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Application of Holt-Winter Exponential Smoothing Method to Design a Drug Inventory Prediction Application in Private Health Units

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Abstract

This research aims to see how to design a drug supply prediction application using the Holt-Winter Exponential Smoothing method. The collection methods used in the research are as follows: observation, interviews. The prototyping system development method includes several important stages in designing research applications. The first stage is communication. After that, the Quick Plan stage. Construction of prototype stages. The final stage, deployment delivery and feedback, is the phase of system use by users. In addition, the team also conducts regular system maintenance to ensure optimal performance. These stages together form an iterative process for developing research applications using the prototyping method. Based on the research results, it was found that the test results for the drugs amoxicillin, cefixime, paracetamol, and CTM showed that the MAPE value was less than 10% for these four drugs, which means that the predictive value has quite high accuracy. So it can be concluded that the Holt Winter Exponential Smoothing algorithm can be well implemented to predict drug supplies.

Keywords: Holt-Winter Exponential Smoothing, Mysql, Drug Supply, Time Series.

1. Introduction

Various types of health personnel, led by a medical officer, manage a clinic, which is a health service facility providing basic and specialist medical services. The availability of medicines is a crucial element in maintaining and improving the quality of health services in clinics [1]. Ensuring the availability of medicines needed to treat the patient's illness or as prescribed by the doctor. The availability of adequate medicines is very important in the context of health services. This allows the clinic to provide appropriate and effective services to patients, ensuring that they receive the necessary treatment according to their health condition [2]. In this context, good drug supply management becomes a vital aspect of meeting patient needs and ensuring efficient drug stock management within the clinic. By ensuring adequate medication availability, clinics can maintain optimal quality of health services, increase patient trust, and strengthen their reputation as reliable health service providers. Thus, the role of the availability of medicines is an inseparable aspect of efforts to improve the quality of health services in the clinical environment [3].

Medicines are a vital component in the implementation of health efforts, and the costs allocated to medicines form a significant part of total health costs. In developed countries, costs for medicines generally account for around 12% of the overall health budget. However, in developing countries, the proportion of drug costs can be higher, reaching between 45 and 60% [4]. The national drug policy confirms that drug costs form a significant share of total health costs. Based on surveys conducted, the average cost of medicines ranges from 40–50% of the total operational costs of health services. With this huge proportion of costs, effective and efficient drug management becomes very important. Appropriate medication management involves steps to ensure adequate medication availability, assured quality, and rational use [5]. Good coordination between all related parties is very necessary to ensure that the drug supplies needed by doctors are always available when needed. This supports the provision of quality and efficient health services and helps reduce health costs that can occur due to irregular medication management. Thus, correct medication management is a key factor in improving the overall quality of health services [6].

Medicine is an irreplaceable tool. Because a shortage of medicines in health care facilities can have an impact on decreasing public trust in these institutions, Therefore, drugs need to be managed well. Drug management aims to ensure that drugs of sufficient type and quantity are easily obtained at the right time. In order to achieve this goal, it is necessary to create an effective drug management planning system that ensures the drugs planned are in accordance with the needs [7]. Fluctuations in drug use from the results of interviews and observations show

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that some drugs tend to have seasonal data patterns. Seasonal data patterns are short-term movements of less than one year that repeat regularly [8]. In January, April, July, and October, demand for paracetamol always increases every year. In January 2020, it was 1,200; in April, it was 1,250; in July, it was 1,240; and in October, it was 1,240, while in February, May, August, and November, the demand for medicines decreases every year. In February, the demand for medicines is 1,200; in May, it is 1,300; in August, it is 1,250; and in November, it is 1,220. This makes it difficult to estimate drug needs for the following month. Therefore, we need a method to predict and plan drug needs more precisely [9].

Three forecasting techniques the Holt-Winter Exponential Smoothing Method, the Single Moving Average Method, and the Autoregressive Integrated Moving Average (ARIMA) Method can be applied in light of prior study findings. Each of these three approaches has benefits and drawbacks. The Holt Winter Exponential Smoothing Method is better suited for drug data with seasonal data patterns, while the Single Moving Average method is better suited for data with stagnant patterns. Prior studies contrasted Holt-Winter Exponential Smoothing and the ARIMA technique [10]. The Holt-Winter approach is straightforward and can yield precise forecasting outcomes. When used in practice, this approach is often simple to implement and effective. Although the Holt-Winter approach is the best for predicting future events, future forecasts should not be made more frequently than the seasonal cycle of the series because doing so could decrease the accuracy of the forecast. In the meanwhile, forecasting with the ARIMA approach does not always yield the expected outcomes [11]. Aside from that, there are other unmet assumptions in the ARIMA model. The idea that the past data pattern won't alter throughout forecasting is among the most crucial ones. Therefore, the Holt-Winte approach was used by researchers to execute drug supply planning. Since exponential smoothing is appropriate for seasonal data patterns and can yield precise forecasting results, it is used to handle data that exhibits seasonal trends [12].

Forecasting time series data often utilizes the exponential smoothing method. This technique aims to smooth data by removing irregular components from it [13]. In predictions using this method, predictions for one unit of time in the future (t+1) are known based on past data and the latest data (Xt) using a weighted average of previous data [14]. This smoothing technique is known as the single (or simple) exponential smoothing method and is usually applied to data that does not have trend or seasonal components [15]. One unit of time in the future (t+1) is predicted by this method [16]. On the other hand, Holt's exponential smoothing approach with two parameters (sometimes called double exponential smoothing) can be applied if there is a trend in the data [17]. While beta (β) smoothes the trend, alpha (α) smoothes the data's "level" or average. When there are trend and seasonal components in the data, the Holt-Winters Exponential Smoothing method can be applied [18] [19]. Three smoothing factors are needed for this method: α for "level," β for trend, and γ for seasonal component. Holt-Winters uses two models: the multiplicative seasonal model and the additive seasonal model, depending on the features of the data [20]. This exponential smoothing method with its various variants has become a useful tool in time series data forecasting, allowing better analysis of trends, seasonal patterns, and other components in the data to make more accurate predictions for the future [21].

Prototyping often means that customers define a number of general software goals [22]. However, it cannot specify detailed requirements for the functions and features that the software being developed will have [23]. In other cases, software developers may feel uncertain about the efficiency of an algorithm that will be used in software development, or they may also feel uncertain about the software's ability to adapt to the operating system used [24]. Concerns over the type of human-computer interaction that would be employed might also be present. The prototyping paradigm might be the best choice in these and many more circumstances [25]. When creating a device that will be redeveloped, the prototyping paradigm works well. A prototype needs to be assessed and changed; it is not a finished product. When a prototype is made to satisfy user needs and help developers better understand those needs, changes may be made [26].

2. Research Methods

Data collection methods are the techniques used to collect data. The data collection methods used in the research are as follows: observation and interviews. The prototyping system development method includes several important stages in designing research applications. In the first stage, we conduct interviews and observations and collect data from various sources such as journals, books, and the internet to analyze software needs. After that, the Quick Plan stage is a continuation of the process of analyzing the user's needs to plan the next steps. Quick design modeling then translates the analyzed requirements into software planning with a focus on algorithm design, database design, UML design, and user interface design. The construction of prototypes stage is a code creation process that implements a previously created design. After coding, the system undergoes testing to ensure its success. The final stage, deployment delivery and feedback, is the phase of system use by users. In addition, the team also conducts regular system maintenance to ensure optimal performance. These stages together form an iterative process for developing research applications using the prototyping method [27].

3. Results and Discussion

Based on the results of the interviews conducted, the drug planning process currently still relies on manual calculations to order drugs every month. The current method used lacks a specific calculation to determine the exact quantity that should be ordered. As a result, there are irregular fluctuations in drug availability, resulting in an excess or shortage of drug stock. Several unexpected or less accurately predicted factors in manual calculations can cause this irregular drug fluctuation. This condition can cause an inability to accurately estimate the required amount of medication for monthly needs. To increase efficiency and accuracy in drug supply planning, it is necessary to use more systematic and structured methods, such as more sophisticated historical data-based forecasting methods such as Holt-Winters Exponential Smoothing or other methods. By applying appropriate forecasting techniques and using available historical data, it will be possible to make more accurate estimates regarding the amount of drug inventory needed for a certain period. Apart from that, the use of an automated inventory management system or application can also help in monitoring drug stocks, identifying demand patterns, and providing warnings or predictions to reduce the risk of an excess or shortage of drugs in the future. Thus, the implementation of more sophisticated technology and planning methods can help improve the accuracy of drug inventory planning and reduce the problem of irregular stock fluctuations.

The proposed system, based on an analysis of existing systems, focuses on key steps in drug supply management in clinics. First, the pharmacist's main responsibility is to check the available drug supplies. After checking the available drug supplies, the pharmacist uses prediction methods to estimate future drug supply needs. Next, the pharmacist must create a report that includes a list of medicines requiring purchase based on these predictions. The pharmacist then submits this report to the head of the clinic for review and approval. After approving the drug purchase report, the head of the clinic carries out the drug purchase process in accordance with the needs stated in the report. The head of the clinic will hand over the purchased medicine to the pharmacist. The pharmacist's duty is to receive newly purchased medicines and update the medicine stock according to the receipt. The aim of this series of processes is to improve drug inventory management in clinics. This system aims to ensure that drug supplies are available in adequate quantities according to needs, avoid unwanted stock shortages or excesses, and ensure the availability of the right drugs when needed. This proposed system aims to increase efficiency and accuracy in drug inventory management in the clinical environment.

Designing an application flowchart for the drug procurement prediction process begins with retrieving drug sales data from the previous period. The system then calculates existing levels, trends, and seasonal factors. The next step is to initialize the alpha, beta, and gamma values used in the Holt-Winters method. The process continues by carrying out exponential smoothing, trend smoothing, and seasonal smoothing to then forecast future drug needs. The forecasting results are displayed, and the process is repeated iteratively to obtain the smallest mean squared error (MSE) value, indicating the best accuracy in forecasting. Next, we will explain the manual calculation of the Holt-Winters Exponential Smoothing method. This method involves estimating levels, trends, and seasonal components to perform forecasting. The calculation begins with the initialization of initial values for level, trend, and seasonal factors. Next, we carry out calculations to adjust these values using formulas related to the Holt-Winters method. After iterating and adjusting the values, the Holt-Winters method produces forecasting results for the next period. To increase forecasting accuracy in predicting future drug needs, we continually repeat and update this process with the latest data.

The series of activities presented describes in detail how users interact with the medication inventory management system application. The initial login-related stage asks the user to access the application URL and displays the login page. Here, users are asked to enter their username and password before pressing the login button. The system then synchronizes to verify the combination. If the user enters correct data, they will be directed to the dashboard page; otherwise, a login failure message will appear, redirecting them back to the login page. Then, there are a series of activities related to drug sales transaction management, where users select the sales menu to carry out various actions. The sales data input process involves accessing the sales page, filling out a data addition form, and saving the entered transaction information. Users can also view, print, or delete recorded sales transactions in the system. Apart from that, there are activities related to drug data management, where users can access the master data menu to manage drug, user, and contact information. Users can add, update, or delete drug and user information by accessing the appropriate form and saving the necessary changes. In addition to managing contact information, administrators can access special menus, fill in relevant forms, and save changes that have been made. The entire series of activities reflects how interactions occur between users and the drug inventory management system application, which involves a number of important functions such as login and sales transactions, as well as effective and structured management of drug, user, and contact data.

The sequence diagram depicted illustrates the interaction between the administrator and the system in the drug inventory prediction planning system. First, the admin interacts with the login system to enter the application. The administrator is asked to enter a username and password. After that, the system validates the username and password entered by the admin. If the data entered is incorrect, the system will display an error notification message. However, if the data entered is correct, the system will display a dashboard page as access to the system. Furthermore, there are interactions related to input, deletion, display of details, and printing of sales transaction data by the admin. The admin selects the sales menu, which the system responds to by displaying the sales page. From there, admins can take actions such as adding sales data, deleting transactions with confirmation via alerts, viewing detailed transaction data, and printing sales reports. Each of these interactions involves a system response in displaying the appropriate page or alert as well as carrying out checks and actions based on admin input and requests regarding sales transactions. This entire sequence diagram provides a detailed overview of the step-by-step interactions between the admin and the system in a drug inventory management system, which includes login validation, sales transaction management, detail display, and sales report printing.

The process explained through these steps describes the admin's interaction with the system in managing drug, user, and contact data in the application. First, the admin selects the master data menu, to which the system responds by displaying the master data page. From there, admins can perform various actions related to data management, such as adding, deleting, or editing information. In drug data management, the admin can select the drug details menu to display a list of existing drug data. Admins can add new drugs via the input form, delete drugs by clicking the delete button and confirming through an alert, or edit drug data by selecting the edit button and making the necessary changes. Each of these actions is accompanied by a system response, saving the changes and redisplaying the drug details page. Meanwhile, in user and contact data management, the steps are similar. Admins can access the user or contact menu, add, delete, or edit user or contact data via the appropriate form, with the system saving changes and displaying the relevant page again. This entire process provides an overview of how the admin interacts with the system in managing drug, user, and contact data, with each step based on the selected menu, followed by the system's response to the changes made.

At the system coding stage, using the HTML, PHP, Javascript, and MySQL programming languages as the database, a number of lines of code will be implemented in this final project. The structure and function of the previously designed system will be described by this line of code. This line of code will consist of setting up the interface using HTML, application logic using PHP, setting dynamic interactions using Javascript, and storing and managing data using MySQL. After the code implementation is complete, the researcher will test the system using the black-box testing method. The researcher carries out this testing by running the system as a whole to ensure that it runs according to the plan set at the beginning. The main focus of this testing is to ensure that the system functions according to the predefined specifications, without considering the internal structure of the code. The goal of testing is to verify whether the system behaves according to predefined specifications without regard to the internal structure of the code. Black-box testing involves testing the entire system by providing input and evaluating the resulting output. Researchers can assess system functionality from the user's perspective, without considering the internal logic of the code used. This testing can help ensure that the system can operate according to its stated objectives and deliver the expected performance to end users. Thus, this system development stage involves implementing code using the previously mentioned programming language, followed by system testing using the Black-Box method to ensure the system's functionality and conformity with previously established specifications.

The process of implementing the Holt-Winter Exponential Smoothing method in planning drug supplies for the next month involves structured steps to predict drug needs. In the first stage, we select the drug data to be predicted. For example, to predict drugs in January 2023, the system will take drug data from the previous two years, namely drug data from January 2020 to December 2022. The system uses this data to improve the accuracy of prediction results for the following month. After the data to be predicted has been selected, the system will determine the alpha, beta, and gamma values that produce the smallest mean absolute percentage error (MAPE) values. The system uses MAPE as an evaluation metric to assess prediction accuracy. The system will experiment with several combinations of alpha, beta, and gamma values to find the combination of values that produces the smallest MAPE. After the alpha, beta, and gamma values are selected, which produce the smallest MAPE, the next step is to display the prediction results for the next month, in this case, February 2023. These prediction results will be displayed in the form of numbers or graphs showing estimated inventory needs for medicine for the coming month based on the Holt-Winter Exponential Smoothing method. The system aims to assist in planning drug supplies more accurately and efficiently by providing users with information on predicted drug supply needs for the next period. These predictions are based on historical data processed using the Holt-Winter Exponential Smoothing method.

4. Conclusion

Drug testing results for Amoxicillin, Cefixime, Paracetamol, and CTM in January 2023 showed that the mean absolute percentage error (MAPE) value for these four drugs was below 10%. The Holt-Winter Exponential Smoothing algorithm produces a forecast or prediction value with a fairly high level of accuracy, as indicated by this condition. The low MAPE indicates a small difference in percentage between the actual value and the value predicted by the Holt-Winter Exponential Smoothing method. The high accuracy in predicting drug supplies indicates that the algorithm can effectively forecast drug supplies for the following months. The conclusion that

can be drawn is that the Holt-Winter Exponential Smoothing algorithm is feasible and effective to use in forecasting the supply of drugs such as amoxicillin, cefixime, paracetamol, and CTM. The use of this algorithm provides accurate predictions and can be a good basis for planning and managing drug supplies in the future.
Further development is needed to improve the quality of the applications created. Several suggestions have been proposed to enhance the usefulness and quality of this application in the context of further development like Expansion of Forecasting Methods. This system should not solely rely on the Holt-Winter Exponential Smoothing method. Future research could consider combining it with other forecasting methods. Combining it with other forecasting methods is expected to increase the level of accuracy of drug predictions, taking into account the unique characteristics of each drug. Several forecasting methods will be utilized to enhance the application's ability to provide more precise and accurate predictions regarding drug supply needs. Future research is expected to focus on developing a more attractive, dynamic, and modern user interface, in addition to functional aspects. The goal is to make the application's user interface more attractive, dynamic, and modern. By improving the display design, it is hoped that users can interact with the application more easily and more pleasantly, which can improve the overall user experience. By combining broader forecasting methods and improvements to the user interface, it is hoped that this application can provide greater benefits and become a better solution for planning and managing drug supplies in clinical and pharmaceutical environments.

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