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Design and Development of Fuzzy Logic Application Tsukamoto Method in Predicting the Number of Covid-19 Positive Cases in West Java

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Abstract

The increase in covid-19 positive patients in Indonesia, especially in West Java, is unpredictable, resulting in unpreparedness in dealing with covid-19 cases. People in monitoring and patients under supervision are the category that is breast-positive patients after passing the incubation period for 14 days. Fuzzy logic is one derivative of artificial intelligence that is able to predict a thing.
The study used the fuzzy logic of the Tsukamoto method to predict the percentage increase in positive cases of covid-19 with measures performed are fuzzification, rule formation, inference, and defuzzification. The results showed a 4.5% error rate indicating that predicting covid-19 using the fuzzy logic of the Tsukamoto method was successful.

Keywords: Fuzzy, Tsukamoto, prediction, Covid-19, West Java

1. Introduction

The development of science and technology is now an important need to run an agency. It can also influence the development of agencies to achieve a certain goal so that the agency has a good image. In order to achieve a goal that has been set by the agency, the activities of the agency must be productive. Productivity can develop with a tool or application to make it easier to do work, decisions, or in predicting an event. Predicting an event can help an agency in determining the exact steps to take in the future.

Many ways can be done to predict a thing, one of which is fuzzy logic. Fuzzy logic is a problem-solving system control methodology, which allows its membership to be between 0 and 1. Cases solved by fuzzy logic are cases of uncertain or vague nature (Ashraf et al., 2020; Asih, 2018; Mujiarto et al., 2019). In the Seventies, E.H. Mamdani researchers from London have shown that fuzzy logic can be implemented in control systems. Since then, research has been widely conducted and theories relating to fuzzy logic are increasingly popping up in magazine journals (Ghosh et al., 2020; Trisnawan et al., 2019).

One of the methods found in fuzzy logic is the Tsukamoto method which has a high validity rate. The use of Tsukamoto method in research on forecasting has been widely done (Chen and Honda, 2020; Mardani et al., 2020; Bao et al., 2019). Research conducted from the implementation of Tsukamoto method in predicting the number of dengue fever patients at Purbalingga health center for twelve months in 2016 obtained a percentage of errors (MAPE) when the prediction was 8.13% or vice versa had an accuracy rate of 91.87% (Hikmawati and Arifudin, 2017). As for research to predict the behavior of consumers of building stores using Tsukamoto method with calculation accuracy between 50% to 100%. Testing results from this study using MAPE found the percentage of errors for wall renovation was 43.91%, floor renovation by 36.23% and roof renovation by 18.11% (Caraka et al., 2015). Then a five-month study concluded that the prediction of bread production using the Tsukamoto method has an error value of 0.5%, which means the system is successful and can be used by the company (Wiguna and Haryanto, 2015). Furthermore, there are studies that compare fuzzy logic methods such as Tsukamoto, mamdani, and sugeno methods in order to determine the amount of production based on the previous data by filling the input of demand and inventory. Of the three methods tested, the Tsukamoto method has the least error value which means that the predicted production amount with the Tsukamoto method does not differ much from the amount of production done by the company with an error value of 1% using data from February 1 to February 29, 2016 (Minarni and Aldyanto, 2016).Other research, namely the application of Fuzzy Tsukamoto in seeking the percentage of risk level hanger enter maintenance makes the research results better in terms of the process of calculation speed, accuracy of presents results and accuracy in decision making (Prakarsa and Nasution, 2019).

Covid-19 is the first virus found in Wuhan City of China and spreads very quickly around the world including Indonesia. Covid-19 pandemic causes Indonesian governments and hospitals to be unprepared for the surge in Covid-19 cases (Setiati and Azwar, 2020). One of the provinces affected by the covid-19 pandemic is the province of west Java. West Java was the second largest province to have a positive case of COVID-19 on May 4, 2020 with the addition of 193 positive cases. As of June 28, 2020, there were 1,396 confirmed cases with an additional 18 patients.

As a newly discovered virus the government analyzes the designations for people affected by the covid-19 virus, among others:

a. Monitoring Person (ODP) is a person who meets a number of criteria and has a history of travel to countries that have local transmission of covid-19.
b. Patients under Supervision (PDP) are people who meet the criteria and have a history of traveling to the country or to the City in Indonesia who have local transmission of covid-19.
c. Positive patients are people who are confirmed positively covid-19.

ODP and PDP are breastfeed to be positive patients after passing the incubation period for 14 days (Abdillah, 2020).

The increase in positive cases of covid-19, (ODP), and (PDP), which is unpredictable causes the unpreparedness of officials in dealing with this covid-19 outbreak. The Health Office of West Java Province acknowledged the lack of covid-19 treatment facilities at 52 regional public hospitals (hospitals) in West Java Province to closely monitor covid-19 positive patients, one of which lacked the number of isolation rooms.

The number of COVID-19 cases in West Java Province has changed daily. The COVID-19 handling task force in West Java records data on the number of people in monitoring (ODP), patients under surveillance (PDP), and the number of patients confirmed by the COVID-19 virus. The data that has been recorded is shared or informed to the public through the website pikobar. Pikobar is the information and coordination center of COVID-19 West Java Province. There is a feature of providing information on the number of covid-19 cases or confirmed cases per day in West Java in detail. In addition to increasing information, pikobar website provides service center features on COVID-19 in every city and district in

West Java, pretical info, news about COVID-19 in West Java, and donation or social assistance. The data shared by pikobar website is statistical data and case distribution data. The available statistical data is the confirmed total data of active, cured, and deceased. In addition, ODP and PDP amount data is also available on the pikobar website.

2. Material and Methods

In 1965, Professor Lutfi A. Zadeh, a computer science researcher at the University of California, Barkley, introduced fuzzy logic for the first time (Zadeh, 1966). Professor Zadeh believes that right and wrong logic cannot represent all human thought, and therefore develops fuzzy logic that can represent every situation or represent human thought (Fan and Wang, 2020; Singh et al., 2020).

Fuzzy logic is an enhancement of Boolean logic that introduces the concept of partial truth value. When classical logic states that anything can be represented in binary terms (0 or 1, black or white, yes or no), fuzzy logic replaces Boolean truth values with truth levels. Therefore, fuzzy logic can allow membership values to be between 0 and 1 (black and white) (Haseeb et al, 2020). Fuzzy logic is one of the components of soft computing. The basis of fuzzy logic is the fuzzy set theory. In fuzzy set theory, the degree of membership is very important to determine the absence of elements in the set. Membership degree or membership value is a key feature of this fuzzy logic reasoning (Sri Kusumadewi, 2010).

2.1. Fuzzy Set

The fuzzy set is a collection of mathematical principles, which are based on membership degrees rather than using classical binary logic to describe knowledge. A fuzzy set is one or more groups that represent a specific condition in a fuzzy variable. The fuzzy set is arguably an extension of the crisp set which only divides a group of individuals into two categories: members and non-members. In other words, the membership value of an item indicates not only the member but also not the member (Zadeh, 1988). The fuzzy set has 2 attributes, namely (Kusumadewi, 2010):

a. Linguistics is the naming of a group that uses natural language to reveal a particular state or condition
b. Numeric is a value that indicates the size of a variable.

2.2. Membership Functions

The membership function is a curve that represents the mapping of the input data point to its membership value at intervals of 0 to 1. A function approach is a method that can be used to obtain membership value (Ross, 2004; Karnik et al., 1999). Membership functions that can be established and used to represent a fuzzy set include (Kusumadewi, 2010):

2.2.1. *S-Curve Representation*

Growth and contraction curves are S curves or sigmoid curves, each corresponding to non-linear surface ups and downs. The S curve is defined using three parameters, namely: membership value (α), full membership value (γ) and turn point or intersection (β), i.e. a point with 50% of the actual domain. There are 2 forms of set on the S-Curve, namely:

a. The S-Growth Curve is a curve that moves from the far left (membership value = 0) to the far right (membership value = 1). Membership functions will depend on 50% of the membership value, commonly called an inflection point. Figure 1 shows the characteristics of the S-Growth Curve.

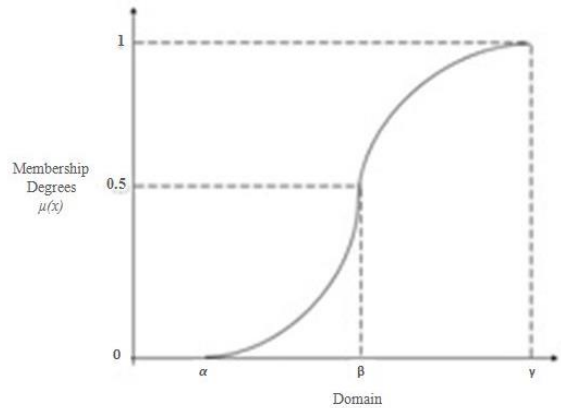

Figure 1: Growth S-Curve

b. Curve-S Depreciation is a curve that moves from the far right side (membership value = 1) to the far left side (membership value = 0) as seen in Figure 2.

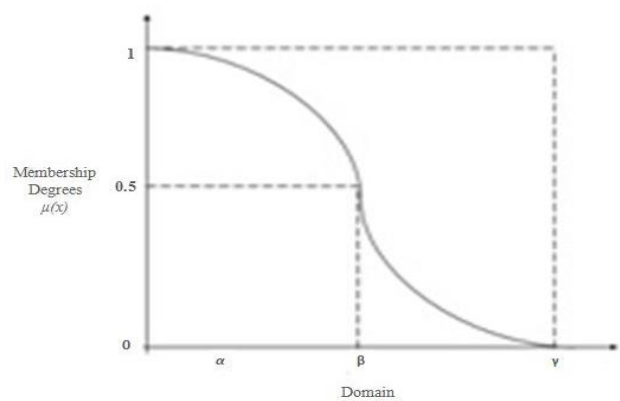

Figure 2: S-Curve Depreciation

2.2.2. Phi Bell Curve Representation

The bell curve can represent a fuzzy number. A bell-shaped curve with a membership degree of 1 is located in the middle of the domain (γ), and the width of the curve (β) is shown in Figure 3.

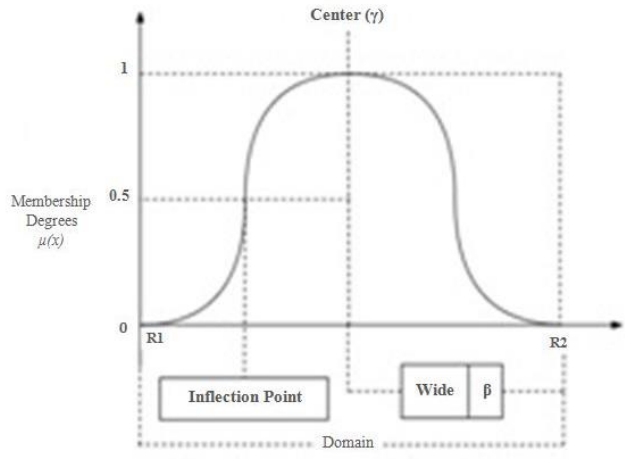

Figure 3: Phi Bell Curve

2.3. Fuzzy Set Base Operation

Some operations are defined in fuzzy sets, specifically to merge and modify fuzzy sets. The membership value resulting from the operation of 2 sets is usually called fire strength or predicate. One of the basic operations created by Zadeh is the AND operator. This operator handles intersection operations on set. By using the minimum membership value between elements on the correlation operator, it can be obtained with the AND operator.

2.4. Tsukamoto Fuzzy Inference System (FIS) Method

Tsukamoto's method is an extension of monotonous reasoning. In the Tsukamoto method, any result of the IF-THEN rule must be represented by a fuzzy set with monotonous membership functions. As a result, based on fire strength, the inference output of each rule is express and uses a weighted average to get the final result. The stages contained in the Tsukamoto method are as follows:

a. Fuzzification is the process of converting a system input with a fixed or clear value into a fuzzy set and determining the degree of its membership in a fuzzy set. The fuzzification process is the first stage of fuzzy calculation.
b. The establishment of IF-THEN Rules is the process of forming rules, which will then be stored in the fuzzy membership base in the form of IF-THEN.
c. Application of implication function is the process of converting fuzzy input into fuzzy output by fuzzification on each specified rule (IF-THEN rule). Use the MIN implications function, and use the base operator set AND to get the alpha value of each rule. Then, each alpha predicate value is used to calculate the output (z value) of each rule.

Defuzzification is the process of converting fuzzy output obtained from an inference machine into a firm or crisp value. The final result is obtained using the weighting average equation using the weight average method or weighted average.

3. Research Method

The research method used by the authors in this study used a descriptive method, which is to explain and describe data related to the current state, the relationship between emerging variables, and the differences in existing facts and their impact on conditions. Descriptive methods also aim to compare what can be done to get the most suitable solution. The following explanations of the research methods conducted in this study are as follows:

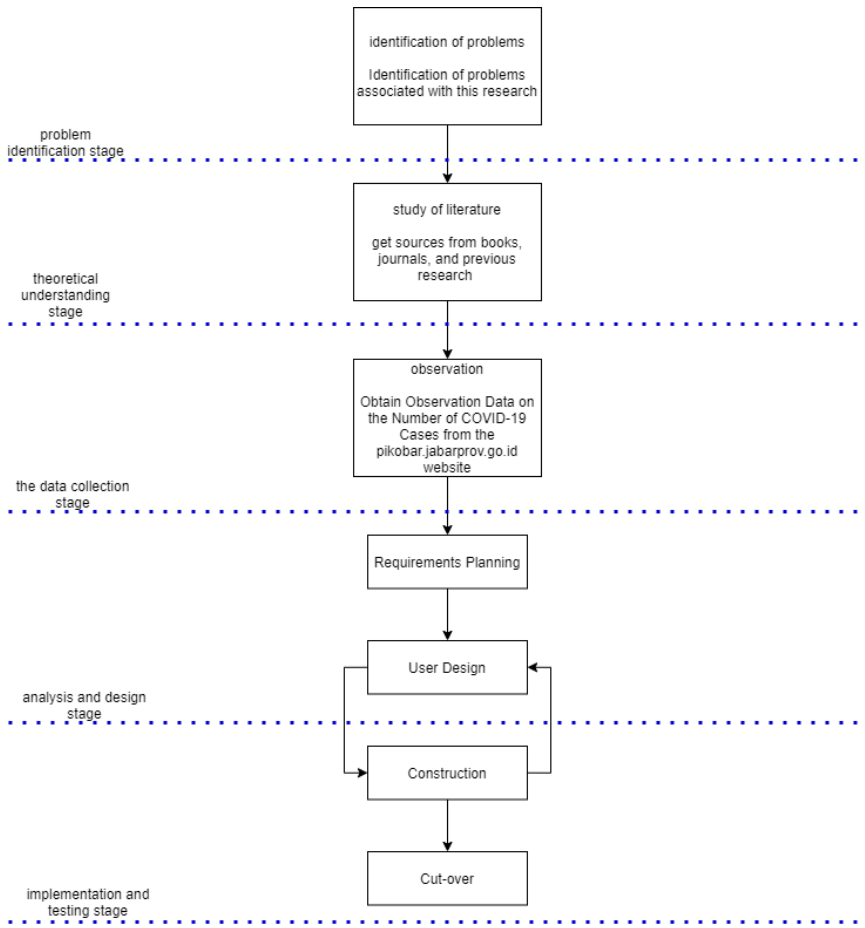

Figure 4: Research Methods

The identification of the problem is the importance of knowing the problem related to predicting the number of covid-19 cases to be implemented to fuzzy logic Tsukamoto method as well as how to design the build of a prediction application for the number of COVID-19 cases with the implementation of fuzzy logic Tsukamoto method. From the identification of the problem, it is obtained the formulation of the problem and the purpose of the research itself, as a measuring tool for achieving the established research. At this stage, the authors look for sources of previous research relevant to the topic of predicting things using the Tsukamoto method to be used as a reference that reinforces existing arguments.

Furthermore, the theoretical understanding stage is the stage to examine the basic theories relevant to this research. To understand the theory it is necessary to search for the right information or source. The authors conducted a search of resources using literature study techniques to collect data sourced from trusted books, journals, and previous research to find out the creation of fuzzy logic models of Tsukamoto methods and design a COVID-19 case prediction app.

The third phase is to conduct the data collection phase using observation techniques aimed at obtaining quantitative data from the website of the covid-19 increase in West Java every day from March to July 2020 for the needs of this research. The number of COVID-19 increases sought is the number of ODP, PDP, and positive cases in West Java.

Phase Four is the analysis and design stage is the first stage to know the needs and flow of the system to be created. This stage uses rapid application development (RAD) development methods to analyze and design systems. The analyst and design stage is divided into 2 sections, namely the stage of planning needs and user models. The activity of planning needs is an activity carried out by the author in analyzing what needs is needed in the development of the program to be built. Next the author defines the needs of the system to be built. After analyzing and defining the needs of the system, the next is to develop a model to know the processes, inputs, and outputs on the system built. These activities include the creation of a fuzzy inference system of Tsukamoto method consisting of 4 stages, namely fuzzification, rule formation, application of implication functions, and defuzzification. After the fuzzy logic was created, the authors then tested the results of the Tsukamoto method in predicting covid-19 cases with field sample data.

The final stage of this research is the Implementation and Testing phase. This stage is an advanced stage of the implementation of RAD development methods, namely construction and cutover. Construction is an implementation activity of the design model that has been created. The author uses a java programming language with an object-oriented programming paradigm and Net beans tools. When there is an error in designing the system, the author can return to the user model stage until there are no more errors in the construction of the application. While the cutover is the testing stage done after the application is built to know the quality of the application. The authors used the black-box method to test the COVID-19 case prediction app.

4. Result and Discussion

Predictions of covid-19 positive increase cases using the fuzzy logic of the Tsukamoto method include fuzzification stages, rule formation, implication functions, and defuzzification. This activity will explain the stages of the implementation of the fuzzy logic Tsukamoto method to predict the positive rise of COVID-19 up to the example of the case.

Table 1: Speaker Universe

Variable	Set	Domain
Number of ODP Increases	Low	[1,01;34,31]
	Medium	[1,01;34,31;67,60]
	High	[34,31;67,60]
Number of PDP Increases	Low	[1,02;31,94]
	Medium	[1,03;31,94;62.86]
	High	[31,94;62,86]
Number of Positive Increases	Low	[1,07;67,20]
	Medium	[1,07;67,20;133,33]
	High	[67,20;133,33]

The first thing to do in creating a fuzzy logic model is to make the determination of the speaker universe to be a fuzzy set. The variables needed to be used as crisp inputs are the number of percentage increases in ODP and PDP. While the crisp output is the amount of positive percentage increase. Data collection conducted by authors with vulnerable time from March 6, 2020 to July 19, 2020 obtained on pikobar website. To find the number of ODP and PDP increases, an additional calculation of the number of ODP, PDP, and Positive each day is then reduced by the data of the amount recovered and died on the

date to be calculated (See Table 1). The data is processed to look for a percentage increase each day and look for the minimum and maximum values to be domain for each variable that has been set, and is searched for the middle value of each domain.

4.1 Fuzzification

The first stage of the fuzzy logic of the Tsukamoto method is fuzzification. Fuzzification is the calculation of crisp inputting value into membership degree value. Here are the stages of modeling the ODP Upgrade Variable and calculating the Variable Number of ODP, PDP, and Positive Variables membership functions.

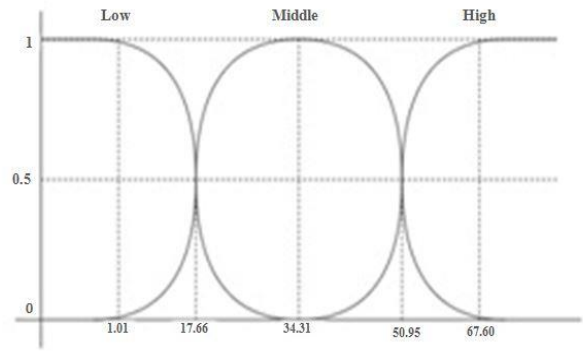

Figure 5: ODP Upgrade Set

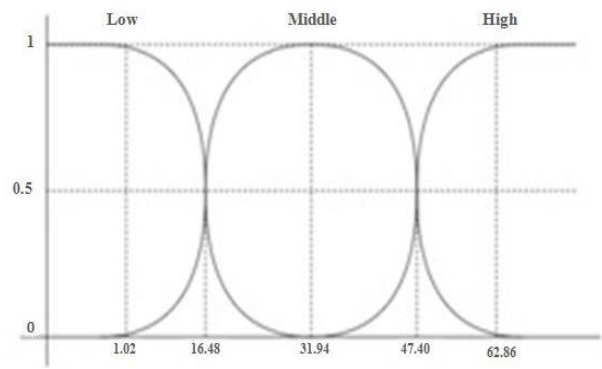

Figure 6: PDP Improvement Set

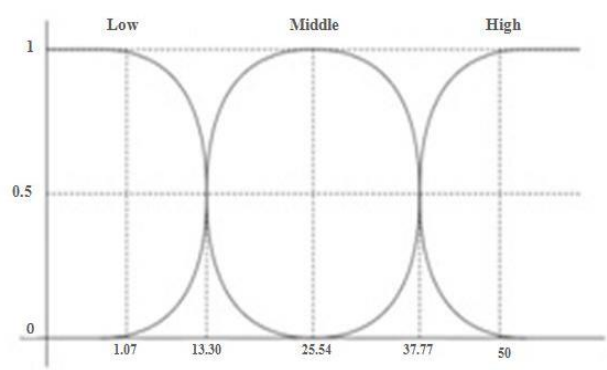

Figure 7: Positive Improvement Set

4.2 Formation Rules IF-Then

Rule formation is done by the method of the rule formation scheme based on numeric data taking into account the type and correlation value of each input variable against the output variable as follows:

[R1] IF ODP is low AND PDP is THEN low-positive
[R2] IF ODP is low AND PDP is THEN positive is
[R3] IF ODP is low AND PDP high THEN positive is
[R4] IF ODP is AND PDP is THEN low-positive
[R5] IF ODP is AND PDP is THEN positive is
[R6] IF ODP is AND PDP is THEN high-positive
[R7] IF ODP is AND PDP high THEN positive is
[R8] IF ODP is up AND high to high positive

4.3 Application Function Implications (Inference)

The rule used in the implications of the Tsukamoto method is the MIN Implication Function to get the predicate value of each fuzzy rule. Then each predicate value is used to calculate the output firmly (crisp). The example of an ODP increase is 9.30 and the PDP increase is 9.24.

α-predicate 1 = 0.04
z1 = 22.08
α-predicate 2 = 0.04
z2 = 4.53
α-predicate 3 = 0.42
z3 = 12.28
α-predicate 4 = 0.04
z4 = 22.08
α-predicate 5 = 0.04
z5 = 4.53
α-predicate 6 = 0.04
z6 = 22.08
α-predicate 7 = 0.58
z7 = 14.33
α-predicate 8 = 0.58
z8 = 38.8

4.4 Defuzzification

Once the α-predicate and z values are obtained, the next step is to defuzzification using the weighted average method to convert the fuzzy set input into crisp values, by divide sigma alpha-predicate multiplied z with sigma alpha-predicate as follows:

$$Z = \frac{38{,}985}{1{,}78} = 21{,}90$$

5. Conclusion

The results of this study to predict the percentage increase in covid-19 positive cases in West Java Province using the fuzzy logic of Tsukamoto method with membership functions in the form of S-Curve and Phi Bell Curve, can be concluded that this study produced an error value in predicting 4.5% or vice versa the accuracy value of 95.5%.

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