past data [20]. Usually, the weighting factor is calculated from the sum of days used in WMA calculation [21,22], with the formula can be described as follows [23]

$$WMA = \frac{nP_m+(n-1)P_{m-1}+\cdots+2P_{(m-n+2)}+P_{(m-n+1)}}{n+(n-1)+\cdots+2+1} \quad (1)$$

where n refers to the period or time interlude used in forecasting formula and P_m refers to the actual value of time series data at point m.

2.2. Exponential Moving Average (EMA)

The development of weighted moving average leads to exponential moving average. Just like WMA, exponential moving average also places more weight on recent data [24], but unlike WMA, the weight for each older data decreases exponentially, so it's never reaching zero value [25]. EMA is also known as single exponential smoothing technique and can be used to predict any time series data.

As described by NIST [26], EMA can be calculated recursively as:

$$S_1 = Y_1, \qquad \text{for } t > 1, S_{t+1} = \alpha \cdot Y_t + (1-\alpha) \cdot S_t, \quad (2)$$

where Y_t is the actual value at time period t, S_t is the smoothed value of EMA at time period t, and α represents a constant smoothing factor between 0 and 1. As can be found in [24] and [27], α can be calculated using the formula

$$\alpha = \frac{2}{(m+1)} \quad (3)$$

where m is the number of days used as time period in the forecasting formula.

2.3. Brown's Double Exponential Smoothing (B-DES)

Brown's double exponential smoothing is a type of double exponential smoothing technique, which is an improvement of single exponential smoothing or exponential moving average. It uses two different smoothed series, both of them are centered at different points on time [28]. It is said that the double exponential smoothing techniques can predict future values of time series data where a trend pattern spotted better than the single exponential smoothing technique. Nau [28] explained the procedures of B-DES as follows.

First, we need to find the single-smoothed series, S', by applying EMA to time series Y, as:

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

Then, by using the single-smoothed series, we could find the double-smoothed series, denoted as S'', by applying EMA to S',

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

Next, we could get the forecast value Y_{t+k}, for any $k \geq 1$, by

$$F_{t+k} = L_t + kT_t, \quad (6)$$

where L_t refers to the predicted level at time t, T_t refers to the predicted trend at time t, which both of them can be found as follow:

$$L_t = 2S'_t - S''_{t-1} \quad (7)$$

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

2.4. Brown's Weighted Exponential Moving Average (B-WEMA)

Brown's weighted exponential moving average was first introduced in 2016 [16]. It is an improved version of weighted exponential moving average (WEMA) method which had been introduced in 2013 [25]. Using the basic principle found in WEMA, B-WEMA combines the weighting factor calculation formula found in weighted moving average with Brown's double exponential smoothing method. Same with other double exponential smoothing techniques, B-WEMA could be used to predict future values of time series data with a trend pattern.

The procedures of B-WEMA method can be explained as three recursive steps [16]:
(1) Using equation (1) for a given time series data and periods, we calculate the base value, B_t.
(2) Using the base value obtained, we calculate the prediction value by implementing equation (4)-(8), but we start the model by letting

$$S'_{t-1} = S''_{t-1} = B_t \quad (9)$$

(3) Return to the first step until all data point in the time series data given have ended.

2.5. Mean Square Error (MSE)

The most popular technique to measure forecast error is mean square error. It is the average of the square error sum between the real data and the forecasted data. We can use the formula below to find MSE [29],

$$MSE = \frac{\sum_{t=1}^{n} e_t^2}{n} \quad (10)$$

where n denotes the number of data point used in the forecasting and e_t denotes the forecasting error, which can be found from the differences of real data (Y_t) and forecasted data ($\hat{Y}_t$).

2.6. Mean Absolute Percentage Error (MAPE)

Mean absolute percentage error is another popular forecast error measurement technique. It gives us an indication about how much the average of absolute error of the forecasted data compare to the actual data. The formula can be expressed as [29],

$$MAPE = \frac{\sum_{t=1}^{n} \left|\frac{e_t}{Y_t}\right|}{n} \times 100 \quad (11)$$

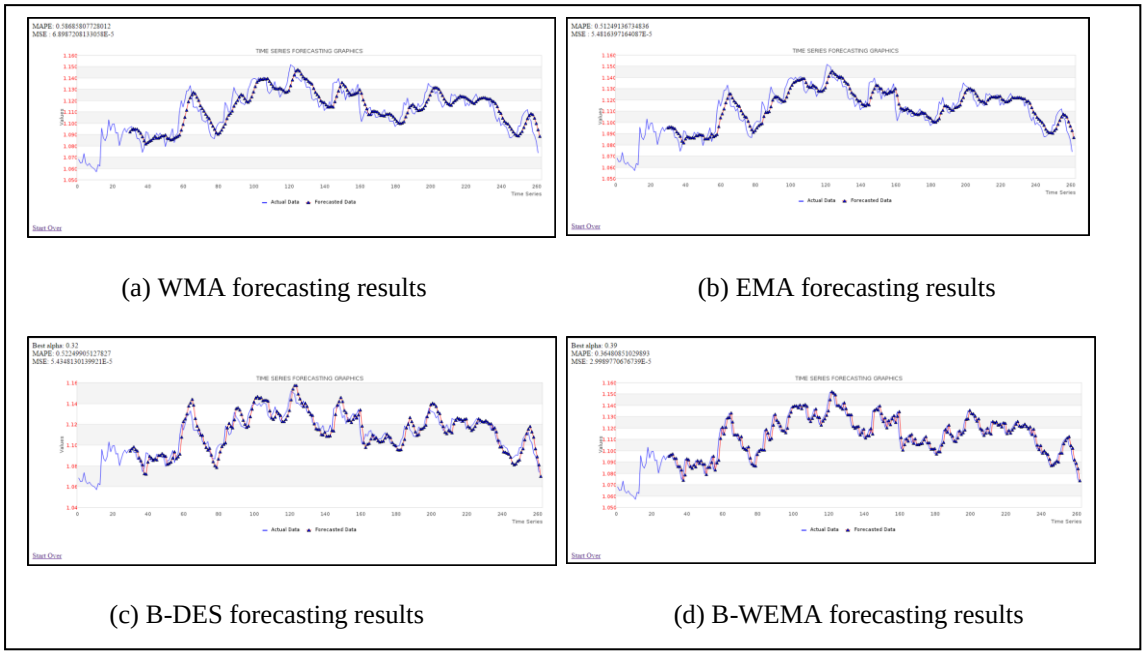
where n denotes the number of data point used in the forecasting and e_t denotes the forecasting error from the differences of real and forecasted data, $Y_t - \hat{Y}_t$.

3. Results and Discussion

On this study, implementation of Brown's weighted exponential moving average on a real case financial data, i.e. the foreign exchange (forex) was conducted. Therefore, five major currency pairs in forex transactions, i.e. EUR/USD, AUD/USD, GBP/USD, USD/JPY, and EUR/JPY closing data were recorded daily from November 16th, 2015 to November 15th, 2016 [30] and be used as the dataset. Then, B-WEMA together with WMA, EMA, and B-DES will be implemented on the same dataset. We used MSE and MAPE criteria to calculate the accuracy level of each method implemented on this study.

3.1. Forex Forecasting Implementation

Figure 1 shows us the graph of forecasting results on EUR/USD closing data using WMA, EMA, B-DES, and B-WEMA methods. Moreover, Figure 2 shows the forecasting results using the same methods for AUD/USD dataset, Figure 3 shows the forecasting results for GBP/USD dataset, Figure 4 shows the forecasting results for USD/JPY dataset, and Figure 5 shows the forecasting results for EUR/JPY dataset. The real (actual) forex closing data are indicated by the blue line on the graph, while the predicted data are indicated by the red line.



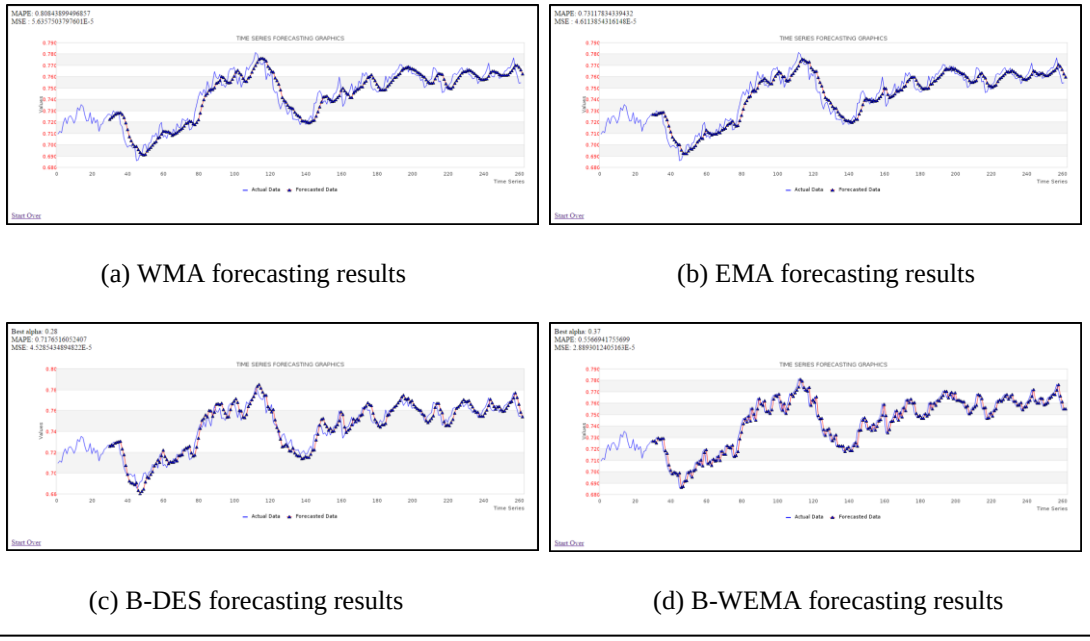
(a) WMA forecasting results

(b) EMA forecasting results

(c) B-DES forecasting results

(d) B-WEMA forecasting results

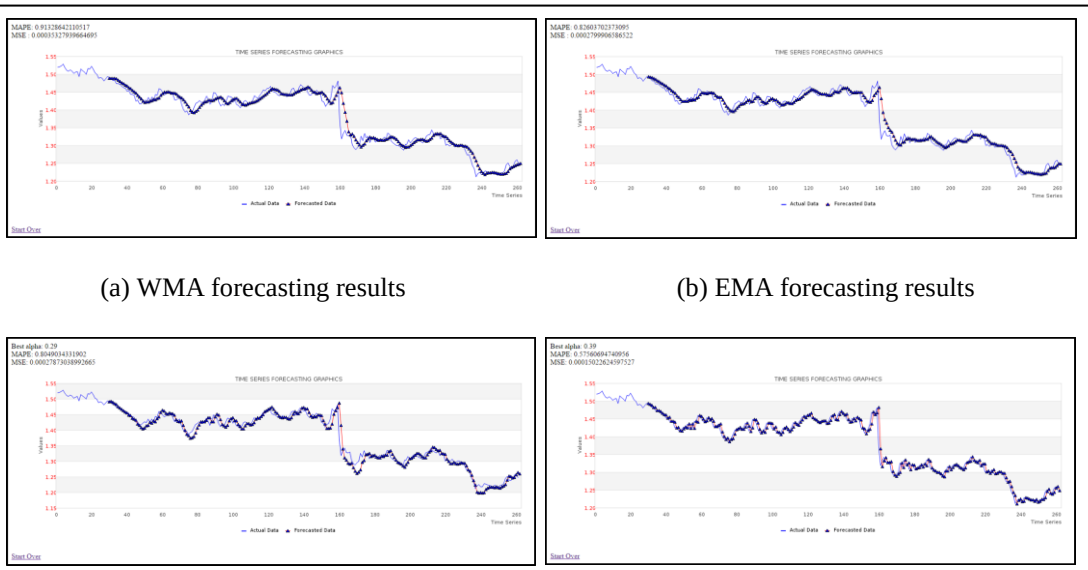
Figure 1. Forecasting results for EUR/USD



(a) WMA forecasting results (b) EMA forecasting results

(c) B-DES forecasting results (d) B-WEMA forecasting results

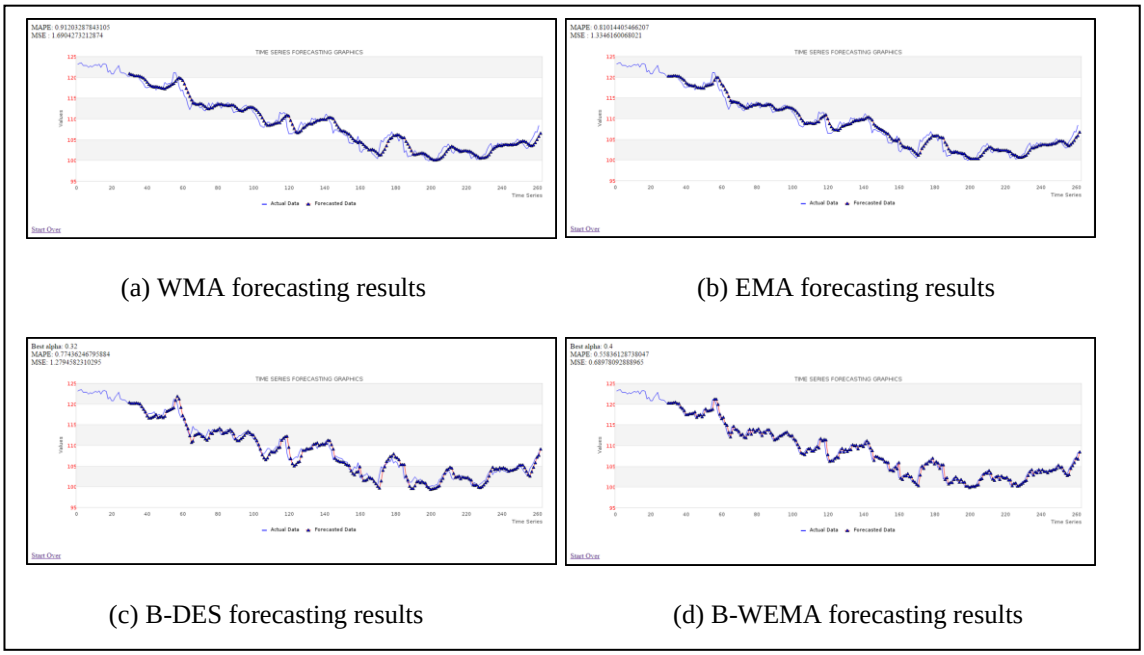
Figure 2. Forecasting results for AUD/USD



(a) WMA forecasting results (b) EMA forecasting results

(c) B-DES forecasting results (d) B-WEMA forecasting results

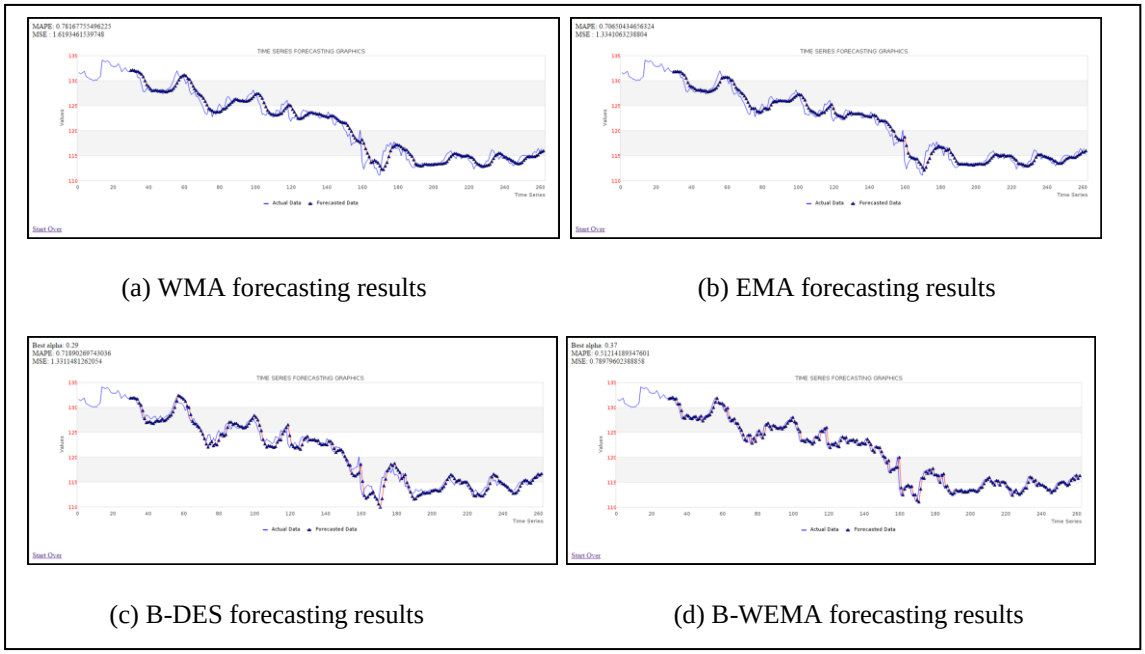
Figure 3. Forecasting results for GBP/USD



(a) WMA forecasting results (b) EMA forecasting results

(c) B-DES forecasting results (d) B-WEMA forecasting results

Figure 4. Forecasting results for USD/JPY



(a) WMA forecasting results (b) EMA forecasting results

(c) B-DES forecasting results (d) B-WEMA forecasting results

Figure 5. Forecasting results for EUR/JPY

4.2. MSE and MAPE Comparison

The experiments then continued to calculate the accuracy of each moving average method implemented on the system. Mean square error (MSE) and mean absolute percentage error (MAPE) criteria were used as forecast error measurement tools. The results of MSE and MAPE can be seen on Table 1.

Table 1. MSE and MAPE values of each method

FX Currency Pairs	MSE			
	WMA	EMA	B-DES	B-WEMA
EUR/USD	6.89872E-05	5.48164E-05	5.43481E-05	2.99898E-05
AUD/USD	5.63575E-05	4.61139E-05	4.52854E-05	0.000028893
GBP/USD	0.000353279	0.000279991	0.00027873	0.000150226
USD/JPY	1.690427321	1.334616007	1.279458231	0.689780929
EUR/JPY	1.619346154	1.334106324	1.331148126	0.789796024
Average	0.66205042	0.53382065	0.522196944	0.295957212

FX Currency Pairs	MAPE			
	WMA	EMA	B-DES	B-WEMA
EUR/USD	0.586858077	0.512491367	0.522499051	0.36480851
AUD/USD	0.808438995	0.731178343	0.717651605	0.556694176
GBP/USD	0.913286421	0.826037024	0.804903433	0.575606947
USD/JPY	0.912032878	0.810144055	0.774362468	0.558361287
EUR/JPY	0.781677555	0.706504347	0.718902697	0.512141894
Average	0.800458785	0.717271027	0.707663851	0.513522563

From Table 1, we can conclude that all the forecasting methods applied on this study can be used to forecast forex data with a relatively small error value. Moreover, from the MSE and MAPE value, we know that exponential moving average has a better accuracy level compare to weighted moving average method. Brown's double exponential smoothing has a better accuracy level compare with exponential moving average, but has worse accuracy than Brown's weighted exponential moving average method. Therefore, since B-WEMA excels all other moving average methods implemented in this study, we could conclude that B-WEMA can be used to forecast forex data transaction.

4. Conclusion

Brown's weighted exponential moving average (B-WEMA) had been successfully implemented to forecast foreign exchange (forex) data transaction. Using five major currency pairs in forex transactions, i.e. the EUR/USD, AUD/USD, GBP/USD, USD/JPY, and EUR/JPY closing data, we conclude that B-WEMA can be used and proved to be a better technique compare with WMA, EMA, and B-DES methods. Based on the experimental results, B-WEMA gives the smallest mean square error average value at 0.295957212 and the smallest mean absolute percentage error average value at 0.513522563.

For the future study, we can try to further develop B-WEMA method to predict future value of time series data where not only trend but also seasonal data spotted. Another study to combine other moving average methods, such as Holt-Winters triple exponential smoothing can also be done to complete the variant of WEMA methods.

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