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Design and Implementation of Inventory Forecasting System using Double Exponential Smoothing Method

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***Abstract*— Recently, information systems have an essential role in companies, especially in companies that engaged in the production of goods and services. Prediction or forecasting is a mandatory supporting component in planning activities in making business predictions for maximum profit.**

To tackle this issue, this paper proposes to design and implement an inventory forecasting system. The proposed system utilizes the Double Exponential Smoothing forecasting method, which is a form of quantitative inventory control based on the historical data (time series) so that the movement of data from the past can be analyzed. In the end, the proposed system may computationally draw the movement trends in the future. The forecasting itself employs two parameters, *alpha* (α) and *beta* (β). In this study, two values are observed to obtain the best form of optimal forecasting results for the future with the minimum error rate.

In this study, forecasting experiments are conducted by using one of the examples of the stock of goods with a range of five periods based on months by using the parameter values alpha (α) = 0.5 and beta (β) = 0.5. After conducting the number of experiments, it is shown from testing that the obtained MAPE (Mean Absolute Percentage Error) showed decent results, which is around 33.18%.

Keywords— *Double exponential smoothing, inventory, forecasting, information system*

I. INTRODUCTION

Recently, information technology has played an important role in companies, especially for companies that engaged in production and trade. Information technology, specifically information systems, holds many roles, including collecting, processing, compiling, storing, and manipulating data to produce information as a reference for quality decision making. In the long term, quality decision making will determine the sustainability of the company in an effort to achieve optimum profit and mitigate any risks that may arise.

One of the most important decisions making in a company engaged in production and services is the provision of stock of goods or raw materials for production. There are several implications that will affect the sustainability of the company when the management is not prudent in making related policies.

For example, when a company decides to provide limited raw materials while the demand for manufactured goods increases. This will cause disruption over the production process. Furthermore, the company will not adequately supply the needs of the market, which leads to a digression in profits.

On the other hand, sometimes it happens when a company is not thorough and supplies too many raw materials. This can affect more losses for the company, including the risk of expired and unusable raw materials, the need to provide large storage space, the risk of decreasing the economic value of raw materials, and failure in sales figure over the market. Of course, this is somewhat the company that engaged in producing goods or services must be avoided absolutely.

Currently, most small and medium enterprises still carry out the manual way and do not have a specific strategy in carrying out the task of supplying raw materials to support the production of goods and services. Of course, this will make it tough for them to achieve an effective and efficient decision in running the production operations over goods and services.

Several approaches were taken to mitigate those cases. Among them, there exist the forecasting techniques. Forecasting is the process or work of making predictions of the future based on the previous and current data and, in general, using trend analysis. An example of the simplest form is estimating the future value of a variable that has been determined based on the data given. The prediction itself is a bigger part of forecasting. Both can lead to formal statistical methods that use the concept of cross-sectional [1], based on time series [2], or less formal methods of judgment [3].

There are several categories of forecasting methods, including qualitative forecasting methods, including the Delphi method [4], market research, and historical life-cycle analogy [5]. Next is a quantitative forecasting method that predicts future data as the function of past data [6]. This method is very appropriate to be implemented in the short- and medium-term decision making, including the simple and weighted N-Period moving average [7], multiplicative seasonal indexes [8], Poisson process [9], and simple exponential smoothing [10]

There also exist other categories of forecasting approaches, including the average approach [11], naïve approach [12], time-series methods [2], seasonal naïve approach [13], drift method [14], AI-based method [15], simulation method [16] and others.

Among the popular methods, there exists double exponential smoothing as an alternative method to tackle the

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forecasting problem [17]. This method can be classified as a qualitative technique that is lean on the time series and has compatibility with the seasonality characterized data. Seasonality character is a character of time series-based data where the data reflects regular patterns and predictable changes that will occur in each season or annual calendar.

Double exponential smoothing is a method to perform forecasting task that uses the level and trend components for each calculation period. In addition, double exponential smoothing also employs two weights (or better known as smoothing parameters) to update the parameters in each time granules. At the end of the calculation, double exponential smoothing will use the Mean Absolute Percentage Error (MAPE) to indicate the level of accuracy of the adjusted time-series based values. MAPE will further express accuracy as a percentage. Meanwhile, there also exists Mean Absolute Deviation (MAD). MAD provides the amount of error expressed in the same unit, which is a percentage. As the last component, there is Mean Squared Deviation (MSD), which is a more sensitive measurement in representing errors. Among the three, MAPE is the most often used indicator to measure forecasting quality.

Previously, double exponential smoothing has also been widely used in several problems such as clock recovery problem [18], resource prediction over cloud computing [19], and pig price forecasting [20]. Moreover, double exponential smoothing is also used for short-term electricity demand forecasting problems and is used for forecasting palm oil production [21]. In this work, how the double exponential smoothing method deal with the real data to tackle the inventory forecasting problem will be intensively discussed. Experiments on functionality and accuracy will also be provided to enrich the study.

The main problem that will be discussed in this work is the planning and implementation of an inventory forecasting information system that utilizes the double exponential smoothing method. The solution offered by this work is how to predict the appropriate number of raw material requirements over a certain period of time with acceptable accuracy. From this objective, this work will measure Double Exponential Smoothing.

This paper discusses the problem as following: the related work will be briefly discussed in Section II, and Section III will mainly discuss the problem background. Moreover, the design and implementation of the proposed system will be discussed in Section IV. Section V will focus on the experiment over the proposed system. Finally, Section VI provides the conclusion from the discussion.

II. Related Works

Forecasting problems are a notable problem. Forecasting itself has various type, including forecasting with qualitative methods. It is a subjective forecasting technique based on the opinion of consumers or experts and is used when no previous data references are discovered [2]. [6] offers forecasting solutions in inventory planning using quantitative methods.

Meanwhile, works in [11] provide an alternative discussion for forecasting inventory procurement figures using the average approach. It is a technique to predict all future numbers as the average of the previous number values. While [14] discusses how the drift method, a method where the magnitude of change in the time series is calculated as the average of changes that appear in historical data, is employed to deal with the planning problem over inventory.

Then, in the discussion of forecasting, there exists a method called the time series method. Assuming that historical needs beforehand are a valuable reference source for determining future demand forecasts, the time-series method is a method that uses the basis of calculations using estimates of future outcomes. In [22] Hannan developed a solution for forecasting inventory using past values and past prediction errors as a consideration, otherwise known as autoregressive moving average, or ARMA. Then, authors in [23] utilize the ARIMA, autoregressive integrated moving average. This method is the alteration of ARMA that use inter-period change as its main forecast parameter to predict malaria. Furthermore, the deployment of a forecasting system to predict the inventory using the recurrent neural network is proposed in [24].

Finally, there exists a method called double exponential smoothing [17], the improved version of the previous one, simple exponential smoothing. Our discussion will mainly focus on this method to tackle the proposed problem.

III. Problem Background

Information systems play an essential role to support the operation in the company. Information systems provide numerous of assistance, especially in data management, namely to collect, process, index, store, manipulate, and produce suggestions or recommendations as a reference for quality decision making. For greater purposes, providing quality advice and recommendations can support the sustainability of the company in achieving its main goals, which is achieving optimum profit by reducing production costs and mitigating any risks that may arise.

Among the many problems and significant decisions that must be taken in companies, especially those engaged in trading in goods and services, there exist challenges with inventory or stock of production materials. There are high implications and risks of company operational when inaccurate decision making occurs.

When the number of predicted inventories is overly small compared to the original requirement, it will certainly have an impact on the efficiency over the production process. Meanwhile, if too many inventories are provided, there are other implications such as the emergence of storage costs, impairment of the value of the goods, and others.

The main problem in this work is how to design and implement an inventory planning information system based on the Double Exponential Smoothing method. In the end, the proposed system is able to provide forecasting with a small or acceptable margin of error.

IV. Proposed Solution

In this work, our works provide a solution that is a web-based inventory planning information system to deal with the main problem. The designed application uses a web application based on the model-view-controller (MVC), by utilizing the CodeIgniter framework. Furthermore, the proposed system will use the Double Exponential Smoothing

method in predicting the required inventory supply to support the production process.

A. MCV-Based Web Application

Model-View-Controller is a programming pattern or concept that separates the parts of application development based on the main components of an application, especially those based on websites, such as user interfaces, data processing, or manipulation, and the main part, the application controllers.

In brief, it gets that the design and process parts are separately placed. Today, MVC is the most popular concept of web-based application development. MVC itself consisted of:

a) Model

Model is part of a program that connects data and interacts with the display interface via a query on the database or web service. The model itself is a representation of the data structure in the application, which is manifested in the form of classes and functions.

b) View

View relates to everything that will be placed on the end-user, usually in the form of web pages, RSS, Javascript, and others. The programmer ought to sidestep any data processing logic in the view. Inside the view, there exist only variables containing data that ready to be displayed. The view can be said as a website page created using HTML with the help of CSS, Javascript and Jquery. Over the view, the programmer is restricted to create a direct connection to the database. The view is only devoted to displaying the resulting data from the model and controller. This section does not have direct access to parts of the model.

c) Controller

The controller is a special part that connects the model components with the view or interface. Controllers are also manifested in class and function structures, and it does not contain direct queries to the database. Its main task is preparing various variables that will be called by the view, call the model to call access to the database, and validate the data that will be inputted into the database.

The MVC used in the development of this application itself is CodeIgniter (CI) [25]. CI is a PHP framework that provides a collection of numerous libraries that can help carry out specific tasks required. The main purpose of developing CodeIgniter is to simplify programming tasks in developing a website-based application.

B. Application Flow

The main flow of this application consists of the login menu and several main flows, including the recap of inventories data, incoming inventories data, outgoing inventories data, reports, forecasting, and sales data (cashier data) as depicted in Figure 1.

C. Databases

The database used in this work is MySQL [26]. There exist eight tables to support the system, as depicted in Fig.2., to support the system, namely roles, users, incoming_goods, outgoing_goods, constant, forecast, inventory, and inventory_code tables. The 'role' table stores the distribution of user privileges, the 'user' table stores data from application users, and the 'incoming_goods' table stores data on the flow of incoming goods. While the 'outgoing_goods' table stores the outgoing goods flow data, the 'constant' table stores the alpha and beta values that will be used for forecasting, the 'forecast' table stores the forecasting results, and 'inventory_code' stores the goods or inventory code.

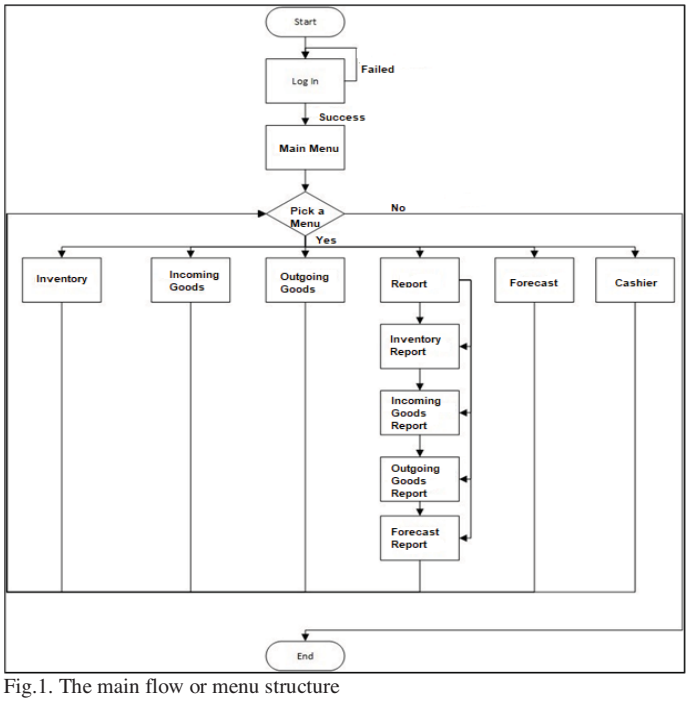

Fig.1. The main flow or menu structure

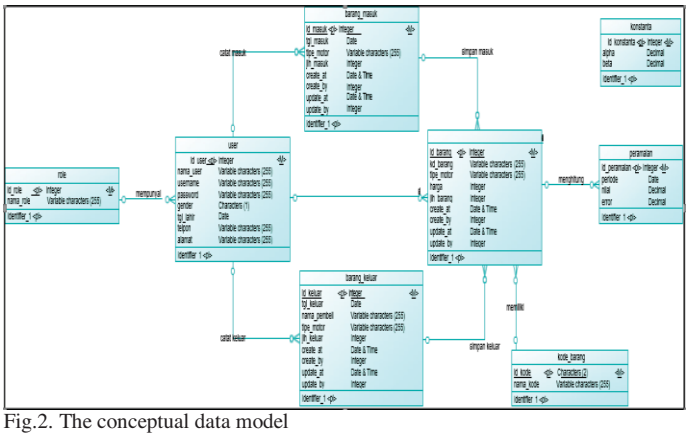

Fig.2. The conceptual data model

D. Double Exponential Smoothing

The Double Exponential Smoothing method is a single linear forecasting method proposed by Holt [17]. This forecasting performs a single smoothing then is accomplished with a double smoothing task. This method is utilized when the data shows a trend. Exponential smoothing with a trend is like simple smoothing, except that the two components have to be updated every period - the level and

the trend. The level is an estimate that is transferred from the data value at the end of each period. The trend is a smoothed estimate of the average growth at the end of each period.

The rationale for both single and multiple exponential smoothing methods is that the smoothing value will be present before the actual data if there is a trend component in the data. Therefore, for single smoothing values, it is required to combine a double smoothing value to adjust the trend. The double exponential smoothing method that can be used to solve linear trends is the Holt two-parameter method. In the Holt method, the trend value is not straightened out by double smoothing directly, but the trend smoothing process is carried out by using different parameters from the one that is used in the original data smoothing.

In predicting data, Exponential Smoothing will estimate the average value of the period data used to obtain the forecast value for the next period. Holt Double Exponential Smoothing is a model that is usually used on data with linear trends that are not influenced by seasons.

In performing smoothing, different parameters are used from the actual data. After smoothing is performed, the system estimates the trend. The Holt model uses two parameters, namely, α and β.

The formula used in the Double Exponential Smoothing method is:

$$S_t = \alpha X_t + (1 - \alpha)(S_{t-1} + T_{t-1}) \quad (1)$$

$$T_t = \beta(S_t - S_{t-1}) + (1 - \beta)T_{t-1} \quad (2)$$

The system requires the first value ($S1$) as written in Equation 1 to calculate the smoothing value. However, because the value of $S1$ at $T1$ is not known, the value of $S1$ can be used as the first actual data value, namely $X1$. So the value $S1 = X1$. Meanwhile, to calculate the estimated trend, $T1$ can be assumed as $T1 = X2 - X1$. Then, to calculate the forecast value for the future period, it is as depicted in Equation 3.

$$F_{t+p} = S_t + TtP \quad (3)$$

, where:

S_t = Single smoothing value
T_t = Trend smoothing value
F_{t+p} = Forecasted value in the next period
X_t = Actual data in time – t
α = Smoothing constant value (0 – 1)
β = Smoothing constant value (0 – 1)

E. Mean Absolute Percentage Error (MAPE)

MAPE is one of the popular methods for measuring the quality of forecasting results against the real value condition [27]. MAPE is obtained from the average of the overall percentage error (differences) between the actual data and the forecasted data for all time granules. In measuring accuracy, the forecast results will be compared with time series data and are shown as a percentage. Equation 4 shows the percentage error in a time granule, while MAPE in Equation 5 calculates the average of all error percentages from all time-series data.

$$PE = \frac{(Xt - Ft)}{Xt} \times 100\% \quad (4)$$

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}|PEt| \quad (5)$$

F. Implementation

Our application consists of several in which depicted in Fig.1. The application has been built using PHP version 7 and uses the structure of the MVC framework, CodeIgniter. Some of the pages and forms that have been successfully presented are depicted in the following: the login form and the dashboard page is depicted in Fig.3 and Fig.4, respectively. Moreover, Fig.5, along with Fig.6, represents the Staff and Inventory Management page. Finally, Fig.7 depicts the figures over the inventory forecast page.

Fig.3. Login form

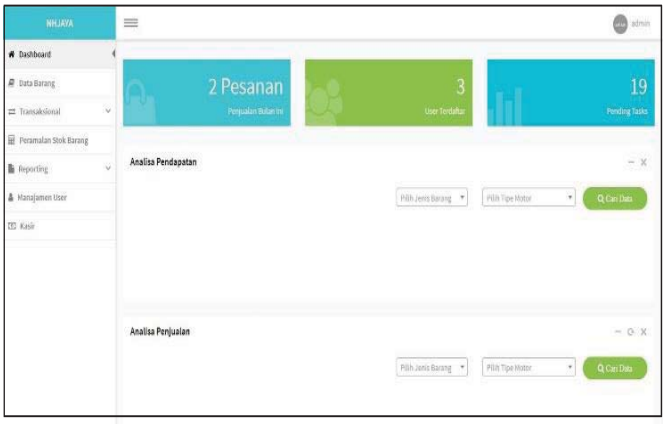

Fig.4. Dashboard page

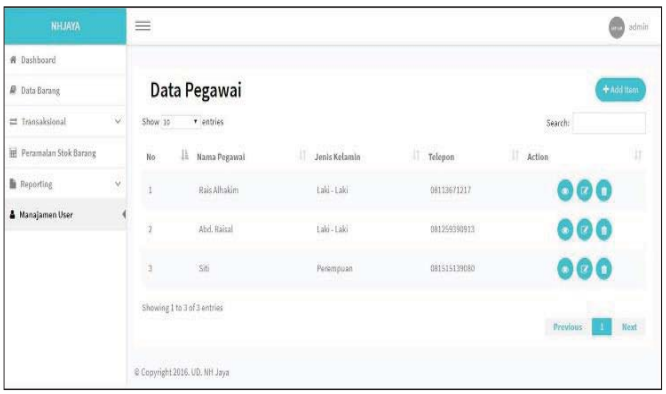

Fig.5. Staff Management Page

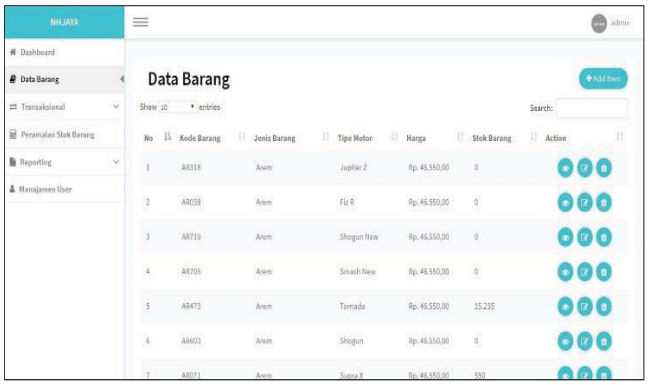

Fig. 6. Inventory Management Page

Fig. 7. Inventory Forecast Page

V. Result

In the evaluation and testing section, our discussion carried out a series of scenarios, namely for functionality testing and accuracy testing. The functionality test is carried out to test whether the basic functions of an application are in accordance with the design and development planning, while the accuracy test is used to measure the accuracy of functions based on Double Exponential Smoothing in forecasting inventory supply figures.

Functionality tests are carried out on several forms and basic functions, including the login function, inventory management function, incoming goods function, outgoing goods function, forecasting function, and staff management function. The results obtained from the functionality test are described in Table I.

TABLE I. Result Of Functionality Test

Page Name	Result	Status
Login	The login form performs properly. Authentication is running correctly, and it is appropriate according to the database.	Valid
Dashboard	Data appears correctly. All diagrams display appropriate data. The login form is working well.	Valid
Staff Management	The staff management page displays the entire data. The edit and delete functions also work well.	Valid
Inventory Management	The inventory management page is able to display data and quantities correctly. All functions of recording incoming and outgoing inventory are running well.	Valid
Inventory Forecast	The forecast page works well according to the input of alpha and beta values from users. The system can also provide the level of accuracy that is obtained.	Valid

Table I describes that all functions runs properly and fit according to the initial design of the system. All forms are able to display, store, and modify data according to system requirements. Furthermore, the forecast function has also been implemented and provides the appropriate response to the system. In conducting the accuracy test, the discussion uses the real sales data from a medium-sized industry in Indonesia from November 2018 to April 2019. By setting the value of $\alpha = 0.5$ and $\beta = 0.5$, Fig.8 describes the results of the comparison between real sales data and forecast-based data when the values over. It can be seen from the figure that the difference between forecast data and real data is getting smaller until it has a difference of only about 2.65% at the end of the calculation phase. Overall, the MAPE value obtained was quite small at around 33.18%.

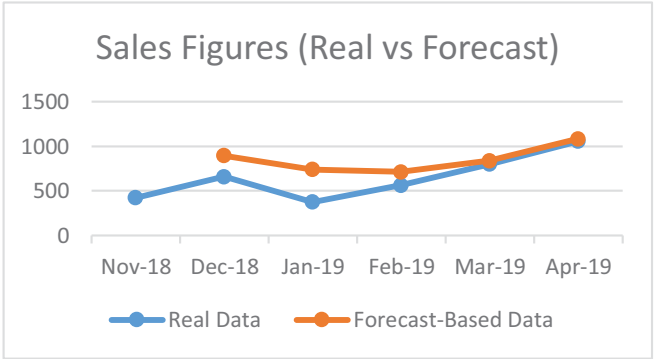

Fig. 8. Sales Figures (Real vs Forecast)

VI. Conclusion

This work has designed and implemented an inventory forecasting information system by utilizing a well-known Double Exponential Smoothing. From the functionality tests carried out, it has been proven that all system functionality runs properly in accordance with the initial design. Moreover, the accuracy test, it finds that at the end of the forecasting point, the difference between the original data and the forecast data is only around 2.65%. Meanwhile, the overall MAPE value obtained is around 33.18%.

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