



Intelligent Forecasting of Apple Stock Prices Using Fuzzy Time Series Cheng Method

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Abstract: Stocks are a vital component in the global financial system because they not only provide alternative financing for companies, but also become investment instruments for individuals and institutions. stock prices tend to be volatile and are influenced by many external factors, so forecasting methods are needed that can effectively handle these dynamics and uncertainties. Conventional approaches such as technical and fundamental analysis still have limitations in overcoming complex and non-linear data patterns. Therefore, this research uses Cheng's Fuzzy Time Series method as a more flexible alternative in analyzing and predicting stock prices. This research focuses on Apple Inc. stock, which is one of the issuers with the largest market capitalization in the world. Historical data is taken from the Kaggle platform with a time span of 1980 to 2025, but the period used for forecasting starts from January 2020 to June 2, 2025. The prediction process was carried out for June to December 2025, using three configurations of the number of intervals, namely 7, 9, and 11, to determine the effect of interval selection on the accuracy of the model. Based on the evaluation results, the use of 11 intervals provides the best performance with a MAPE value of 2.36% and an RMSE of 6.28. Furthermore, long-term forecasting until December 2026 was also conducted using the same intervals, and the results showed that the model maintained a stable level of accuracy.

Keywords: Fuzzy Time Series Cheng; Artificial Intelligence; Stock Price Forecasting; Financial Data Analysis.

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Introduction

In today's global economic development, the stock market is one of the financial instruments that plays a strategic role in the world economy. The stock market provides opportunities for companies to obtain funding for business expansion as well as a means for investors to allocate assets to achieve financial goals. Every investor expects an optimal rate of return with minimum risk. However, stock prices are volatile and influenced by various factors, so analyzing stock movements is an important aspect in making investment decisions [1]–[4].

Stock prices are influenced by various factors such as macroeconomic conditions, company performance, geopolitical issues, and market sentiment. Traditional approaches such as technical and fundamental analysis are often insufficient to capture non-linear patterns and uncertainty in stock data. Therefore, there is a need for methods that can accommodate the complexity of the data and identify price movement patterns more effectively [5], [6].

Apple Inc is one of the largest technology companies in the world. Amidst its success, Apple also faces regulatory challenges in various countries. Recently, Indonesia banned the circulation of iPhone 16 because it has not met the TKDN certificate requirements[7]. This shows that external factors such as policies and regulations can have a significant impact on Apple's share price volatility in the international market.

Various methods have been developed to predict stock prices, ranging from technical analysis, fundamentals, to artificial intelligence-based approaches such as machine learning. These methods often require big data and complex algorithms that require deep technical expertise[8] . One of the simpler but still effective methods is Fuzzy Time Series (FTS), which is able to capture historical patterns and accommodate data uncertainty well. Time series forecasting aims to identify patterns in historical data to predict future values [9]–[11].

Fuzzy Time Series is a method that represents historical data in the form of linguistic values, making it more flexible in handling uncertain data. This method does not require stationary



assumptions as conventional forecasting methods [12]. The Fuzzy Time Series concept was used by Song and Chissom in forecasting student enrollment [13]. Unlike the ARIMA method, Fuzzy Time Series does not require the fulfillment of strict statistical assumptions so that it can be applied to various data characteristics. The accuracy of forecasting results can be evaluated by calculating the error rate using the Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) methods [14], [15].

One variant of the Fuzzy Time Series method that has been developed is Cheng's Fuzzy Time Series method. This method uses a Fuzzy Logical Relationship (FLR) that includes all relations to then be given weight based on the order and repetition of similar FLRs [16]–[19]. The advantage of Cheng's method is its ability to handle data that has a high level of uncertainty such as stock prices, without requiring complex statistical assumptions [14].

Based on the description that has been presented previously, this study aims to analyze the movement of Apple's stock price using Cheng's Fuzzy Time Series method. This study focuses on identifying patterns of stock price movements within a certain period to provide insight for investors in understanding historical trends and potential future stock price movements.

Method

The research flow on the analysis of apple stock price movements using the fuzzy time series cheng method begins with a literature study, which is the process of searching for information related to the theory and calculation method used. This information is obtained through various scientific sources such as journals and relevant research articles. After that, the data collection stage is carried out, where historical Apple stock price data is obtained through the Kaggle site at www.kaggle.com/code/rikinzala/apple-stock-market-analysis-lstm. The dataset includes stock price data from 1980 to 2024. The next step is data pre-preparation, which involves cleaning and sorting the data to ensure the quality and consistency of the data before analysis. This stage is important so that the model can provide accurate results. Next, the forecasting process is performed using Cheng's Fuzzy Time Series method implemented through the Google Colab platform due to its ease of use and ability to handle data efficiently. After forecasting is done, the evaluation stage is used to measure the accuracy of the model. This evaluation uses the MAPE (Mean Absolute Percentage Error) method, which calculates the amount of forecasting error in percentage form based on the difference between the forecast value and the actual value. Finally, the prediction and evaluation results are analyzed to determine the trend of Apple's stock price movement in 2025 and beyond, whether it has increased or decreased.

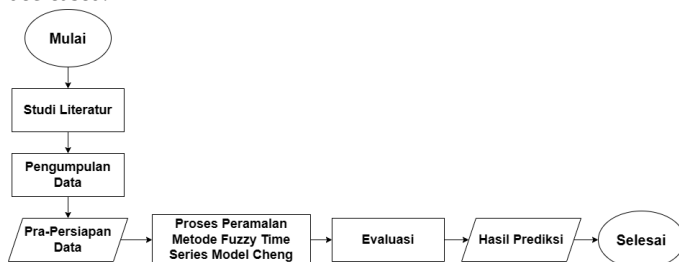


Figure 1. Research flow

Data Collection

The data used in this study was obtained from the Kaggle website, which is a platform that provides various datasets for data analysis and machine learning purposes. The downloaded dataset is historical data of Apple Inc (AAPL) stock prices in the period January 2020 to June 2, 2025 and is stored in .xlsx format.

Results and Discussion

Results

Implementation of Cheng's FTS Method

Forecasting Apple stock price movements is carried out using Cheng's Fuzzy Time Series method with the aim of knowing how accurate the model is in predicting stock prices. The analysis process is carried out using Google Colab by applying the method as a basis for forecasting. The data used in this forecasting calculation is the movement of Apple shares from January 2020 - June 2, 2025.

Data Pre-Preparation

The data pre-preparation stage is carried out to ensure that the closing price data (Close) is clean, numeric type, and in the appropriate time format. This process also includes importing the required libraries and reading data from Excel files. After all the required libraries have been successfully imported, the next step is to prepare the historical Apple stock price data that will be used in the forecasting process. After all the data preparation processes have been completed, the data will be displayed using the 'df.head()' function. This function is used to view the first few rows of the dataset to ensure that the data has been read and processed correctly. After the data is successfully displayed then create a graph to see the stocks from January 2020 -2 June 2025.



Figure 2. Apple Stock Historical Data

Forecasting Process using Cheng's Fuzzy Time Series

After the Apple stock data has been successfully prepared and cleaned, the next step is to apply Cheng's Fuzzy Time Series method to perform stock price forecasting. This forecasting process starts from determining the universe set to evaluating the prediction results. These stages are carried out systematically and implemented using the help of the Python programming language to ensure that the forecasting results can be generated accurately and efficiently.

Determining the Universe Set

The first step in Cheng's Fuzzy Time Series method is to determine the universe of discourse, which is to find the range of values from historical data that will be used in the forecasting process. This universe set is divided into several intervals which are then used as

the basis for the fuzzification process. In this study, the data used is the closing price (Close) of Apple shares from 2020 to June 2, 2025. Determination of the universe set is done by finding the minimum and maximum values of the closing price data, then dividing it into a certain number of intervals. The number of intervals is determined manually for more optimal forecasting results.

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=== Himpunan Semesta ===
Min: 61.67, Max: 249.79, Interval Size: 26.87
Interval A1: 61.67 - 88.54
Interval A2: 88.54 - 115.42
Interval A3: 115.42 - 142.29
Interval A4: 142.29 - 169.17
Interval A5: 169.17 - 196.04
Interval A6: 196.04 - 222.92
Interval A7: 222.92 - 249.79

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Figure 3. Universe set

Based on the results of the universe set calculation in Figure 5, it is known that the minimum value of Apple stock closing price data is 61.67, while the maximum value is 249.79. The difference between the two values is divided into seven intervals with a length of about 26.87 points each. The formation of these intervals aims to group the closing price values into several linguistic categories (A1 to A7) so that numerical data can be processed using the fuzzy approach. The A1 interval covers a value range of 61.67 to 88.54, followed by A2 which covers 88.54 to 115.42, and so on to the A7 interval which covers 222.92 to 249.79. These interval ranges will be the reference in the fuzzification process, which is the next stage that will convert the closing price values into linguistic symbols according to the intervals obtained.

Determining FLR

After the fuzzification process is complete, the next step is to determine the Fuzzy Logical Relationship (FLR). FLR is formed by matching each fuzzy value on day- t with the fuzzy value on day- $(t + 1)$. For example, if on day 1 the data is categorized into A3 and on day 2 into A4, the relation $A3 \rightarrow A4$ is formed. All these pairs will be the basis for the formation of FLRG (Fuzzy Logical Relationship Group).

Determining FLRG

After the FLR is successfully obtained, the next step is to form groups of these relationships based on the fuzzy values on the Left-Hand Side (LHS) of the FLR. This process is called Fuzzy Logical Relationship Group (FLRG). FLRG serves to group possible fuzzy values that may occur after a certain fuzzy value appears. To form a Fuzzy Logical Relationship Group (FLRG) from previously obtained FLR data. The method is to group all fuzzy relationships based on the value on the left (LHS) of each FLR. Each fuzzy value on the LHS will be used as a key in a data structure in the form of a dictionary. Then the value on the right (RHS) of the FLR will be included in the list belonging to the key. If the RHS value is not already in the list, it will be added. This step can determine all possible price movements of a fuzzy condition based on historical patterns. For example, if one day the price is at A3, the FLRG can see the possibility of the next price staying at A3, going down to A2, or going up to A4.

Defuzzification

After the Fuzzy Logical Relationship Group (FLRG) is formed, the next step is to perform defuzzification, which is to convert fuzzy data back into numerical form so that it can be used in actual price forecasting. The defuzzification results obtained by showing that each fuzzy rule (such as A1, A2, and so on) has a representative value in the form of an average number. For example, A1 is converted to 88.54, A2 to 115.42, and so on up to A7 which has a value of 222.92. These values are calculated based on the average of the interval midpoints that appear on the right-hand side of the FLRG.

Multi-Step Forecasting

In the previous stage, forecasting was only carried out until December 2025, so in this section, the prediction will be extended until December 2026. This step aims to see if the model can still maintain its level of accuracy when used to predict over a longer period of time. In addition, the results of this extended forecasting will also be analyzed to see the patterns that emerge and how much the results differ compared to short-term forecasting.

This long-term forecasting process uses the same method as in the previous step, with an adjustment to the time parameter. If in the previous section the forecasting was limited to December 2025, then at this stage the forecasting period is extended to the end of December 2026. The adjustment is made by changing the value of the end_date variable to '2026-12-31' in the code shown in Figure 4.12, so that the model automatically predicts the daily stock price for up to one year longer.

After the long-term forecasting process has been completed using Cheng's Fuzzy Time Series model with a total of 11 intervals, the next step is to analyze the prediction results in more detail. One approach used is to calculate the average value of the forecasting results for each month, starting from June 2025 to December 2026. This calculation aims to provide an overview of the stock price trends predicted by the model over a longer time span. Table 1 presents a summary of the average value of daily forecasting results that have been grouped by month.

Table 1. Average Forecasting Results Per Month

No	Month	Forecasting
1	June 2025	213.02
2	July 2025	221.90
3	August 2025	217.62
4	September 2025	224.13
5	October 2025	211.49
6	November 2025	220.71
7	December 2025	193.65
8	January 2026	198.48
9	February 2026	220.71
10	March 2026	224.91
11	April 2026	165.05
12	May 2026	133.74

13	June 2026	88.87
14	July 2026	165.39
15	August 2026	215.99
16	September 2026	212.47
17	October 2026	219.47
18	November 2026	224.13
19	December 2026	186.95

Based on Table 1, fluctuations in the average value of monthly forecasting results from June 2025 to December 2026. In 2025 the predicted value looks quite stable with a price range around 213 to 224. However, in 2026 there was a significant decline from April to June 2026, where the average value of predictions dropped dramatically to 88.87 in June 2026. This shows the tendency of the model to produce lower predictions as the forecasting time horizon increases.

After June 2026, the model again showed an increase in the predicted value, with the peak being in November 2026 at 224.13. Despite the recovery, the average value in December 2026 decreased again to 186.95. These fluctuations indicate that the accuracy of the model tends to decrease in long-term forecasting, mainly due to the absence of historical data updates that can affect the prediction results. This pattern indicates that the use of Cheng's Fuzzy Time Series model for long horizons needs to be considered carefully, especially when used for long-term decision making.

MAPE and RMSE Results of Cheng's FTS Model with Intervals of 7, 9, and 11

After the forecasting process is carried out using Cheng's Fuzzy Time Series method, the next step is to evaluate how well the model predicts stock prices. The evaluation is done by comparing the forecasting results to the actual stock price data for the last 30 days contained in the dataset. In this evaluation, two main metrics are used, namely Mean Absolute Percentage Error (MAPE) and Root Mean Squared Error (RMSE).

1. MAPE is used to measure the average error in percentage terms between the predicted value and the actual data. A lower MAPE value indicates a smaller error rate, meaning that the model is more accurate.
2. RMSE measures how far the predicted value deviates from the actual value on the same scale, i.e. stock price units. The RMSE value is also better if the value is small.

Table 2. Cheng's FTS Model Evaluation

Number of Intervals	MAPE	RMSE
7	3.98%	10.99
9	2.79%	7.72
11	2.36%	6.28

Forecasting Graphs with Intervals 7, 9, and 11

The difference in forecasting results based on the interval value used in Cheng's Fuzzy Time Series method is visualized in the form of a line graph.

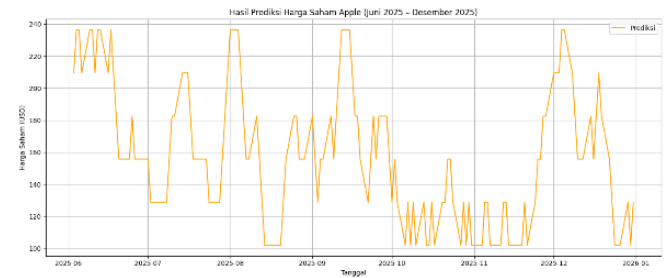


Figure 4. Forecasting Graph with Interval 7

Figure 4 shows the results of forecasting with interval 7. It can be seen that the prediction experiences quite high fluctuations with sharp price changes between days. This shows that intervals that are too small can result in predictions that are too sensitive to changes in historical data.

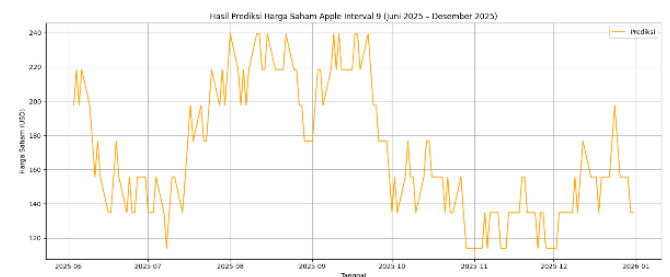
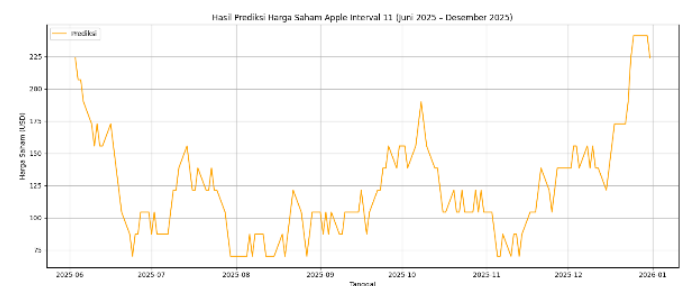


Figure 5. Forecasting Graph with Interval 9

Compared to interval 7, this graph looks more stable and tends to follow the historical price pattern more smoothly. The resulting predictions seem more realistic and less extreme.



Forecasting Graph with Interval 11

Discussions

The forecasting process utilizes the FLRG results and defuzzification values that have been formed previously. The first step is to fuzzify all historical closing price values to determine which interval each value falls into. Then, the forecasting process is performed by looking at the fuzzy values of the previous day and checking the FLRG for possible transitions.

Forecasting Apple's stock price dynamically for the months of June to December 2025. The process starts by determining the forecasting start date which is one day after the last historical data, and the end date which is December 31, 2025. A frequency of 'B' is

used to ensure that only business days are predicted, which corresponds to the active time of the stock market. The last value of the historical stock price is used as the starting point. Then each last price is converted into a fuzzy value through the fuzzification process. Based on the FLRG results, the next possible fuzzy value is determined and from there the midpoint of the interval is taken as the predicted value.

If the last fuzzy condition does not have a rule in FLRG then the system assumes the next day's price is the same as the previous day (naïve forecast). The forecasting result is stored in a DataFrame forecast_df which contains two columns: date (Date) and forecast result (Forecast).

The resulting forecast value has a tendency to repeat certain values repeatedly. The value 209.478571 appears several times in early June, while the value 101.981429 appears several times towards the end of December. This happens because Cheng's Fuzzy Time Series method approach uses interval representations (fuzzy sets) to model the values in the historical data. Each daily prediction is determined based on the defuzzification result of the FLRG where one fuzzy value (e.g. A6) can have several possible transitions to another fuzzy value. In the implementation used, the selection of transitions is done randomly from the list of possibilities in the FLRG. If the selected transition leads back to the same fuzzy set (e.g. A6 → A6) then the defuzzification value will be fixed. Therefore, when the model often selects transitions to the same fuzzy set repeatedly, the value of the forecasting results will also be repeated.

Conclusion and Suggestions

Based on the forecasting results, it can be concluded that the data used in this research is sourced from the Kaggle platform, which includes historical Apple stock price data from 1980 to 2025. However, the training and forecasting process focused on data from January 2020 to June 2, 2025. Cheng's Fuzzy Time Series method is proven to be effectively applied to analyze and predict Apple's stock price movements. The implementation stages include determining the universe set, interval formation, fuzzification process, fuzzy logical relations (FLR and FLRG), and defuzzification process to obtain accurate forecasting results. Forecasting was conducted for the period June to December 2025 by testing three variations in the number of intervals, namely 7, 9, and 11. The evaluation results show that the more the number of intervals used, the better the accuracy of the resulting model. The model with interval 7 recorded a MAPE value of 3.98% and an RMSE of 10.99, while the model with interval 9 showed improved accuracy with a MAPE value of 2.79% and an RMSE of 7.72. The model with 11 intervals provided the most optimal performance, with a MAPE of 2.36% and an RMSE of 6.28. This finding shows that increasing the number of intervals can refine the representation of the data, resulting in more accurate predictions. Based on the evaluation results, the model with 11 intervals was then used for long-term forecasting, namely the period from June 2025 to December 2026. The forecasting results show that the MAPE and RMSE values remain stable at 2.36% and 6.28, just like the results in short-term forecasting. This consistency indicates that the model remains accurate even though it is used for predictions over a longer period of time. Overall, Cheng's Fuzzy Time Series method is shown to perform well in modeling and forecasting volatile stock time series data. The accuracy of the model can also be improved

through the selection of the right number of intervals according to the characteristics of the data.

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