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Rainfall prediction in Blora regency using mamdani's fuzzy inference system

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ABSTRACT

In the case study of weather prediction, there are several tests that have been carried out by several figures using the fuzzy method, such as the Tsukamoto fuzzy, Adaptive Neuro Fuzzy Inference System (ANFIS), Time Series, and Sugeno. And each method has its own advantages and disadvantages. For example, the Tsukamoto fuzzy has a weakness, this method does not follow the rules strictly, the composition of the rules where the output is always crisp even though the input is fuzzy, ANFIS has the disadvantage of requiring a large amount of data. which is used as a reference for calculating data patterns and the number of intervals when calculating data patterns and Sugeno has the disadvantage of having less stable accuracy results even though some tests have been able to get fairly accurate results. In research on the implementation of the Mamdani fuzzy inference system method using the climatological dataset of Blora Regency to predict rainfall, it can be concluded as follows: (1) The fuzzy logic of the Mamdani method can be used to predict the level of rainfall in the city of Blora by considering the factors that affect the weather, including temperature, wind speed, humidity, duration of irradiation and rainfall. (2) Fuzzy logic for prediction with uncertain input values can produce crisp output because fuzzy logic has tolerance for inaccurate data. (3) The results of the accuracy of calculations using the Mamdani fuzzy inference system method to predict rainfall in Blora Regency are 66%.

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1. INTRODUCTION

Nowadays, predictions are indispensable and as a source to support decisions in upcoming events. In previous days, forecasts were aimed at supporting humans in anticipating natural disasters. Weather forecasting in Indonesia is the responsibility of the Meteorology, Climatology and Geophysics Agency (BMKG). By predicting weather conditions using IF-THEN, it displays the part of the imprecision and uncertainty that is calculated using an effective algorithm.

All water flowing in rivers and in various reservoirs above the ground surface and below it comes from rain [1]. The amount, intensity, and distribution of rain are factors that affect the amount and variation of river discharge [2]. Rainfall in the watershed also has a relationship with river discharge. Rain recording data can be an alternative if there is no debit recording data [3], [4].

It is said by Navianti [5] that the weather tends to change quickly, resulting in unavoidable deviations in the process. This deviation can be seen from the event of continuous rain for several days which can cause catastrophic flooding. Weather and its elements are important to pay attention to and study well because its effects will cause problems for humans and living things.

The concept of fuzzy logic is analogous to the perception of human emotions and the process of interpretation [6]. Distinguishing the approach from classical controllers, which are point-to-point control systems, fuzzy logic control systems are range-to-point or range-to-system control distances. The concept of a fuzzy logic system was introduced by Zadeh in 1965. Fuzzy logic is aimed at strengthening reasoning methods that are estimated to be more than accurate [7].

In the case study of weather prediction, there are several tests that have been carried out by several figures using the fuzzy method, such as the Tsukamoto fuzzy , Adaptive Neuro Fuzzy Inference System (ANFIS), Time Series, and Sugeno [8], [9]. And each method has its own advantages and disadvantages. For example, the Tsukamoto fuzzy has a weakness, this method does not follow the rules strictly, the composition of the rules where the output is always crisp even though the input is fuzzy, ANFIS has the disadvantage of requiring a large amount of data. which is used as a reference for calculating data patterns and the number of intervals when calculating data patterns and Sugeno has the disadvantage of having less stable accuracy results even though some tests have been able to get fairly accurate results.

And besides the above method, there is one method called fuzzy mamdani. On this occasion, we will calculate rainfall predictions using the Mamdani fuzzy method using a dataset with inputs of temperature, humidity, duration of irradiation, wind speed [10]. So, it is hoped that better calculation results are used for case studies of rainfall forecasts in the Blora Regency area.

2. METHOD

In this study, researchers used the Mamdani method to predict rainfall using rainfall data in Blora Regency [11]. The data used are data on temperature, wind speed, humidity and duration of irradiation from January 2014 to December 2014.

Broadly speaking, this research is divided into five stages, namely: (1) Literature study, (2) Data collection, (3) Fuzzy Inference System Design, (4) Fuzzy Inference System Testing, and (5) Drawing conclusions. The flowchart of the research can be seen in Figure 1.

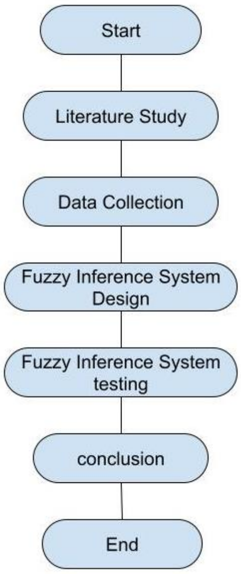

Figure 1. Research design

2.1. Literature Study

Literature study is an activity to find and collect data to be analyzed according to the existing problems. This literature study can be done by reading articles, journals, news and books.

2.2. Data Collection

The data collected in this study include data on temperature, wind speed, humidity, duration of irradiation and the amount of rainfall from January 2012 to December 2012 [11]. Data obtained from Public Works of Water Resources and Spatial Planning, Open Data of Central Java Province and data on the amount of rainfall Rainfall is obtained from the 2015 book Blora in Figures. The data of rainfall amount is presented in Table 1 below.

Table 1. Data on the amount of rainfall from January 2014 – December 2014 (*Source: Meteorological Station of Blora Regency*)

Month	Temperature (℃)	Wind Speed (KM/Day)	Air Humidity (%)	Exposure Time (%)	Rainfall (mm)
January	25.82	23.81	98.68	19.16	261
February	25.84	30.45	98.82	23.50	128
March	25.85	13.52	98.61	46.79	136
April	25.87	11.57	98.60	50.05	177
May	25.85	45.90	98.74	58.30	41
June	25.89	52.00	98.73	57.54	45
July	25.85	54.13	98.55	57.25	91
August	26.33	63.61	94.61	65.26	28
September	25.66	71.03	91.27	65.44	10
October	27.66	63.68	95.87	59.72	38
November	27.45	27.70	95.07	42.96	137
December	26.84	10.52	93.29	27.14	251

2.3 Fuzzy Inference System Design

In the design stage of the fuzzy inference system, there are five stages, namely (1) set formation, (2) fuzzification, (3) implication function, (4) rule composition, and (5) defuzzification. The flowchart of the fuzzy inference system can be seen in Figure 2.

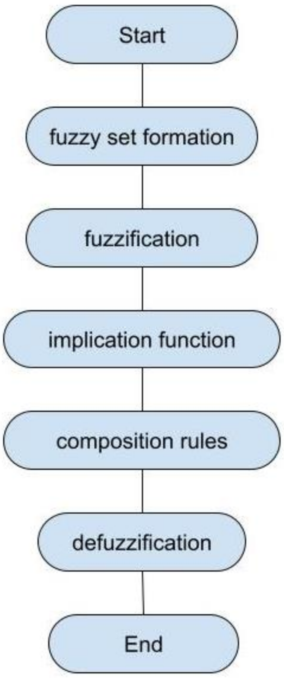

Figure 2. Fuzzy Inference System

2.3.1 Formation of Sets

In the process of predicting rainfall requires four criteria. These various criteria are referred to as fuzzy input variables. Input variables include temperature, wind speed, air humidity and irradiation time. While the output variable is rainfall. The membership function of each variable is as follows:

a. Input Variable

• Air temperature

The air temperature variable forms three fuzzy sets, namely cool, normal and hot that shown in Table 2.

Table 2. Air Temperature Fuzzy Set

Fuzzy Set	Interval
Cool	[20 - 27]
Normal	[25 - 30]
Hot	[28 - 40]

The membership function of air temperature is shown in equation below.

$$\mu_{Cool}[x] = \begin{cases} 0, & x \le 20 \text{ } or \text{ } x \ge 27 \\ (x-20)/(20-20), & 20 \le x \le 20 \\ 1, & 20 \le x \le 25 \\ (27-x)/(27-25) & 25 \le x \le 27 \end{cases} \quad (1)$$

$$\mu_{Normal}[x] = \begin{cases} 0, & x \le 25 \text{ } or \text{ } x \ge 30 \\ (x-25)/(27-25), & 25 \le x \le 27 \\ 1, & 27 \le x \le 28 \\ (30-x)/(30-28) & 28 \le x \le 30 \end{cases} \quad (2)$$

$$\mu_{Hot}[x] = \begin{cases} 0, & x \le 28 \text{ } or \text{ } x \ge 40 \\ (x-28)/(30-28), & 28 \le x \le 30 \\ 1, & 30 \le x \le 28 \\ (40-x)/(40-40) & 40 \le x \le 40 \end{cases} \quad (3)$$

• Wind velocity

Wind speed variables form three fuzzy sets, namely: slow, medium, and fast that shown in Table 3.

Table 3. Wind Speed Fuzzy Set

Fuzzy Set	Interval
Slow	[0 - 19]
Medium	[6 - 50]
Fast	[29 - 119]

The membership function of wind speed is shown in equation below.

$$\mu_{Slow}[x] = \begin{cases} 0, & x \le 0 \text{ } or \text{ } x \ge 19 \\ (x-0)/(0-0), & 0 \le x \le 0 \\ 1, & 0 \le x \le 6 \\ (19-x)/(19-6) & 6 \le x \le 19 \end{cases} \quad (4)$$

$$\mu_{Medium}[x] = \begin{cases} 0, & x \le 6 \text{ } or \text{ } x \ge 50 \\ (x-6)/(19-6), & 6 \le x \le 19 \\ 1, & 19 \le x \le 29 \\ (50-x)/(50-29) & 29 \le x \le 50 \end{cases} \quad (5)$$

$$\mu_{Tight}[x] = \begin{cases} 0, & x \le 29 \; or \; x \ge 119 \\ (x-29)/(50-29), & 29 \le x \le 50 \\ 1, & 60 \le x \le 119 \\ (119-x)/(119-119) & 119 \le x \le 119 \end{cases} \tag{6}$$

• Humidity

The air humidity variable forms three fuzzy sets, namely: dry, moist, and wet that shown in Table 4.

Table 4. Air Humidity Set

Fuzzy Set	Interval
Dry	[0 - 70]
Moist	[65 - 80]
Wet	[75 - 100]

The membership function of air humidity is shown in equation below.

$$\mu_{Dry}[x] = \begin{cases} 0, & x \le 55 \; or \; x \ge 70 \\ (x-55)/(55-55), & 55 \le x \le 55 \\ 1, & 55 \le x \le 65 \\ (70-x)/(70-65) & 65 \le x \le 70 \end{cases} \tag{7}$$

$$\mu_{Moist}[x] = \begin{cases} 0, & x \le 65 \; or \; x \ge 92 \\ (x-65)/(70-65), & 65 \le x \le 70 \\ 1, & 70 \le x \le 87 \\ (92-x)/(92-87) & 87 \le x \le 92 \end{cases} \tag{8}$$

$$\mu_{Wet}[x] = \begin{cases} 0, & x \le 87 \; or \; x \ge 95 \\ (x-87)/(92-87), & 87 \le x \le 92 \\ 1, & 92 \le x \le 100 \\ (100-x)/(100-100) & 100 \le x \le 100 \end{cases} \tag{9}$$

• Exposure Time

The variable length of irradiation or duration of solar irradiation forms three fuzzy sets, namely: low, medium and high that shown in Table 5.

Table 5. Fuzzy Set Exposure time

Fuzzy Set	Interval
Low	[0 - 30]
Medium	[20 - 65]
High	[55 - 100]

The membership function of exposure time is shown in equation below.

$$\mu_{Low}[x] = \begin{cases} 0, & x \le 0 \; or \; x \ge 0 \\ (x-0)/(0-0), & 0 \le x \le 0 \\ 1, & 0 \le x \le 20 \\ (30-x)/(30-20) & 20 \le x \le 30 \end{cases} \tag{10}$$

$$\mu_{Medium}[x] = \begin{cases} 0, & x \le 20 \; or \; x \ge 65 \\ (x-20)/(30-20), & 20 \le x \le 30 \\ 1, & 30 \le x \le 55 \\ (65-x)/(65-55) & 65 \le x \le 55 \end{cases} \tag{11}$$

$$\mu_{High}[x] = \begin{cases} 0, & x \leq 55 \; or \; x \geq 92 \\ (x-55)/(65-55), & 55 \leq x \leq 65 \\ 1, & 65 \leq x \leq 100 \\ (100-x)/(100-100) & 100 \leq x \leq 100 \end{cases} \tag{12}$$

b. Output Variable

- Rainfall

  Rainfall variables form five fuzzy sets, namely: very light, light, normal, heavy and very heavy that shown in Table 6.

Table 6. Rainfall Fuzzy Set

Fuzzy Set	Interval
Very Light	[0 - 5]
Light	[2.5 - 20]
Normal	[15 – 50]
Heavy	[45 – 165]
Very Heavy	[150 – 270]

The membership function of rainfall is shown in equation below.

$$\mu_{Very\ Light}[x] = \begin{cases} 0, & x \leq 0 \; or \; x \geq 5 \\ (x-0)/(0-0), & 0 \leq x \leq 0 \\ 1, & 0 \leq x \leq 2.5 \\ (5-x)/(5-2.5) & 2.5 \leq x \leq 5 \end{cases} \tag{13}$$

$$\mu_{Light}[x] = \begin{cases} 0, & x \leq 2.5 \; or \; x \geq 20 \\ (x-2.5)/(5-2.5), & 2.5 \leq x \leq 5 \\ 1, & 5 \leq x \leq 15 \\ (20-x)/(20-15) & 15 \leq x \leq 20 \end{cases} \tag{14}$$

$$\mu_{Normal}[x] = \begin{cases} 0, & x \leq 15 \; or \; x \geq 20 \\ (x-15)/(20-15), & 15 \leq x \leq 20 \\ 1, & 20 \leq x \leq 45 \\ (50-x)/(50-45) & 45 \leq x \leq 50 \end{cases} \tag{15}$$

$$\mu_{Heavy}[x] = \begin{cases} 0, & x \leq 45 \; or \; x \geq 100 \\ (x-45)/(50-45), & 45 \leq x \leq 50 \\ 1, & 50 \leq x \leq 115 \\ (165-x)/(165-115) & 95 \leq x \leq 165 \end{cases} \tag{16}$$

$$\mu_{Very\ Heavy}[x] = \begin{cases} 0, & x \leq 150 \; or \; x \geq 270 \\ (x-150)/(170-150), & 150 \leq x \leq 170 \\ 1, & 270 \leq x \leq 270 \\ (270-x)/(270-270) & 270 \leq x \leq 270 \end{cases} \tag{17}$$

3. RESULTS AND DISCUSSIONS

3.1. Rules

Rule Based System is a system that is used as a way to store and manipulate knowledge to be realized in an information that can assist in solving various problems or can also be defined as an Expert System that uses rules to present its knowledge. In other words, a rule-based system is a software that presents expert expertise in the form of rules in a particular domain to solve a problem.

After the formation of the fuzzy set, then the formation of fuzzy logic rules is carried out. Due to using the Mamdani method, the membership function used is the MIN function using 81 (eighty-one) rules that contain a combination of all input variables. From the 81 rules, Table 7 shows some rules used.

Table 7. Table of Rules

No	Rule
1	If (Temperature is Cool) and (Wind_Speed is Strong) and (Air_Moisture is Wet) and (Sun_Rain is Moderate) then (Weather_Rain is Very_Heavy) (1)
2	If (Temperature is Cool) and (Wind_Speed is Strong) and (Air_Moisture is Wet) and (Sun_Rain is High) then (Weather_Rain is Light) (1)
3	If (Temperature is Cool) and (Wind_Speed is Medium) and (Air_Moisture is Wet) and (Sun_Rain is Moderate) then (Weather_Rain is Heavy) (1)
4	If (Temperature is Cool) and (Wind_Speed is Medium) and (Air_Moisture is Wet) and (Sun_Rain is Moderate) then (Weather_Rain is Normal) (1)
5	If (Temperature is Normal) and (Wind_Speed is Slow) and (Air_Moisture is Dry) and (Sun_Rain is Low) then (Rain_Weather is Light) (1)
6	If (Temperature is Normal) and (Wind_Speed is Slow) and (Air_Moisture is Wet) and (Sun_Rain is Low) then (Rain_Weather is Normal) (1)
7	If (Temperature is Hot) and (Wind_Speed is Slow) and (Air_Moisture is Dry) and (Sun_Rain is Low) then (Rain_Weather is Very Light) (1)
8	If (Temperature is Hot) and (Wind_Speed is Strong) and (Air_Moisture is Dry) and (Sun_Rain is Low) then (Rain_Weather is Light) (1)
9	If (Temperature is Hot) and (Wind_Speed is Slow) and (Air_Moisture is Dry) and (Sun_Rain is High) then (Rain_Weather is Very Light) (1)
10	If (Temperature is Hot) and (Wind_Speed is Moderate) and (Air_Moisture is Humid) and (Sun_Rain is Moderate) then (Rain_Weather is Light) (1)

3.2. Implementation

The calculation test is done by comparing the results of rainfall predictions contained in the dataset with the results of rainfall predictions using a system with the python programming language. The test results is shown in Table 8.

Table 8. Calculation table of test results

Month	Rainfall (mm)	Description	Prediction System	According (Yes/No)
January	261	Very thick	Heavy	No
February	128	Heavy	Heavy	Yes
March	136	Heavy	Heavy	Yes
April	177	Heavy	Heavy	Yes
May	41	Normal	Light	No
June	45	Normal	Normal	Yes
July	91	Normal	Normal	No
August	28	Light	Light	Yes
September	10	Light	Light	Yes
October	38	Normal	Normal	Yes
November	137	Heavy	Heavy	Yes
December	251	Very thick	Heavy	No

Based on the test table data, it is known that from 12 cases there were 4 failed cases, so that performance measurements can be made using the formulation of accuracy and error rate.

Formula Accuracy

$$Accuracy = \frac{The\ amount\ of\ data\ \text{"}Yes\text{"}}{Total\ amount\ of\ test\ data} \tag{18}$$

Error rate formula

$$Error = \frac{The\ amount\ of\ data\ "Yes"}{Total\ amount\ of\ test\ data} \tag{19}$$

The calculation results

$$Accuracy = \frac{8}{12} = 66\% \tag{20}$$

$$Error = \frac{4}{12} = 33\% \tag{21}$$

In the study using the Mamdani fuzzy inference system after performing calculations using a dataset of 12 data resulted in an accuracy of 66%

4. CONCLUSION

In research on the implementation of the Mamdani fuzzy inference system method using the climatological dataset of Blora Regency to predict rainfall, it can be concluded as follows: (1) The fuzzy logic of the Mamdani method can be used to predict the level of rainfall in the city of Blora by taking into account the factors that affect the weather, including temperature, wind speed, humidity, duration of irradiation and rainfall. (2) Fuzzy logic for prediction with uncertain input values is able to produce crisp output because fuzzy logic has tolerance for inaccurate data. (3) The results of the accuracy of calculations using the Mamdani fuzzy inference system method to predict rainfall in Blora Regency are 66%.

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