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Application of Fuzzy Time Series Method Cheng Model in Forecasting Stock Prices PT Bukit Asam Tbk

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ABSTRACT

Investment in stocks is one type of investment that can get huge profits, but there are also great risks. So it is necessary to analyze in advance before starting an investment in stocks, in order to avoid losses. One way is to forecast the stock price using fuzzy time series Cheng. The data used is weekly period stock price data from PTBA in January 2020 - December 2022, which can be categorized as a form of time series. From this research, the forecasting value for the next period is Rp. 3797. Which results in a MAPE of 4.2%, which means that FTS Cheng method is very good to use in forecasting the share price of PT Bukit Asam Tbk, because it produces a MAPE value <10%, and produces an RMSE of 158 rupiah, which means the average of the difference between actual and forecast values.

Keywords: Fuzzy Time Series Cheng, MAPE, RMSE.

Introduction

Stock investment is one type of investment that can generate a lot of profit, but investing in stocks can also provide big losses too. So that an analysis must be carried out before starting to invest in stocks. One way to analyze it is by forecasting the stock price [1]. There are several forecasting methods, such assuch as Fuzzy Time Series (FTS), ARCH-GARCH model, Exponential Smoothing, Box-Jenkins, and Moving Average. In this study I chose FTS because stock price data is time series data, which requires historical data to process FTS [2]. The advantage of the fuzzy time series method is that it can determine the characteristics of the actual data, and can find a pattern which will then be used for stock price forecasting [3]. In the FTS process, it also does not require anything learning systems from complex systems, such as artificial neural networks or genetic algorithms, so that they can be processed or processed and developed more easily[4].

Fuzzy logic is a component of soft computing, which has been widely applied in various fields. One of its applications is to help humans in making a decision. In this study, fuzzy logic will be used to analyze stock price time series data, which will be formed into a forecasting model. Fuzzy logic is used in stock price forecasting because fuzzy set theory can provide an appropriate and precise theoretical framework in calculating data patterns, and can produce tolerance for uncertainty [5].

Several studies have used the FTS method, including [6] in this study FTS was used to predict PT Telkom Indonesia's share price in January - December 2017. The forecasting results have good criteria, because it produces a MAPE of 0.57. In research [7] used the FTS Cheng model to predict an increase in the number of BPJS participants who receive APBN contributions. From this research obtained an increase in BPJS participants who received APBN contribution assistance in 2019-2021 by 52,071 participants. Forecasting in this study has very good criteria, because it produces a MAPE value of <10%. Which produces a MAPE of 0.97%, which means the forecasting accuracy in this study is 99.03% [8].

This study uses the FTS Cheng method to forecast PTBA's share price, using data for the period January 2020 to December 2022.

Literature Review

Forecasting.

Forecasting is one of the sciences that discusses predicting what might happen in the future. Because, forecasting requires historical data which will then be projected in the future using a mathematical model.

Time Series

A time series or time series is a collection of data that represents the behavior of one or more random variables over time, and its main characteristics are that each variable in a time series is not independent of one another, and analysis of time series must consider the order of the data to be observed [7]

Fuzzy Time Series Cheng

The FTS Cheng method has a slightly different processing step compared to other FTS, which is in determining the interval, namely using FLR (Fuzzy Logical Relationship) by entering all relationships and giving weights based on the sequence and repetition of the same FLR [9].

Processing steps using Cheng's fuzzy time series method can be seen as follows[10]–[15]:

1. Finding the universal set (U)

$$U = [D_{min} - D_1, D_{max} + D_2] \quad (1.1)$$

Which one $D_1$and D_2 are any positive value to be chosen by the researcher.

2. Form a set of classes
   a. Range

$$R = D_{max1} - D_{min1} \quad (1.2)$$

   b. Class Intervals

$$K = 1 + 3{,}322 \log\ n \quad (1.3)$$

Which one n is the amount of actual data

   c. Interval Length

$$I = \frac{data\ ranges\ (R)}{number\ of\ class\ intervals\ (K)} \quad (1.4)$$

   d. Middle value

$$m_i = \frac{(lower\ limit\ +\ upper\ limit)}{2} \quad (1.5)$$

Which one i is the number of fuzzy sets

3. Define fuzzy sets

$$A_1 = \frac{1}{u_1} + \frac{0{,}5}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \cdots + \frac{0}{u_p}$$
$$A_2 = \frac{0{,}5}{u_1} + \frac{1}{u_2} + \frac{0{,}5}{u_3} + \frac{0}{u_4} + \cdots + \frac{0}{u_p} \quad (1.6)$$
$$\cdots$$
$$A_p = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \cdots + \frac{0{,}5}{u_{p-1}} + \frac{1}{u_p}$$

Where $u_i(i = 1,2,3, \dots, p)$ is part of the universe set and the number given the symbol "—" means that the degree of the member to the value $A_i(i = 1,2,3, \dots, p)$where the value is 1 or 0.5 or 0.

4. Fuzification

Fuzzification is the initial process of a system that uses fuzzy logic, which is a way of converting membership data from ordinary (conventional) sets into membership fuzzy sets.

5. Form a fuzzy logical relationship (FLR)
   Determines the FLR view of the actual data according to time. FLR is denoted by $A_i \rightarrow A_j$, which A_i is called the current state or LH (Left Hand) and A_j is called the next state or RH (Right Hand). The current state value is obtained from the actual data fuzzification result $(t-1)$ and the next state value is obtained from the actual data fuzzification result (t).
6. Define fuzzy logical relationship group (FLRG)
   In determining the FLRG weights, it is done by including all the relationships from the FLR and giving weights by looking at the same sequence and repetition. FLRs that have the same Left Hand () will be grouped togetherA_i
   $(t=1)\ A_2 \rightarrow A_2$, is given a weight of 1
   $(t=2)\ A_2 \rightarrow A_3$, is given a weight of 1
   $(t=3)\ A_3 \rightarrow A_2$, is given a weight of 1
   $(t=4)\ A_2 \rightarrow A_2$, is given a weight of 2 1.7
7. Create a weighting matrix
   Weight matrix $W = (w_{ij})$, which w_{ij} is the matrix weight in the i-th row and j-th column, each of which corresponds to the left hand (A_i) and right hand (A_j). So that the matrix can be written as follows:

$$W = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1p} \\ w_{21} & w_{22} & \cdots & w_{2p} \\ \vdots & \vdots & w_{ij} & \vdots \\ w_{p1} & w_{p2} & \cdots & w_{pp} \end{bmatrix}$$

   which value $i, j = 1,2, \dots, p$
8. Standardize the weighting matrix
   to get a standardized weighting matrix $W^* = \left(w_{ij}{}^*\right), i, j = 1,2, \dots, p$, which $w_{ij}{}^*(t)$ is done with the following formulation:

$$w_{ij}{}^*(t) = \frac{w_{ij}}{\sum_{i=1}^{p} w_{ij}} \qquad 1.8$$

   The equation of the weighting matrix W^* is written as follows:

$$W^* = \begin{bmatrix} w_{11}{}^* & w_{12}{}^* & \cdots & w_{1p}{}^* \\ w_{21}{}^* & w_{22} & \cdots & w_{2p}{}^* \\ \vdots & \vdots & w_{ij}{}^* & \vdots \\ w_{p1}{}^* & w_{p2}{}^* & \cdots & w_{pp}{}^* \end{bmatrix}$$

9. Defuzzification
   To determine the forecast value, the matrix W^* is multiplied by the middle value (m_i), so that the forecast calculation is obtained as follows:

$$F_i = w_{i1}{}^*(m_1) + w_{i2}{}^*(m_2) + \cdots + w_{ip}{}^*(m_p) \qquad 1.9$$

F_i is the result of forecasting.

If the result of fuzzification at time- i is A_i , which A_i does not have FLR at condition $A_i \rightarrow \emptyset$, and also the maximum value of the degree of its members is at u_i, then the value F_i is the middle value of u_i, which is denoted by m_i [16]–[21].

Forecasting Accuracy

Generally, the accuracy of a forecasting result is calculated by comparing actual data and research data, to determine the accuracy of the research results and the errors (errors) obtained from the forecasting. In this study, MAPE and RMSE indicators were used to determine the accuracy of the forecasting

$$MAPE = \frac{\sum_{t=1}^{n} \left| \frac{D_t - F_t}{D_t} \right| \times 100\%}{n} \qquad 10$$

which D_t is the actual value in the t-period, F_t is the forecasted value in the-th period, and n is the amount of data.

Forecasting criteria based on MAPE values [22], are as follows:

Table 1 Forecasting Criteria

MAPE value	Forecasting Criteria
less than 10%	Very Accurate
10% to 20%	Accurate
20% to 50%	Pretty Accurate
more than 50%	Not accurate

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n} (D_t - F_t)^2}{n}} \qquad 1.11$$

Research Methods

The data to be used in this study is secondary data, in which the data is taken from existing sources. The data to be processed is stock price data with a weekly period, from January 2020 to December 2022. Stock price data is time series data, so the Fuzzy Time Series Cheng method will be used in this study. The data will then be applied using the fuzzy time series method. Next, calculate the accuracy of the forecasting results using the Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE) indicators. Then several forecasting experiments were carried out on the historical data of PT Bukit Asam Tbk stock prices with different time periods and amounts of data, using the help of a program that had previously been created by the researcher https://api-ptba.alyanadhira.repl.co/. The next step is to draw conclusions and suggestions obtained after conducting this research [23][24][25], [26].

Results and Discussion

The data used is weekly stock price data from PT Bukit Asam Tbk from January 2020 to December 2022 in rupiah units (Rp). The data is obtained from the Investing.com website (https://www.investing.com/equities/tb-bukit-asam-historical-data).

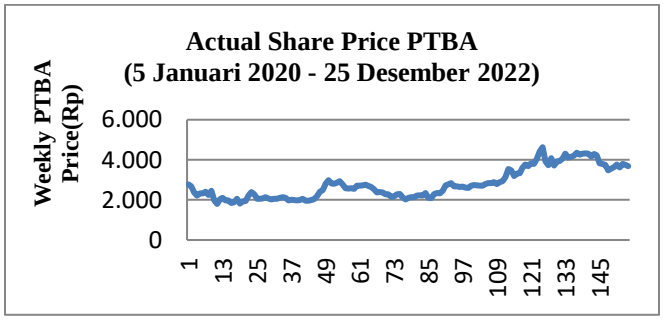

Figure 1.actual data

From this graph, the lowest price for PT Bukit Asam Tbk shares is Rp. 1,800 and the highest price is Rp. 4,630,-

The actual data processing steps for PT Bukit Asam Tbk's share price using the fuzzy time series method are as follows:

1. Finding the universal set (U)
   Based on actual data the smallest data (D_{min}) is obtained which is 1800 and the largest data (D_{max}) is 4630. Then it D_1 and D_2 is given a value of 0 and 14. So that the universe set is obtained based on equation (1.1), which is as follows:
   $U = [1800;\ 4644]$
2. Form a set of classes
   a. Range
      Based on equation (1.2), so we get:
      $R = 4644 - 1800 = 2844$
   b. Class Intervals
      Based on equation (1.3), so we get:
      $K = 1 + 3{,}322 \log\ 155 = 8{,}276 \approx 8$
   c. Interval Length
      Based on equation (1.4), so we get:
      $I = \frac{R}{K} = \frac{2844}{8} = 355{,}5$

   Division of class intervals and mean values:

u_i	Lower limit	Upper limit	Middle value
u_1	1,800.0	2,155.5	1,977.75
u_2	2,155.5	2,511.0	2,333.25
u	2,511.0	2,866.5	2,688.75
u_4	2,866.5	3,222.0	3,044.25
u_5	3,222.0	3,577.5	3,399.75
u_6	3,577.5	3,933.0	3,755.25
u_7	3,933.0	4,288.5	4,110.75
u_8	4,288.5	4,644.0	4,466.25

3. Determine the fuzzy set on the universal set
   Obtain the form of the fuzzy set equation, based on equation (1.6):

$$A_1 = \frac{1}{u_1} + \frac{0.5}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0}{u_6} + \frac{0}{u_7} + \frac{0}{u_8}$$

$$A_2 = \frac{0.5}{u_1} + \frac{1}{u_2} + \frac{0.5}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0}{u_6} + \frac{0}{u_7} + \frac{0}{u_8}$$

$$A_3 = \frac{0}{u_1} + \frac{0.5}{u_2} + \frac{1}{u_3} + \frac{0.5}{u_4} + \frac{0}{u_5} + \frac{0}{u_6} + \frac{0}{u_7} + \frac{0}{u_8}$$

$$A_4 = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0.5}{u_3} + \frac{1}{u_4} + \frac{0.5}{u_5} + \frac{0}{u_6} + \frac{0}{u_7} + \frac{0}{u_8}$$

$$A_5 = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0.5}{u_4} + \frac{1}{u_5} + \frac{0.5}{u_6} + \frac{0}{u_7} + \frac{0}{u_8}$$

$$A_6 = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \frac{0.5}{u_5} + \frac{1}{u_6} + \frac{0.5}{u_7} + \frac{0}{u_8}$$

$$A_7 = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0.5}{u_6} + \frac{1}{u_7} + \frac{0.5}{u_8}$$

$$A_8 = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0}{u_6} + \frac{0.5}{u_7} + \frac{1}{u_8}$$

4. Fuzification

   Fuzzification is carried out based on previously obtained class intervals, on actual data that has been converted into linguistic numbers. Determining the fuzzification value is done by defining the actual data into the appropriate class intervals.

No	Date	Price	Fuzzification
1	1/5/2020	2,780	A3
2	1/12/2020	2,670	A3
3	1/19/2020	2,370	A2
⋮	⋮	⋮	⋮
11	3/15/2020	1,800	A1
⋮	⋮	⋮	⋮
155	12/25/2022	3,690	A6

5. Form a fuzzy logical relationship (FLR)

   Fuzzy relations can be formed from $n-1$ data to n data fuzzification results, which can be written as $A_{n-1} \rightarrow A_n$.

No	Date	Fuzzification	LH	RH	FLR
1	1/5/2020	A3	NA	A3	
2	1/12/2020	A3	A3	A3	A3->A3
3	1/19/2020	A2	A3	A2	A3->A2
4	1/26/2020	A2	A2	A2	A2->A2
⋮	⋮	⋮	⋮	⋮	⋮
154	12/18/2022	A6	A6	A6	A6->A6
155	12/25/2022	A6	A6	A6	A6->A6

6. Define fuzzy logical relationship group (FLRG)

   From formation the former FLR can be formed FLRG, can be formed based onequation (1.7), so that the FLRG of all actual data is obtained as follows:

Group	*Current State*	*Next State*
G1	A1	A1(36), A2(5)
G2	A2	A1(5), A2(22), A3(2)
G3	A3	A2(2), A3(30), A4(4)
G4	A4	A3(3), A4(2), A5(2)
G5	A5	A4(1), A5(3), A6(2)
G6	A6	A5(1), A6(13), A7(3)
G7	A7	A6(2), A7(3), A8(5)
G8	A8	A6(1), A7(4), A8(3)

7. Create a weighting matrix
   From the FLRG it can be seen the weighting value. As an example, current state A_1 own next state A_1 and A_2. So that we get weights $A_1 \rightarrow A_1$ there are as many as 36 and $A_1 \rightarrow A_2$ the weight value are 5.

Current State	*Next State*							
	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
A_1	36	5						
A_2	5	22	2					
A_3		2	30	4				
A_4			3	2	2			
A_5				1	3	2		
A_6					1	13	3	
A_7						2	3	5
A_8						1	4	3

8. Standardize the weighting matrix
   Based on equation (1.8), a standardized weighting matrix can be formed as follows:

Current State	*Next State*							
	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
A_1	36	5						
A_2	5	22	2					
A_3		2	30	4				
A_4			3	2	2			

Current State	*Next State*							
	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
A_5				1	3	2		
A_6					1	13	3	
A_7						2	3	5
A_8						1	4	3

9. Defuzzification
   Based on equation (1.9) the defuzzification value can be obtained as follows.

FLRG	F(t)
G1	2021.103659
G2	2296.474138
G3	2708.5
G4	2993.464286
G5	3459
G6	3797.073529
G7	4217.4
G8	4199625

Based on the defuzzification value, PTBA's stock price forecasting value is obtained as follows.

No	Date	Price	FLRG	Forecasting
1	1/5/2020	2,780		
2	1/12/2020	2,670	G3	2708.5
3	1/19/2020	2,370	G3	2708.5
4	1/26/2020	2,210	G2	2296.4741
⋮	⋮	⋮	⋮	⋮
10	3/8/2020	1,970	G2	2296.4741
11	3/15/2020	1,800	G1	2021.1037
⋮	⋮	⋮	⋮	⋮
154	12/18/2022	3,740	G6	3797.0735
155	12/25/2022	3,690	G6	3797.0735

Forecasting Accuracy

MAPE	RMSE
4.2246849	157.78678

PTBA's stock price forecasting produces a MAPE value of 4.2%, because the MAPE value is <10%, the forecast using FTS Cheng has very good criteria. On this fortune-telling also earnthe average error or difference from actual and forecast data is 158 rupiah.

The experiment uses a program that has been created by the researcher

1. First try
   Using PT Bukit Asam Tbk stock price data for the period January 2018 to March 2023.

MAPE	RMSE
4.47	179.6

2. Second try
   Using PT Bukit Asam Tbk share price data for the period June 2020 to November 2020.

MAPE	RMSE
2.72	75.3

3. Third try
   Using PT Bukit Asam Tbk share price data for the period October 2020 to June 2022.

MAPE	RMSE
4.79	163.4

Conclusion

PTBA's stock price forecasting using FTS Cheng has very good criteria, because it produces a MAPE value of less than 10%, namely 4.2%. The average difference from actual and forecast data is 158 rupiah.

After several forecasting experiments, it was found that when the stock price movement pattern tends to be stable or the price movement pattern is not too extreme, forecasting using FTS Cheng will be more accurate, because it will produce a smaller MAPE value. Then it was found that, by conducting experiments with a larger amount of data does not have implications for the accuracy of forecasting results on stock prices.

Suggestion

From the research results of stock price forecasting using the method that has been done, this research can only predict one period ahead. So it is suggested for further research to use different observation data or use different forecasting methods. Which can produce forecast values in more periods and which can produce forecast values that are more varied, such as the Artificial Neural Network (ANN) method, Adaptive Neuro Fuzzy Inference System (ANFIS), or can use other fuzzy time series methods. So it is hoped that the results of this study can be used as material for consideration or reference to expand research on FTS Cheng for further research.

References

[1] M. Pant, "Particle swarm optimization and intuitionistic fuzzy set-based novel method for fuzzy time series forecasting," *Granul. Comput.*, vol. 7, no. 2, pp. 285–303, 2022, doi: 10.1007/s41066-021-00265-3.
[2] P. Melin, "Optimization using the firefly algorithm of ensemble neural networks with type-2 fuzzy integration for COVID-19 time series prediction," *Soft Comput.*, vol. 27, no. 6, pp. 3245–3282, 2023, doi: 10.1007/s00500-020-05549-5.
[3] Y. Tang, "Building Trend Fuzzy Granulation-Based LSTM Recurrent Neural Network for Long-Term Time-Series Forecasting," *IEEE Trans. Fuzzy Syst.*, vol. 30, no. 6, pp. 1599–1613, 2022, doi: 10.1109/TFUZZ.2021.3062723.
[4] E. Egrioglu, "Recurrent fuzzy time series functions approaches for forecasting," *Granul. Comput.*, vol. 7, no.

1, pp. 163–170, 2022, doi: 10.1007/s41066-021-00257-3.
[5] H. Nasiri, "MFRFNN: Multi-Functional Recurrent Fuzzy Neural Network for Chaotic Time Series Prediction," *Neurocomputing*, vol. 507, pp. 292–310, 2022, doi: 10.1016/j.neucom.2022.08.032.
[6] N. Kumar, "A novel hybrid fuzzy time series model for prediction of COVID-19 infected cases and deaths in India," *ISA Trans.*, vol. 124, pp. 69–81, 2022, doi: 10.1016/j.isatra.2021.07.003.
[7] V. M. S. Ardila, "Fuzzy Time Series Methods Applied to (In)Direct Short-Term Photovoltaic Power Forecasting," *Energies*, vol. 15, no. 3, 2022, doi: 10.3390/en15030845.
[8] A. M. AlRassas, "Advance artificial time series forecasting model for oil production using neuro fuzzy-based slime mould algorithm," *J. Pet. Explor. Prod. Technol.*, vol. 12, no. 2, pp. 383–395, 2022, doi: 10.1007/s13202-021-01405-w.
[9] A. Azizpour, "Simulation of time-series groundwater parameters using a hybrid metaheuristic neuro-fuzzy model," *Environ. Sci. Pollut. Res.*, vol. 29, no. 19, pp. 28414–28430, 2022, doi: 10.1007/s11356-021-17879-4.
[10] Y. Wang, "Data-driven prediction method for characteristics of voltage sag based on fuzzy time series," *Int. J. Electr. Power Energy Syst.*, vol. 134, 2022, doi: 10.1016/j.ijepes.2021.107394.
[11] P. D'Urso, "Spatial robust fuzzy clustering of COVID 19 time series based on B-splines," *Spat. Stat.*, vol. 49, 2022, doi: 10.1016/j.spasta.2021.100518.
[12] S. Xian, "Improved seagull optimization algorithm of partition and XGBoost of prediction for fuzzy time series forecasting of COVID-19 daily confirmed," *Adv. Eng. Softw.*, vol. 173, 2022, doi: 10.1016/j.advengsoft.2022.103212.
[13] H. Yang, "An oil imports dependence forecasting system based on fuzzy time series and multi-objective optimization algorithm: Case for China," *Knowledge-Based Syst.*, vol. 246, 2022, doi: 10.1016/j.knosys.2022.108687.
[14] R. Cerqueti, "Weighted score-driven fuzzy clustering of time series with a financial application," *Expert Syst. Appl.*, vol. 198, 2022, doi: 10.1016/j.eswa.2022.116752.
[15] J. Hu, "Weighted Kernel Fuzzy C-Means-Based Broad Learning Model for Time-Series Prediction of Carbon Efficiency in Iron Ore Sintering Process," *IEEE Trans. Cybern.*, vol. 52, no. 6, pp. 4751–4763, 2022, doi: 10.1109/TCYB.2020.3035800.
[16] A. Rostami, "A fuzzy-based flood warning system using 19-year remote sensing time series data in the Google Earth Engine cloud platform," *Adv. Sp. Res.*, vol. 70, no. 5, pp. 1406–1428, 2022, doi: 10.1016/j.asr.2022.06.008.
[17] Á. López-Oriona, "Quantile-based fuzzy clustering of multivariate time series in the frequency domain," *Fuzzy Sets Syst.*, vol. 443, pp. 115–154, 2022, doi: 10.1016/j.fss.2022.02.015.
[18] S. Surono, "Optimization of Markov Weighted Fuzzy Time Series Forecasting Using Genetic Algorithm (GA) and Particle Swarm Optimization (PSO)," *Emerg. Sci. J.*, vol. 6, no. 6, pp. 1375–1393, 2022, doi: 10.28991/ESJ-2022-06-06-010.
[19] Á. López-Oriona, "Quantile-based fuzzy C-means clustering of multivariate time series: Robust techniques," *Int. J. Approx. Reason.*, vol. 150, pp. 55–82, 2022, doi: 10.1016/j.ijar.2022.07.010.
[20] D. Zhang, "An Interpretable Station Delay Prediction Model Based on Graph Community Neural Network and Time-Series Fuzzy Decision Tree," *IEEE Trans. Fuzzy Syst.*, vol. 31, no. 2, pp. 421–433, 2023, doi: 10.1109/TFUZZ.2022.3181453.
[21] S. N. Arslan, "A hybrid sigma-pi neural network for combined intuitionistic fuzzy time series prediction model," *Neural Comput. Appl.*, vol. 34, no. 15, pp. 12895–12917, 2022, doi: 10.1007/s00521-022-07138-z.
[22] S. E. Rodrigues, "An approach for evolving neuro-fuzzy forecasting of time series based on parallel recursive singular spectrum analysis," *Fuzzy Sets Syst.*, vol. 443, pp. 1–29, 2022, doi: 10.1016/j.fss.2021.09.009.
[23] F. Pohan, I. Saputra, and R. Tua, "Scheduling Preventive Maintenance to Determine Maintenance Actions on Screw Press Machine," *J. Ris. Ilmu Tek.*, vol. 1, no. 1, pp. 1–12, 2023.
[24] I. N. Permadi and D. B. Nisa, "A Model Experiment Design Using the Taguchi Method: A Case Study Of Making Concrete Roof," *J. Ris. Ilmu Tek.*, vol. 1, no. 1, pp. 36–44, 2023.
[25] G. Filhaq, S. Aprianto, and H. Alfianto, "Design of Smart Locker Door Using Quality Function Deployment Based on ATMega 2560 Microcontroller," *J. Ris. Ilmu Tek.*, vol. 1, no. 1, pp. 25–35, 2023.
[26] T. M. Sari and W. Dini, "Risk Assessment and Mitigation Strategy in The Halal Broiler Supply Chain," *J. Ris. Ilmu Tek.*, vol. 1, no. 1, pp. 13–24, 2023.