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StockTM: Accurate Stock Price Prediction Model Using LSTM

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Abstract
Stock prediction aims to forecast a future stock price trend to assist investors in making strategic investment choices. However, it is hard to predict the price in dynamic conditions, which causes investors hard to anticipate equities because of the unstable prices. Thus, in this paper, we present a novel stock price prediction model based on the Long Short-Term Memory (LSTM) algorithm. Several steps are taken in creating a stock prediction model, including collecting datasets, pre-processing, extracting features, training and validating the model using evaluation metrics techniques. Based on the experimental results, the proposed prediction model can obtain good accuracy with a small error rate in an extensive dataset training. Therefore, it can be a promising solution to deal with the dynamic prices. Moreover, the proposed model can achieve the results obtained: RMSE EMA10 of 0.00714, RMSE EMA20 of 0.00355, MAPE EMA10 of 0.07705, and MAPE EMA20 0.05273.

Keywords:
Prediction, Stocks, Long Short-Term Memory, Deep Learning

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1. Introduction

The stock price is the supply and demand result among buyers and sellers in the stock market over a period of time. The significant elements that influence stock prices are supply and demand. There will be a strong demand for a stock if many people want to purchase it, and the stock price will increase, and vice versa. On the other hand, if many individuals desire to sell a stock, the supply will grow and decrease the price [1]. The fluctuating stock price is influenced by macroeconomic factors such as inflation, gross domestic product, oil prices, and the rupiah exchange rate. Therefore, several communities presented stock price predictions to anticipate the rise and fall of stock prices [2].

The inflation rate can indirectly affect stock prices [3]. Inflation is a market mechanism caused by several factors that can increase costs in general and continuously. First, a high inflation rate can decrease purchasing power. Second, the low profit will affect companies that produce the community's needs. Third, the low level of company profit can impact the investors' dividends. Thus, it is challenging for investors to find an appropriate company and invest in the company [4].

Gross domestic product (GDP) is a factor to estimate economic development in a country. Economic growth can increase the purchasing power of the people, and companies can gain increased profits through increased sales. GDP comes from the number of consumer goods that do not include capital goods. The decrease in the number of consumer goods causes a low economy and causes a decline in sales turnover. The increase in casualties also caused the decreasing share price [5]. Oil price movements

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may be favorable or unfavorable, depending on supply and demand. Moreover, increasing oil prices negatively influence corporate income, which can cause the devaluation of the stock market [6].

The exchange rate is the amount of currency for foreign currencies, for example, the Indonesian currency (Rupiah). Fluctuation in exchange rates is a significant factor in economic growth because it can affect the prices of domestic and foreign products and services. The low exchange rate can weaken purchasing power which can trigger an unattractive level of investment. Furthermore, exchange rates have a negative influence on the stock market. For instance, when the exchange rate against the United States dollar is appreciated, it causes the high price of goods in the domestic market. It reduces the volume of exports [7], decreasing corporate profits and making it challenging to predict shares [8].

The stock market plays a vital role in the growth of a country's economy [11]. Therefore, stock market forecasting has been regarded as a critical issue in economics. However, due to the stock market volatility, accurate market forecasting is often considered as one of the most challenging tasks [9]. Moreover, stock price fluctuations are non-linear and non-stationary. As a result, predicting price movements with any degree of certainty and accuracy is very difficult. In addition, it is very challenging to estimate the prices based on both current and historical data [10].

Fortunately, the learning approach can be a novel solution to predicting the dynamic price of shares. For example, a paper proposed SVM to indicate the active price by accurately predicting stock values. The study tested their model on many datasets to produce more accuracy in prediction. However, it needs to consider macroeconomic factors and other variables as standard input to allow the model in the prediction process [14].

The current paper proposed deep learning to deal with the dynamic stock price. Since CNN was introduced to analyze financial data, many academics have devoted their efforts to forecasting stock market movements by turning stock market data into pictures. However, most existing studies only focus on individual stock information and ignore stock market information [12]. Feature extraction from financial data is one of the most challenging tasks in market prediction in many case studies. It has remained an issue when getting less attention in the current years [13].

Therefore, this paper proposes a new prediction model for addressing stock price prediction problems by adopting a deep learning algorithm to detect dynamic prices. In stock price prediction research, our study has the following contributions:

1. We design a new predictive model to predict stock price movements. Instead of using a conventional learning model, we build a deep learning model to construct a novel stock price prediction. Based on the experimental result, we obtain accurate results with a low error rate.
2. We evaluate the model for more accurate results on stock price predictions. Then, we present a matrix evaluation graph to prove the model. This study trains a massive dataset to produce a predictive model. The model will process the stock dataset as input and use the model to predict stock movement in real-time.
3. This study presents the deep learning method to produce an accurate stock price prediction model based on comparative price data. The proposed model can predict price movements and future stock prices to achieve a better result than the traditional machine learning approach.

Organization: The structure of this journal is prepared as follows: Part II provides insights on related work. Part III explains the problem definition of this study. Part IV describes the experimental arrangements consisting of feature learning techniques, data sets, and data pre-processing, and Part V presents the results and detailed analysis of this study. Finally, part VI provides conclusions and highlights some open issues in stock prediction research.

2. Related Works

Deep learning is a growing research area to deal with various issues [29][30][31][32]. A paper discussed stock prediction using the SVM that showed RMSE score = 0.124 and MAPE = 97%, square SVM gave RMSE 0.097 and MAPE 98%, and cubic SVM gave RMSE 0.10 and MAPE 98%, while acceptable Gaussian existence had fewer errors with RMSE of 0.009 and MAPE of 98.6% [13]. Another article explored the ANN algorithm to forecast a stock's closing price. The findings revealed that the ANN method obtained the best values with RMSE values (0.42), MAPE (0.77), and MBE (0.013) [14]. Another article discussed the GWO-ENN algorithm for predicting stocks. The findings gained that the GWO-ENN model can produce an accurate result for one-day stock forecasts [15].

A study implemented the RNN- LSTM to predict stock market prices, showing that RNN-LSTM algorithms produced more accurate results than traditional machine learning algorithms [16]. Other researchers utilized the LSTM-CNN algorithm to predict stock prices and produced RMSE (0.098), RMAE (0.2291), and MAPE (0.0209), 22.09%, 20.89%, and 38.17% [17]. Another study proposed a CNN to construct a capable model for forecasting stock prices with sequential data [18].

Current communities also explored stock price prediction using the S&P 500 and DJIA dataset. Based on the experimental result, the LSTM approach can gain a coefficient of determination score that is more significant than 0.94, and the MSE is less than 0.05 [19]. To forecast the stock market's closing price, other researchers also used another LSTM technique to improve the accuracy of predictions and reduce the delay time [20]. The current article conducted a study using the Deep-Conv LSTM Model for stock prediction to minimize MSE and an RMSE [21].

An article proposed research on stock price prediction using the LSTM Method. The findings revealed that the LSTM method obtained RMSE and MAPE values of 0.221 and 1.667% [11]. Another researcher proposed the SNN algorithm with 85.37% accuracy score, and the LSTM-SNN hybrid provided 86.28% accuracy score [22]. In another study, researchers adopted the ARFIMA-LSTM algorithm. The findings revealed that the ARFIMA-LSTM hybrid model improved 80% accuracy on RMSE compared to traditional models [23].

Current papers proposed research using the Backpropagation method for stock price prediction. The findings show that the LLE-BP model has a better prediction accuracy and can accurately forecast stock prices [24]. Another researcher presented the CEEMDAN-LSTM which obtained MAE 3.9177, RMSE 4.8291, and MAPE 0.1617 [10]. To predict stock prices, other researchers also use the LSTM method. The research constructed Fuzzy CSA-based Deep LSTM and produced MAE = 0.4811, and the RMSE is at least 0.3905, respectively [25].

Therefore, we propose a novel model to predict stock price fluctuation by training the large dataset as the feature. The model predicts the price movements and helps investors' decisions in the real market. Thus, it can be a promising solution to predict the stock price prediction in the real market.

3. Proposed Method

This section will provide a formal definition of the problem and some concepts in this journal.

A. Problem Definitions

This study focuses on stock price predictions using a close price dataset using the LSTM algorithm. In equation 1, the dataset is represented as a feature vector (x), with a bias (b). Classification will pass data on functions that have parameters. The function calculates the weight of each feature on the vector by multiplying it by the parameter.

Equation 1 can be rewritten as equation 2, where x_1 is the I element of the x vector. This function has a range (-∞, ∞). The regression function will produce a constant value used for the categorical class.

Table 1 Mathematical Notation

Variable	Information
$f(x)$	Feature vector
f_t	Forget gate
i_t	Input gate
o_t	Output gate
C_t	Memory cells
W_f, W_i, W_c, W_o	Matrix weight
b_f, b_i, b_c, b_o	Vector bias
Tanh	Activation function
h_t	exodus

In this paper, we adopt thresholding or giving a specific value limit. For example, if $f(x) >$ threshold is entered into the first class, and vice versa if $f(x) \leq$ A threshold is entered into the second class. Thus, the point becomes the dividing field between the first and second classes. In general, the threshold technique is applied by using the sign function (equation 3) to change the value of the position to [-1,1] as an output (equation 4), where -1 represents the input categorized into the first class and the value 1 represents the input classified into the second class.

$$f(x) = x.w + b \tag{1}$$

$$f(x) = x_1 w_1 + x_2 w_2 + \cdots + x_N w_N + b \tag{2}$$

$$sgn(x) = \begin{cases} -1 if x<0 \\ 0 if x = 0 \\ 1 if x>0 \end{cases} \tag{3}$$

$$Output sgn = \left(f(x)\right) \tag{4}$$

B. Proposed methods

In this study, we utilize the LSTM algorithm to predict stock prices. The LSTM method is one of the most widely used RNNs for processing and forecasting time series. It is designed to prevent long-term dependence difficulties. The RNN's hidden layer neurons are replaced with a sequence of individual memory cells in the LSTM model. The condition of the memory cells is crucial [10].

The LSTM model filters input via the gate structure to maintain and update the state of the memory cell. The door's construction includes information, forget, and output gates. Three sigmoid layers and one tanh layer make up each memory cell [26].

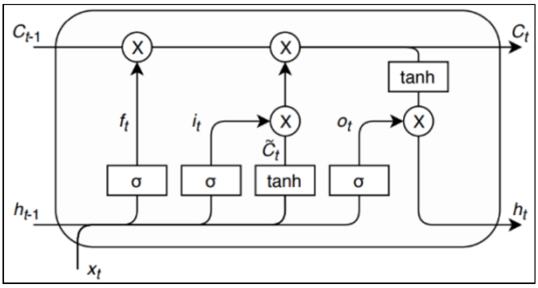

Fig. 1: LSTM Architecture

The forget gate is used to determine what kind of data to store or dispose of in memory cells.

$$f_t = \sigma\left(W_f.[h_{t-1}, x_t] + b_f\right) \tag{5}$$

σ refers to the Sigmoid activation function, whereas w and b denote the weight and offset, respectively.

Sigmoid output a number from 0 to 1, and f_t Determine how much information about the cell's status could pass in the last time. For example, 0 means that no data may die, indicating that all data is permitted to flow through. The input gate is used to identify the information that needs updating.

$$i_t = \sigma(W_i.[h_{t-1}, x_t] + b_i) \tag{6}$$

$$\tilde{C} = tanh(W_c.[h_{t-1}, x_t] + b_c) \tag{7}$$

i_t Refers to the amount of data that sigmoid must update. A value of 0 indicates that it has not been updated, whereas a value of 1 indicates that it has been completely updated. $\tilde{C}_t$ Refers to the production of updated alternative content via tanh. The forget gate and input gate define the information to be transmitted. The cell state gate is used to update the old value C_{t-1} to a new value C_t.

$$C_t = f_t * C_{t-1} + i_t * \tilde{C}_t \tag{8}$$

The Output Gate is used to determine information obtained from the output

$$o_t = \sigma(W_o.[h_{t-1}, x_t] + b_o) \tag{9}$$

$$h_t = o_t * tanh \tag{10}$$

o_t refers to the amount of data that must be included in the output, and 0 indicates that the result contains no information, and one a method to export all of the data, h_t I am referring to specifying the output section.

4. Experimental Setup

A. Main Ideas

The basic idea of our study aims to create a prediction model based on the closing price data feature that uses the LSTM algorithm to forecast future stock prices. The LSTM algorithm is often used to tackle the issue of stock price forecasting. The LSTM algorithm is very suitable for dealing with stock price prediction problems because it can achieve accurate results and overcome long-term matters [27].

B. Dataset

To conduct this experiment, we collected a stock price dataset obtained from yahoo finance which utilizes the close price dataset of the listed company PT. Indofood Sukses Makmur Tbk (Indonesia Listed Company in IHSG). We take the share price from May 2, 2011, to April 30, 2021, with 2,485 data and separate the training dataset to 80% or 1,988, and the testing dataset to 20% or 497. Table 2 describes the dataset to conduct our study.

Table 2 Dataset

Dataset	Sample
Dataset Training	1.988
Dataset Testing	497
Total	2.485

C. Pre-Processing Data

In the pre-processing stage, we conduct several steps, and firstly stock data is cleaned. It's possible that the raw dataset is incomplete or contains missing values. As a result, rows with a value of zero will be deleted during the pre-processing step [28]. To minimize errors, normalization is carried out on the dataset by changing the actual value to a range interval value [0,1] to get the best predictive value. The normalization technique used is the mix-max scaler. As for the min-max scaler normalization formula is:

$$x' = \frac{x - x_m}{x_{max} - x_m} \tag{11}$$

Table 3 Normalization

Variable	Information
x'	Normalized value
x	The actual value of the data to be normalized
x_m	Actual data's minimum value
x_{max}	Actual data's maximum value

D. Prediction Method

This study builds a model for predicting stock prices by conducting training and testing processes. The model calculates the comparative price data feature at the training stage to establish an efficient model. This study also conducts the pre-processing step to convert the integer value into a vector through vectorization techniques. We utilize the normalization and scaling process using Min Max Scaler to simplify building our model.

This experiment constructs our model by calculating 80% training dataset and 20% testing dataset. First, vector training data will be used in the network learning process for the modeling process, and we will provide the validation data to test the network performance. Finally, we use a testing dataset to measure the prediction model's performance. After these stages, we can produce an adequate model using the LSTM algorithm.

5. Result & Analysis

A. Prediction Test

In this study, we gather the dataset by using the close price data feature. Then, we calculate our model performance by considering several indicators such as moving averages and EMA as indicators of the current prices. In this experiment, we test our model to predict the next 20 days of the stock prices. The model concludes that the stock will decline in the next 20 days. The prediction graph's findings are given in Figure 2 below.

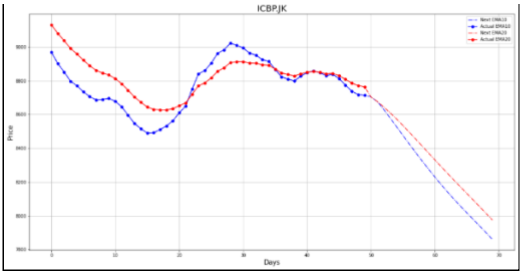

Fig. 2: Prediction graph for the next 20 days

Figure 2 shows the closing movement of stock prices with X label being days and Y label being price. The graph depicts stock price predictions for the next 20 days that the next 20 days stock price movements will decrease drastically.

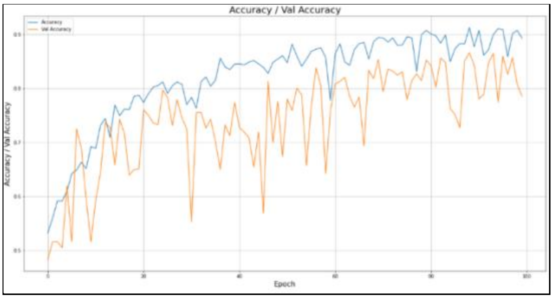

Fig. 3: Accuracy/Val Accuracy

Figure 3 displays the stock price forecast results using the LSTM algorithm with the line plot in blue, which is the actual stock price value, while the orange one is the predicted value. X label is an epoch, and Y label is accuracy /Val accuracy. This line plot is used to compare the current discount and the expected value, whether the predicted value is close to or away from the actual value, and it can be seen in Figure 3 shows how far the stock price forecast findings are from reality.

B. Evaluation Metrics

To ensure the model's performance, this study calculates a variety of assessment criteria to evaluate the accuracy of prediction models. To test the prediction model, we analyzed the prediction outcomes by calculating RMSE and MAPE. RMSE gives more importance to the highest errors. Hence it is more sensitive to outliers whereas on the other hand MAE is more robust to outliers. MAPE stands for mean absolute percentage error. The average multiplicative effect is between each estimated mean and the observed outcome. In this experiment, smaller RMSE and MAPE values indicate more accurate findings and lower error rates. The calculation formula is shown below:

$$RMSE = \frac{1}{n}\sqrt{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2} \quad (12)$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y}_i}{y_i}\right| \times 100\% \quad (13)$$

Where y_i represents the actual value, $\hat{y}_i$ represents the predicted value, dan n represents the number of data points.

Table 4 Results of RMSE and MAPE scores

	RMSE	MAPE
EMA10	0.00714	0.07705
EMA20	0.00355	0.05273

The results of the parameter acquisition are described in table 3. Stock price predictions using the LSTM algorithm show a pretty good error value, with RMSE EMA10 of 0.00714, RMSE EMA20 of 0.00355, and MAPE EMA10 of 0.07705, MAPE EMA20 of 0.05273. From these results, it can be seen that the resulting RMSE and MAPE values are small, thus proving a higher level of prediction accuracy.

6. Conclusion

Stock price prediction is an essential element to predict stock price movements. The current method proposes conventional machine learning to overcome this problem. However, it is costly and time-consuming. This study presents the LSTM algorithm to build a stock price prediction model to improve the model performance. Using the proposed model, we find that LSTM can achieve better accuracy and less error rate. Thus, our model can be a prospective choice for models with exceptional hardware computing capabilities.

Based on the experiments, building the prediction model using LSTM can achieve high accuracy with small errors. In this study, the accuracy score of RMSE EMA10 is 0.00518, RMSE EMA20 is 0.00683, and MAPE EMA10 is 0.06157, MAPE EMA20 is 0.07966. Our proposed model can produce higher accuracy and improve graphics performance. As a result, we suggest that LSTM-based predictive models may be a potential approach for predicting stock price movements in the real stock market.

As the future research direction, the further stock price prediction research can harness the dynamic neural network model, which can be integrated with new approaches like the CuDNN, GRU and GAN. Besides, it can be combined with new techniques such as creating new regulators and improving the gradient computation to accelerate and increase the training accuracy.

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