RAINFALL PREDICTION WITH TSUKAMOTO FUZZY INFERENCE SYSTEM

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ABSTRACT

Rainfall Prediction in Indonesia is very important for the agricultural sector. However, getting accurate predictions is difficult because there are too many input parameters including global climate change that affect their accuracy. Study of weather prediction is a challenge that is always interesting to study. Although there was several methods of weather prediction, but the results have not provided good accuracy. The use of fuzzy logic has been proven by scientists to be applied to the expression of uncertainty, it is not clear and qualitative from a system. A prediction is needed to set a good schedule for planting agricultural commodities. The reliability of this prediction depends on accuracy in choosing correlated variables. If existing historical databases fail to record the most correlated variables, then the reliability of these data-driven forecast approaches is questionable. This paper proposes Tsukamoto fuzzy inference system (FIS) to simulate problem solving. Intensive efforts were made to build a fuzzy membership function based on rainfall data in the South Lampung region from ten years ago. Some numerical experiments prove that the proposed approach produces better than that achieved by other approaches.

Keywords - Prediction, Rainfall, Tsukamoto Fuzzy Inference System, South Lampung

INTRODUCTION

Indonesia is between 6 ° N - 11 ° S and is a tropical region with two seasons namely the dry and rainy seasons which alternate every six months. The dry season lasts between April and October. The rainy season lasts between October and April. Rainfall is important in the rainy season because rainfall in an area determines a series of human activities. For example, climate information and its classification have become a reference for agriculture, transportation, and tourism, such as: shipping, aviation, and planting patterns. Some studies explain that climate affects the condition of economic conditions in an area. This shows that the number of demands from various parties who need information on the condition of the earth's atmosphere is faster, complete, and accurate. Rainfall is influenced by several factors, namely temperature, relative humidity, air pressure, wind speed, total cloud layer, and sun irradiation, these variables tend to change so that irregularities can be avoided. These irregularities can be seen from the continuous occurrence of rain for several days which can cause disasters such as floods. Thus, many people feel disadvantaged because floods can cripple economic activity, hamper transportation, damage city infrastructure, and cause other negative impacts, especially in South Lampung. Existing research, input variables used to predict rain in the form of air temperature, relative humidity, wind, and clouds by applying the method of Fuzzy Clustering, while the output variable in the form of prediction of rain (Safanah,2008) . Given the importance

of information about rainfall, in this study rainfall prediction was carried out by applying the Fuzzy Inference System method.

LITERATURE REVIEW

Many scholars have made efforts to implement different mining techniques in the areas of meteorological data based on weather data analysis and prediction. Meteorology Fuzzy Inference System has been successfully employed in the field of developing important forecasting applications.

Dynes Rizky Navianti,Sept 2012 : Rainfall prediction by applying the Fuzzy Inference System method, obtained rule-based models, namely models in the rainy season and models in the dry season. The model obtained has an average accuracy of 77.68% of the data analyzed. The highest accuracy results in the rainy season model = 70.96% in January, while the accuracy in the dry season model = 100% in August.

Mislan,2015 : this paper applied an Artificial Neural Network (ANN) with the Backpropagation Neural Network (BPNN) algorithm. In this experiment, the rainfall data were tested using two-hidden layers of BPNN architectures with three different epochs which were [2-50-10-1, epoch 500]; [2-50-20-1, with epochs 1000 and 1500]. The mean square error (MSE) is employed to measure the performance of the classification task. The experimental results showed that the architecture [2-50-20-1, epoch 1000] produced a good result with the value of MSE was 0.00096341. Furthermore, BPNN algorithm has provided a good model to predict rainfall in Tenggarong, East Kalimantan - Indonesia.

RESEARCH METHOD

A. Fuzzy Logic

Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1. It is employed to handle the concept of partial truth, where the truth value may range between completely true and completely false.[1] By contrast, in Boolean logic, the truth values of variables may only be the integer values 0 or 1.

Fuzzy Logic allows membership values between 0 and 1, gray level and also black and white, and in linguistic form, uncertain concepts like "little", "pretty", and "very". This logic is related to fuzzy sets and probability theories Or in other terms, fuzzy logic is a way to map an input space into an output space, has a continuous value. Fuzzy is expressed in the degree of a membership and the degree of truth. Therefore something can be said to be partly true and partly wrong at the same time.

B. Fuzzy Set

Fuzzy set is a group that represents a certain condition or condition in a fuzzy variable.

In the science of fuzzy logic we know two sets, namely the set of crisp (strict) and the fuzzy set (cryptic).

a. The set of crisp is a set that states that an object is a member of a set having a membership value (μ) = yes (1) or not (0), therefore the set of crisp is called a strict set.
b. Fuzzy set is a set that states an object can be a member of several sets with different membership values (μ).

In a firm set (crisp), the membership value of an item x in a set A, which is often written with μA [x], has two possibilities, namely: one (1), which means that an item becomes a member in a set or zero (0), which means that an item is not a member in a set.

In the fuzzy set the membership value lies in the range 0 to 1. If x has a fuzzy membership value μA [x] = 0 means that x is not a member of set A, so also if x has a fuzzy membership value μA [x] = 1 means x becomes a member full on set A.

The similarity between fuzzy membership and probability sometimes causes confusion, because it has values at intervals [0,1], but the interpretation of values is very different. Fuzzy membership provides a measure of opinions or decisions, while the probability of indicating the proportion to the frequency of results is true in the long run. (Kusumadewi, 2006)

The fuzzy set has 2 attributes, namely:

1. Linguistics, namely naming a group that represents a certain condition or condition using natural language, such as: Young, Old.

2. Numerical, which is a value (number) that shows the size of a variable such as: 25, 40, 60. (Kusumadewi, 2006: 6)

C. Membership Function

In a fuzzy system, the membership function plays a very important role to represent problem. The membership function is a curve shows mapping of data input points into values membership. The membership function that is used is too much is a triangular membership function and membership function trapezoid (Suyanto, 2011).

1. Triangle Membership Function

The triangle curve is basically a combination of two lines (linear). This function has only one x value has a degree of membership equal to 1, that is when x = b. Triangle curve representation has a membership function, that is in equation .

(x) = trimf (x; a, b, c)

$$= \begin{cases} 0; x \le a, x \ge c \\ \frac{x-a}{b-a}; a \le x \le b \\ \frac{c-x}{c-b}; b \le x \le c \end{cases}$$

2. Trapezoid Membership Function

Triangle curves are basically like triangular shapes, it's just that there are some points that have membership values 1. A trapezoidal curve representation has a membership function, that is in equation .

(x) = trapmf (x; a, b, c, d)

$$= \begin{cases} 0; x \le a, x \ge d \\ \frac{x-a}{b-a}; a \le x \le b \\ 1; b \le x \le c \\ \frac{d-x}{d-c}; b \le x \le c \end{cases}$$

D. Fuzzy Inference System

Fuzzy inference is the process of formulating mapping from input given to an output using fuzzy logic. Mapping then provides the basis from which decisions can be made, or patterns seen. The fuzzy inference process involves all the pieces described in the previous section: Membership Functions, Logical Operations, and If-Then Rules. Fuzzy Inference System (FIS) also called fuzzy inference engine is a system that can do reasoning with similar principles as humans do reasoning with their instincts.

There are several types of FIS known, namely Mamdani, Sugeno and Tsukamoto. FIS is the easiest to understand, because it is best suited to human instincts, FIS Mamdani. The FIS works based on linguistic rules and has a fuzzy algorithm that provides an approximation for mathematical analysis.

FINDINGS AND DISCUSSION

A. Fuzzy Logic

Before calculating the fuzzy inference system, the data needed is rainfall prediction data. Table 1 below presents data taken from observations in the South Lampung region that will be used as input values for each criterion. Predictions will be made with 10 test data.

Table 1 Data Example for input Tsukamoto FIS in South Lampung

No	Zt-1	Zt-2	Zt-17	Zt-34
10/01/18	0	0	0	0
10/02/18	0	0	0	0
10/03/18	0	0	3	0

10/04/18	0	0	0	45
10/05/18	0	0	0	0
10/06/18	0	3	0	0
10/07/18	8	0	0	0
10/08/18	0	0	18	0
10/09/18	0	4	0	0
10/10/18	0	26	1	0

B. Fuzzy Set

The definition of a fuzzy set (fuzzy set) is a set of x objects with each object having a membership value "μ" or also called the truth value. Fuzzy sets can be defined as entities that represent certain situations in fuzzy variables (G. Mazenda, 2015). In this study, the use of fuzzy sets with two linguistic values, low and high. The fuzzy set formation is adjusted to include rainfall data. Linguistic values are combined with fuzzy sets, each of which has a predetermined membership function (N. R. Sari, 2015). Data fuzzy sets and linguistic values are presented in Table 2

Table 2. Fuzzy Association

Fuzzy Association	
Variable Input	**Value Linguistics**
Z t-1	Low
	High
Z t-2	Low
	High
Z t-17	Low
	High
Z t-34	Low
	High
Z t	Low
	Moderate
	High

C. Membership Function

Membership Functionis the process of changing numerical variables into linguistic variables. The fuzzification function is used to change the express value, for example a∈B, to a fuzzy C set with a membership value a. Fuzzification is expected to help simplify the computation that the system must do in the process of its inferiority. In the sense that the fuzzification process can calculate or input sharp values into membership degree values. Fuzzification calculations process based on the boundaries of the membership function (Sri Kusumadewi, 2013)
The membership function of fuzzy sets with 4 input criteria was show in Fig. 1 to Fig 5.

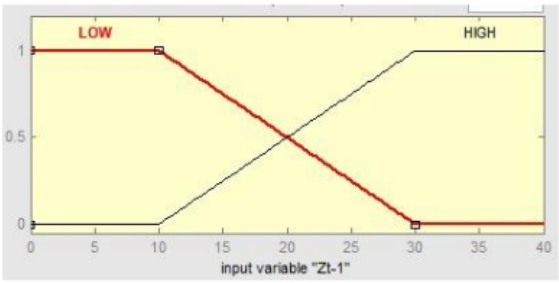

Fig. 1. Membership Function Boundaries for Zt-1

Low degree of membership:

$$\mu_{Zt-1\ Low}(x) = \begin{cases} 1 & ; x \leq 10 \\ \dfrac{30-x}{30-10}; & 10 < x < 30 \\ 0 & ; x \geq 30 \end{cases}$$

High Degree of Membership:

$$\mu_{Zt-1\ High}(x) = \begin{cases} 1 & ; x \geq 30 \\ \dfrac{x-10}{30-10}; & 10 < x < 30 \\ 0 & ; x \leq 10 \end{cases}$$

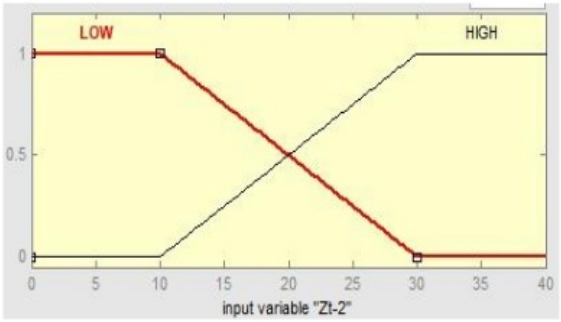

Fig. 2. Membership Function Boundaries for Zt-2

Low degree of membership:

$$\mu_{Zt-2\ Low}(x) = \begin{cases} 1 & ; x \leq 10 \\ \dfrac{30-x}{30-10}; & 10 < x < 30 \\ 0 & ; x \geq 30 \end{cases}$$

High Degree of Membership:

$$\mu_{Zt-2\ High}(x) = \begin{cases} 1 & ; x \geq 30 \\ \dfrac{x-10}{30-10}; & 10 < x < 30 \\ 0 & ; x \leq 10 \end{cases}$$

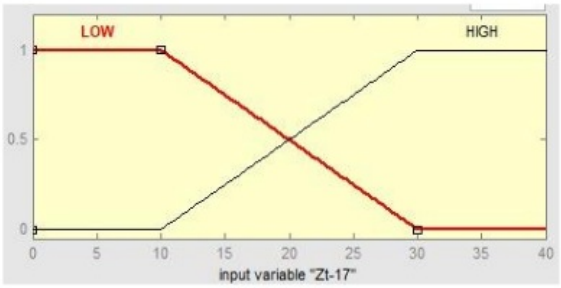

Fig. 3. Membership Function Boundaries for Zt-17

Low degree of membership:

$$\mu_{Zt-17\ Low}(x) = \begin{cases} 1 & ; x \leq 10 \\ \dfrac{30-x}{30-10}; & 10 < x < 30 \\ 0 & ; x \geq 30 \end{cases}$$

High Degree of Membership:

$$\mu_{Zt-17\ High}(x) = \begin{cases} 1 & ; x \geq 30 \\ \dfrac{x-10}{30-10} & ; 10 < x < 30 \\ 0 & ; x \leq 10 \end{cases}$$

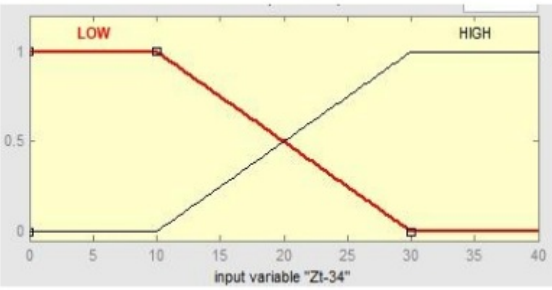

Fig. 4. Membership Function Boundaries for Zt-34

Low degree of membership:

$$\mu_{Zt-34\ Low}(x) = \begin{cases} 1 & ; x \leq 10 \\ \dfrac{30-x}{30-10} & ; 10 < x < 30 \\ 0 & ; x \geq 30 \end{cases}$$

High Degree of Membership:

$$\mu_{Zt-34\ High}(x) = \begin{cases} 1 & ; x \geq 30 \\ \dfrac{x-10}{30-10} & ; 10 < x < 30 \\ 0 & ; x \leq 10 \end{cases}$$

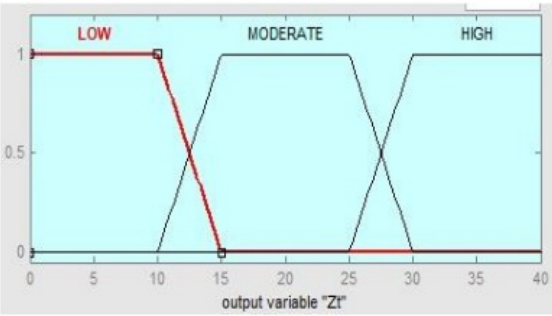

Fig. 5. Membership Function Boundaries for Zt

Low degree of membership:

$$\mu_{Zt\ Low}(x) = \begin{cases} 1 & ; z \leq 10 \\ \dfrac{15-x}{15-10} & ; 10 < z < 15 \\ 0 & ; z \geq 30 \end{cases}$$

Moderate Degree of Membership:

$$\mu_{Zt\ Moderate}(x) = \begin{cases} 1 ; 15 < z < 25 \\ \dfrac{x-10}{15-10} ; 10 < z \leq 15 \\ 0 ; z \leq 10\ atau\ z \geq 30 \end{cases}$$

High Degree of Membership:

$$\mu_{Zt\ High}(x) = \begin{cases} 1 \ ; z \geq 30 \\ \dfrac{x-25}{30-25}; \ 25 < z < 30 \\ 0 \ ; \ z \leq 25 \end{cases}$$

D. Fuzzy Inference System

Fuzzy Inference System (FIS) is a system that does a calculations based on fuzzy set theory, fuzzy concepts rules, and the concept of fuzzy logic, FIS is also one of the algorithms used for decision making. In fuzzy inference system (FIS) is a fuzzy input in the form of crisp values. That Sharp values will be calculated based on existing rules created to produce a number of fuzzifications called fuzzy process.

In Tsukamoto's method, every consequence of an if-then rule must be represented by a fuzzy set with a monotonous membership function, Tsukamoto fuzzy inference system method forms a rule base in the form of "cause-effect" or "if-last". The first step in calculating Tsukamoto's FIS method is to make fuzzy rules. The next step, calculated the degree of membership accordingly with the rules that have been made. Once the value is known membership level of each fuzzy rule, the value of Alpha predicates can be determined using fuzzy sets surgery (B. A. Restuputri, 2015).

Fuzzy rule base was shown in Table 3 and calculation of Tsukamoto fuzzy inference system was shown in Table 4.

Table 3. Fuzzy Rule Base

Rule	IF	Zt-1	Zt-2	Zt-17	Zt-34	Then	Rain
1	**IF**	Low	Low	Low	Low	**Then**	Low
2	**IF**	Low	Low	Low	High	**Then**	Low
3	**IF**	Low	Low	High	Low	**Then**	Low
4	**IF**	Low	Low	High	High	**Then**	Low
5	**IF**	Low	High	Low	Low	**Then**	Low
6	**IF**	Low	High	Low	High	**Then**	Moderate
7	**IF**	Low	High	High	Low	**Then**	Moderate
8	**IF**	Low	High	High	High	**Then**	Moderate
9	**IF**	High	Low	Low	Low	**Then**	Moderate
10	**IF**	High	Low	Low	High	**Then**	Moderate
11	**IF**	High	Low	High	Low	**Then**	Moderate
12	**IF**	High	Low	High	High	**Then**	High
13	**IF**	High	High	Low	Low	**Then**	High
14	**IF**	High	High	Low	High	**Then**	High
15	**IF**	High	High	High	Low	**Then**	High
16	**IF**	High	High	High	High	**Then**	High

Table 4. Calculation of Tsukamoto FIS

Rule	Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7	Data 8	Data 9	Data 10
1	1	1	1	0	1	1	1	0.6	1	0.2
2	0	0	0	1	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0.4	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0.8
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
α-Predikat * Z	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**12.4**	**10**	**11.6**

E. Results

In this research, the predicted results of the region in south Lampung will be shown. The previous year's rainfall data was taken as input data for each criterion. From the input data will be obtained the rainfall prediction results in the next ten days or Zt using calculations with Tsukamoto fuzzy inference system. The prediction results shown are predicting the results of 10 rainfall data in the south Lampung area presented in Table 5.

Table 5. Prediction Results with Tsukamoto FIS in South Lampung

Result Prediction in South Lampung Region		
Data	**Prediction Results (Z)**	**Rain**
10/01/18	10	Low
10/02/18	10	Low
10/03/18	10	Low
10/04/18	10	Low
10/05/18	10	Low
10/06/18	10	Low
10/07/18	10	Low
10/08/18	12.4	Low
10/09/18	10	Low
10/10/18	11.6	Low

CONCLUSION

From the results of the paper, the conclusion is:

1. Rainfall prediction by applying Tsukamoto's Fuzzy Inference Tsukamoto, rule-based models obtained in the rainy season, low (low) rainfall, moderate (moderate) rainfall and high (high) rainfall.
2. This research proves that the Tsukamoto FIS can be used forecast of rainfall in South Lampung. By using rain data 10 days ago (Zt-1), rainfall data 20 days ago (Zt-2), rainfall data 170 days ago (Zt-17), and rainfall data 340 days ago (Zt-34) got a more accurate forecast results.
3. This research can followed by optimization of fuzzy membership serves to get predictions with fewer errors.
4. For further research with the method Tsukamoto Fuzzy Inference System, can add a theory to find the level of accuracy of the Tsukamoto Fuzzy Inference System

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