Analysis of Rainfall Prediction Using Fuzzy Time Series Method in Medan City

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ABSTRACT

The increasingly significant climate change causes high rainfall variability, thus requiring an accurate prediction method for disaster mitigation planning and water resource managment. This study aim to analyze rainfal prediction in Medan City using Fuzzy Time Series (FTS) methode. Historical rainfall data for Medan City for a certain period is collected and processed to build an FTS model. The fuzzification process is carried out to convert numerical data into fuzzy values, then the time series relationship is identified to predict the next rainfall value. Based on Chen's fuzzy time series with the detemination of the average-based interval, the Medan City rainfall forecast based on January 2019-December 2023 data obtained the forecast results for January 2024 is 386.7 mm. From the result of tests that have caried out, the best number of sampels be used in the Medan City rainfall case is 60 data, namely the period January 2019 - December 2023.

Keyword : Rainfall, Fuzzy Time Series, Chen Method, Forecasting

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1. INTRODUCTION

Weather change is a natural phenomenon that occurs dynamically and is influenced by various atmospheric factors. Over the past few decades, global climate change has accelerated weather variations in many regions of the world, including Indonesia. One important component of weather change is rainfall patterns, which play a significant role in the sustainability of ecosystems, agriculture, and the availability of water resources (Luthfiarta et al., 2020). However, erratic changes in rainfall patterns can have negative impacts, such as causing floods, droughts, and disruption of economic activities.

Rainfall is one of the main indicators in weather change studies because it is strongly influenced by global atmospheric dynamics, such as wind movement, air pressure, and sea surface temperature. In Indonesia, which has a tropical climate, rainfall varies throughout the year and is highly dependent on natural phenomena, as well as monsoon circulation. As a result of climate change, rainfall patterns are becoming increasingly difficult to predict, both in terms of intensity and distribution.

As in Medan City, the rainfall is unpredictable, because every day in one week there can be rain with different intensities, or even in that week there is no rain at all (Soekendro, 2021). Every province in Indonesia currently has a source of weather information from BMKG (Badan Meteorologi, Klimatologi, dan Geofisika). The Meteorology, Climatology and Geophysics Agency (BMKG) of Medan City is a government agency responsible for providing information services related to weather, climate and geophysics in Medan and surrounding areas. BMKG Medan City plays an important role in monitoring and predicting weather conditions, including rainfall, temperature, humidity, as well as potential natural disasters such as floods or strong winds. However, BMKG experts still consider that the accuracy of these predictions is not optimal. To find the most suitable approach in providing weather predictions, especially rainfall forecasting with a high level of accuracy, the selection of appropriate methods for prediction is still ongoing (Insani et al., 2020).

Several journals on forecasting activities apply various methods to determine the most accurate and optimal analysis. Fuzzy Time Series (FTS) is a method used to analyze and predict time series data

that has uncertainty or vagueness. In contrast to conventional time series methods, FTS utilizes the concept of fuzzy sets introduced by Lotfi A. Zadeh, where the data being analyzed does not have to be exact numbers, but can be represented by fuzzy values. This allows FTS to handle uncertain data, such as fluctuations in weather, economy, and other natural phenomena. The main processes in FTS include fuzzification of historical data, formation of fuzzy relations, and defuzzification to produce predictions (Rahmawati, 2021).

FTS has a high level of accuracy. So this technique is used in order to evaluate whether rainfall predictions made by the FTS method are more accurate than the prediction methods previously applied. This research is based on using Medan City rainfall data collected from the BMKG website to evaluate the predictions displayed by the system.

2. RESEARCH METHOD

The research method stage is a systematic sequence undertaken to obtain and analyze data to answer research questions. This process begins with the selection and formulation of the research problem, followed by a literature review to understand the context and previous research. After that, the researcher determines the research objectives and hypotheses, then chooses the appropriate method, either qualitative or quantitative, to collect data. The following are the stages in this research. The research began with a literature search to gather knowledge related to rainfall prediction in Medan City and Fuzzy Time Series used in the prediction. The references used came from scientific journals, books, internet (websites), and journals as well as sources of information related to the research. The data used in the study was obtained from secondary data collection from the BMKG Medan City website.

This interview method was conducted by researchers to the Head of the Weather Prediction Sub Division at the BMKG Public Meteorology Center, Mr. Hendro Nugroho, ST, M.SI and Simon Sinaga, ST as staff of the BMKG Weather Prediction Sub Division using the question and answer method which was carried out on March 23, 2024. Observation is done by observing, understanding, and recording important things, and collecting data related to Rainfall in Medan City.

3. RESULTS AND DISCUSSION
A. Data Description

Data collection is carried out to collect the necessary information and data. The rainfall data for the last 5 years taken will be tested with the Fuzzy Time Series (FTS) Method to determine the prediction of high and low rainfall in Medan City. The following presents the research sample data used in the calculation of the FTS method.

Table 1. Rainfall Data (mm) Period 2019 – 2023

Tahun	Periode	Curah Hujan
2019	January	210.0
	February	204.0
	March	112.0
	April	172.0
	May	425.0
	June	373.5
	July	201.0
	August	124.0
	September	388.0
	October	458.0
	November	294.0
	December	317.7
2020	January	317.7
	February	80.0
	March	105.6

	April	354.3
	May	498.8
	June	601.1
	July	293.9
	August	211.0
	September	317.1
	October	484.7
	November	294.6
	December	405.8
2021	January	518.3
	February	87.9
	March	222.7
	April	300.2
	May	158.0
	June	243.8
	July	193.7
	August	295.2
	September	287.1
	October	257.7
	November	497.4
	December	189.2
2022	January	181.0
	February	334.8
	March	191.2
	April	184.2
	May	125.5
	June	313.4
	July	165.9
	August	505.1
	September	308.2
	October	321.5
	November	525.9
	December	321.2
2023	January	164.5
	February	163.2
	March	193.5
	April	196.1
	May	189.1
	June	348.4
	July	196.8
	August	606.6
	September	577.5
	October	278.0
	November	183.6

	December	335.5

Source: (BMKG Region 1 Medan)

B. Fuzzy Time Series Method Calculation

Fuzzy Time Series (FTS) is a prediction method used for time series data that is uncertain or fuzzy. This method was developed to handle uncertainties that cannot be explained by traditional statistical models.

Stages in predicting rainfall using Fuzzy Time Series (FTS).

1) Forming the Universe Set. Determine the range of values of the time series data used. Then sort the historical rainfall data, obtain the minimum value and maximum value of the data using the universal set equation:

$U = [D\_min ; D\_max]$
$U = [80.0 ; 606.6]$
D_min = minimum value of rainfall
D_max = maximum value of rainfall
Then to calculate the range, namely:
Range = D_max- D_min
= 606.6 - 80.0
= 526.6

2) Fuzzy Set Formation: Define fuzzy sets based on the universe set, then define the membership function for each set. Calculate the number of interval classes using the formula:

= 1 + 3.3 LOG (N)
= 1 + 3.3 LOG (60)
= 6.87 rounded to 7

Table 2. Formed Class Interval

Class	Beginning	End	Mean (Middle Value)
A1	80.0	160.0	120
A2	160.0	240.0	200
A3	240.0	320.0	280
A4	320.0	400.0	360
A5	400.0	480.0	440
A6	480.0	560.0	520
A7	560.0	640.0	600

3) Fuzzy Time Series Model Building: Build a model based on predefined fuzzy relations. Defuzzification converts fuzzy prediction results to numerical form to get forecasting results.

Table 3. Prediction Result

Year	Period	Rainfall	Predicted Value
2019	January	210.0	-
	February	204.0	360.0
	March	112.0	360.0
	April	172.0	240.0
	May	425.0	360.0
	June	373.5	386.7
	July	201.0	386.7
	August	124.0	360.0
	September	388.0	240.0
	October	458.0	386.7
	November	294.0	386.7
	December	317.7	320.0
2020	January	317.7	320.0

	Month		
	February	80.0	320.0
	March	105.6	240.0
	April	354.3	240.0
	May	498.8	386.7
	June	601.1	312.0
	July	293.9	440.0
	August	211.0	320.0
	September	317.1	360.0
	October	484.7	320.0
	November	294.6	312.0
	December	405.8	320.0
2021	January	518.3	386.7
	February	87.9	312.0
	March	222.7	240.0
	April	300.2	360.0
	May	158.0	320.0
	June	243.8	240.0
	July	193.7	320.0
	August	295.2	360.0
	September	287.1	320.0
	October	257.7	320.0
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	April	184.2	360.0
	May	125.5	360.0
	June	313.4	240.0
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	April	196.1	360.0
	May	189.1	360.0
	June	348.4	360.0
	July	196.8	386.7
	August	606.6	360.0
	September	577.5	440.0

	October	278.0	440.0
	November	183.6	320.0
	December	335.5	360.0
2024	January	-	386.7

Based on the calculation results with the FTS method, forecasting the amount of rainfall in Medan City, this forecast looks at the fuzzification of previous data. Therefore, forecasting rainfall intensity in Medan City for the January 2024 period using the fuzzification of the December 2023 period resulted in a rainfall prediction of 386,7.

C. Interface Implementation

1) Admin Form Login

This page is the login form interface to access the main page by entering the username and password. The following is the login form interface below.
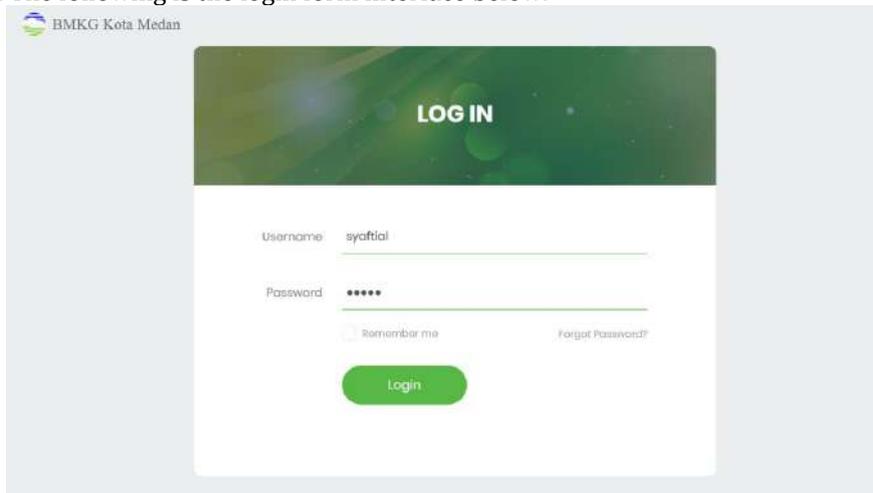
2) Home Page

This page is the main form display that can be used after entering user name and password data. Here is how the main form looks like.

3) Rainfall Form

This display presents information about rainfall data which functions as a medium for entering new rainfall data, as well as editing and deleting existing rainfall data. The following is a view of the page:
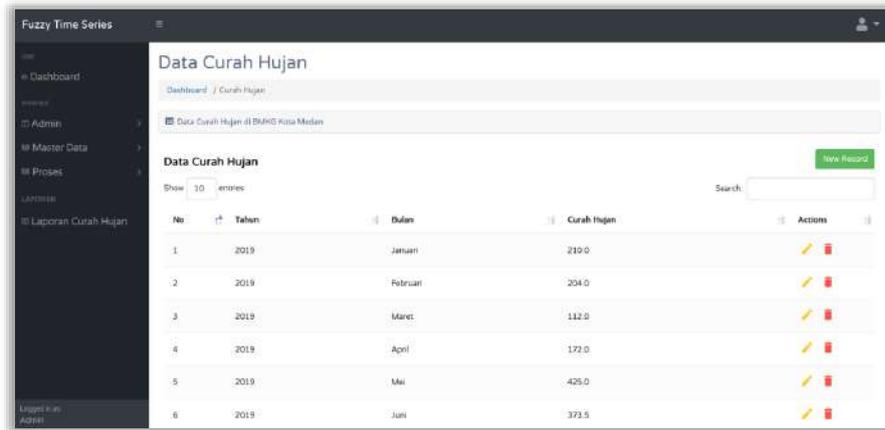
To add rainfall data, it can be done by clicking the add button on the form. The following is the interface of the rainfall data input page:
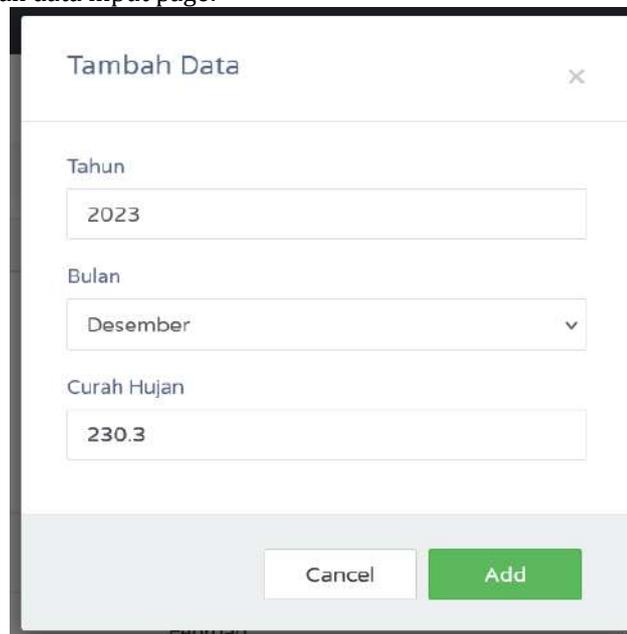
4)   Region Form

This area form display contains sub-district data located in Medan City. The display of the sub-district area form is shown in the following figure:
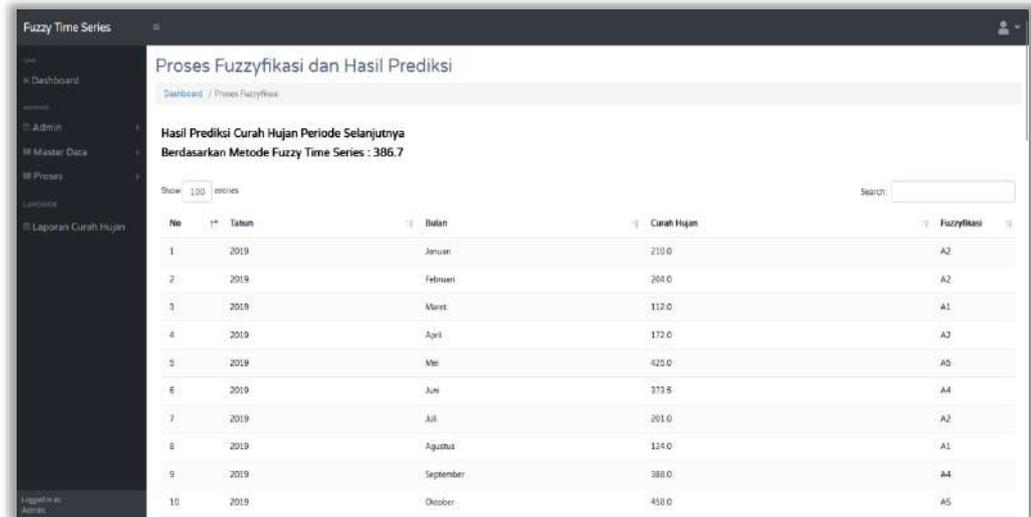
5) Interval Process Form

The interval process page is an interface page for calculating the existing interval process. Thus, this form will produce values and classes for each interval.

6) Result Form Display

On the results page, is an interface that is used in viewing the results of the process of predicting rainfall entered into this system. The following is a description of the results of the design on the results page interface:

After completing the implementation stage, the next step is to conduct a trial to ensure that the system that has been built meets the desired needs. After the test is carried out, a report will be generated, namely the prediction result report as shown in the figure below:

7) Home Page Form Display

On the home page form, is an interface for visitors to access this rainfall prediction application. The following is a description of the implementation results of the interface / home page interface for visitors:

8) Rainfall List Page Form View

On the rainfall list page form, is an interface for visitors to access this rainfall prediction data. The following is a description of the implementation results on the rainfall page:

D. Interface Trial

At the trial stage, it aims to ensure that the system that has been built can function according to its function so that it can be applied as needed. The tool/method used for interface testing is Blackbox Testing.

1) Blackbox Testing

This test aims to check the functional (input and output) in the system or application that is in the development stage. The focus of this test is from the end-user's point of view of the program or application, so that each function must run normally as designed.

Table 4. Blackbox Login

No	Login	Description	Result
1	Click Login	The system will adjust the existing data or inputted into the username or password database, with the data entered through the button on the application. If the username and password match, the system will display the main page. if wrong, the system will remain on the login page.	[✓] Valid

The table is the result of Blackbox testing of the login form which includes the elements in the form. From this test, it can be concluded that the login function functions normally and can be said to be successful.

Table 5. Blackbox Home Page

No	Home Page	Description	Result
1	Click Home	System akan menampilkan halaman utama yang berisi penjelasan singkat mengenai aplikasi prediksi.	[✓] Valid
2	Click Rainfall Data	Sistemakan menampilkan halaman data curah hujan.	[✓] Valid
3	Click Profile	Sistem akan menampilkan halaman informasi singkat mengenai profil BMKG Kota Medan	[✓] Valid
4	Click Admin Login	Sistem akan menampilkan halaman login untuk masukke menu admin	[✓] Valid

The table above is a Blackbox testing table of the main page. There are 4 functional tested in this form, including: Click Home, Click Rainfall, Click Profile, and Click Admin Login. All of these functions produce valid results and work as they should.

Table 6. Blackbox Rainfall Page

No	Rainfall Page	Description	Result
1	Click Rainfall	The system will display the rainfall data page	[✓] Valid
2	Click Add	The system will display a page form to add rainfall data	[✓] Valid
3	Click Edit	The system will display an edit view that allows users to change rainfall data	[✓] Valid
4	Click Delete	The system will delete the selected rainfall data	[✓] Valid

Table 7. Blackbox Region Page

No	Page	Description	Result
1	Click Region Page	The system will display the region page	[✓] Valid
2	Click Add	The system will display a form page to add criteria	[✓] Valid
3	Click Edit	The system will display an edit view that allows users to change the criteria	[✓] Valid
4	Click Delete	The system will delete the selected data.	[✓] Valid

Table 8. Blackbox FTS Process Page

No	FTS Process Page	Description	Result
1	Click FTS Process	The system will display the FTS Process page	[✓] Valid
2	Click Add	The system will display the page form to manage the FTS Process data	[✓] Valid
3	Click Edit	The system will display an edit view that allows users to change the FTS Process data	[✓] Valid
4	Click Delete	The system will display the FTS calculation report.	[✓] Valid

2) Testing Results

After testing the system, it can be concluded that the system results obtained are:
- The application of the Fuzzy Time Series method from the rainfall data input stage to the prediction results on the web page is in accordance with the design stages carried out.
- Prediction applications that use the Fuzzy Time Series method in rainfall prediction at BMKG Medan run well and are able to produce rainfall prediction reports.

4.   CONCLUSION

The conclusions that can be obtained from the stages of research using the Fuzzy Time Series method are The Fuzzy Time Series method has shown a good ability in predicting rainfall in Medan City. The analysis results show that this model can provide fairly accurate predictions, with a relatively low error rate compared to other prediction methods. Forecasting Medan City's rainfall using average-based Fuzzy Time Series, based on Medan City's rainfall data from January 2019 to December 2023, resulted in a prediction for January 2024 of 386,7.

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