

Expert System for Diagnosing Potential Diabetes Attacks Using the Fuzzy Tsukamoto

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Abstract - Diabetes is one of the top three killers in Indonesia. According to the 2014 sample enrollment survey, the number of people with diabetes is increasing year by year. This is because the diagnosis of the disease is delayed. Also unhealthy lifestyle. In an era of fast and efficient technological advancement, this is a very good thing for advancement in various fields. More and more fields of knowledge are developing, one of which is expert systems. An expert system is a software or computer program that matches the ability of an expert, meaning that it can match humans with special abilities that ordinary people cannot solve. Expert systems aim to solve specific problems, such as in fields such as medicine, education, etc. This expert system takes as inputs several variables consisting of transient blood sugar (GDS), fasting blood sugar (GDP), frequent hunger, thirst, weight loss, and urine (BAK), the method used by the author is Fuzzy Tsukamoto. This Tsukamoto method states that every result of IF-Then must be described as a fuzzy set with an immutable or monotonic membership function, and uses PHP for programming. The results obtained in the study conducted by the authors were in the form of an expert system that detects diabetes and obtains results with 94% accuracy.

Keywords –Expert System, Tsukamoto Fuzzy Algorithm, Diabetes

1. INTRODUCTION

Every year, the number of people with diabetes is increasing. Based on data from the World Health Organization (WHO), there are about 347 million people in the world suffer from diabetes and it is estimated that deaths caused by diabetes will increase by two-thirds between 2008 and 2030[1]. The burden of diabetes mellitus is increasing globally, especially in developing countries. In 2011, Indonesia ranks 10th in the number of people with diabetes mellitus in the world with a total of 7.3 million people and if this continues, it is estimated that by 2030 people with diabetes mellitus can reach 11.8 million people. People with diabetes mellitus have an increased risk of developing a number of health problems due to acute and chronic complications[2], [3].

Diabetes occurs where our glucose test results are in the value of 190 mg / dLg or more. When there is a high glucose yield, the glucose will accumulate in the blood because it cannot be absorbed by the body's cells perfectly[4]–[6]. Where if this condition occurs, it will

lead to other chronic disorders, such as heart failure, disorders of the kidney system[6], to the possibility of stroke. People who have glucose pressure above the normal level will usually experience several conditions known as symptoms of diabetes.

Diabetes is one of the diseases that is usually called a very killing disease because this disease does not directly cause early symptoms, namely long symptoms[1], [7]–[10]. The World Health Organization has estimated that the number of people with diabetes in Indonesia will increase. The high intensity of diabetics in Indonesia is caused by many things, one of which is the lack of understanding of the Indonesian people about the symptoms of diabetes and lack of anticipation from an early age[10]–[14], because it is difficult for sufferers to find experts to treat this disease. From this case, the author will create an expert system design that can help sufferers to make it possible to know from the symptoms they felt at the beginning. So that patients already know whether they have diabetes or not. The author will make it easier for users to operate the system to find out the early symptoms of Diabetes by diagnosing the early symptoms of the disease with complaints experienced by sufferers, this system can also be used for underprivileged residents to consult experts because of the high cost.

An expert system itself is a software or computer program that matches the ability of an expert, which means that it can match humans who have special skills that are impossible for ordinary people to solve[3], [6], [12]–[14]. Expert systems aim to solve certain problems, such as in the fields of medicine, education, etc. [1], [15]. Meanwhile, in this study, one method will be used, namely the fuzzy tsukamoto method which is an algorithm in Intelligent Systems science to perform calculations of the level of truth which is also flexible [4]. In this Tsukamoto method, every consequence in the IF-Then must be explained with a fuzzy set that has a membership function that does not change or is monotonous.

2. RESEARCH METHOD

2.1. *Strate of The Art*

The fuzzy tsukamoto method is one of the methods of the branch of artificial intelligence and one of the methods that has been widely used to conduct research in various aspects of the field. There have been many previous studies related to this research. The following are some examples of previous research studies using the Tsukamoto fuzzy method. Research conducted by Achmaf Igaz Falatehan in 2018, discusses the use of an Expert System to diagnose liver disease, the method used is the Fuzzy Tsukamoto Method. The results obtained from this study are an Android-based software that can diagnose patients with liver disease [5]. Research conducted [16] discusses the implementation of the Tsukamoto Fuzzy Method to determine land suitability for rubber and oil palm plantations. The results obtained from this research is a software that can provide answers related to the land in question suitable for planting rubber or oil palm . Research conducted by Fiftin Noviyanto et al in 2018, discussed the use of an expert system with the Fuzzy Tsukamoto Method to recommend drug formulations. The results obtained from this research is a software that can provide guidance on any ingredients to mix a drug [2].

2.2. *Diabetes*

Diabetes or what is often called sugar disease where our glucose test results are in the value of 200 mg / dLg or more. When there is a high glucose yield, the glucose will accumulate in the blood because it cannot be absorbed by the body's cells perfectly[10], [17]–[20]. Where if this condition occurs, it will lead to other chronic disorders, such as heart failure, disorders of

the kidney system, to the possibility of a stroke. People who have glucose pressure above normal numbers will usually experience several conditions called symptoms diabetes. Diabetes is one of the diseases that is commonly called a disease that kills slowly because this disease does not directly cause early symptoms, namely long symptoms. If you experience some of the symptoms above, then immediately see a doctor. Where blood pressure or blood pressure is very high and the level of control is not limited, it can cause a person to experience very critical conditions, such as heart failure, kidney failure, and stroke. There are generally two types of diabetes, type 1 and type 2 diabetes. Type 1 diabetes occurs when the patient's immune system attacks and destroys the pancreas, which produces insulin. Type 1 diabetes can be caused by genetic or environmental factors. Type 2 diabetes is a type of diabetes caused by the body's cells receiving less insulin, so it cannot be used properly. The symptoms of type 1 and type 2 diabetes that can be felt include : often feel thirsty, frequent urination, often feel very hungry, drastic weight loss. Examination to Check Diabetes Mellitus Blood sugar test is a mandatory examination to diagnose type 1 or type 2 diabetes. By looking at the results of blood sugar measurements, it can be known whether a person has diabetes or not. Doctors will usually recommend the patient to undergo a blood sugar test at a time and with a certain method. The following is a blood sugar test method that can be taken by people with diabetes mellitus to check:

1. Blood Sugar Test While. The purpose of this test is to measure blood glucose levels at random at certain hours. To undergo this test, sufferers do not need to fast first. If the results of the blood sugar test show a sugar level of 200 mg/dL or more, then the person can be said to be positive for diabetes.
2. Fasting Blood Sugar Test. While the fasting blood sugar test, aims to measure the blood glucose levels of sufferers in fasting conditions. To undergo this test, the patient will be asked to fast for 8 hours first. After that, a new blood sample will be taken to determine blood sugar levels. If the results of the fasting blood sugar test show that the blood sugar level is less than 100 mg/dL, then the blood sugar level is still normal. However, if the results of the blood sugar test are between 100-125 mg/dL, then the person has a condition called prediabetes. While the results of fasting blood sugar tests, which are at 126 mg/dL or more, indicate that the person is positive for diabetes. Also read: Prevent Diabetes, Here's How to Check Fasting Blood Sugar.
3. Glucose Tolerance Test. Patients also need to fast overnight to undergo this test. Then, the sufferer will undergo fasting blood sugar test measurements. After the test is completed, the patient will be asked to drink a special sugar solution. Then, the blood sugar sample will be taken again after 2 hours of drinking the sugar solution. If the glucose tolerance test result is below 140 mg/dL, it means that blood sugar levels are still normal. Meanwhile, the results of the glucose tolerance test, which are between 140–199 mg/dL, indicate prediabetes. A glucose tolerance test result with a sugar level of 200 mg/dL or more means the person is positive for diabetes.
4. HbA1C test (glycated hemoglobin test). This test aims to measure the average glucose level of the sufferer for the past 2-3 months. This test measures blood sugar levels bound to hemoglobin, the protein in red blood cells that carries oxygen throughout the body. To undergo the HbA1C test, sufferers do not need to fast first. HbA1C test results below 5.7 percent indicate normal conditions. While the HbA1C test results, which are between 5.7–6.4 percent, indicate a prediabetes condition. An HbA1C test result above 6.5 percent means you have diabetes. (Marianti, 2018)

Diabetes Treatment Treatment for type 1 diabetes, including:

1. Certain hormones to control blood glucose. This hormone is given by injection into the layer under the skin about 3-4 times a day according to the dose recommended by the doctor.
2. Healthy diet and regular exercise to help control blood glucose levels. Taking care of your feet and getting your eyes checked.

2.3. Expert System

An expert system is a software or computer program that matches the ability of an expert, which means that it can match humans who have special skills that are impossible for ordinary people to solve. Expert systems aim to solve certain problems, such as in the fields of medicine, education, etc. [8].

Expert systems have several basic concepts, namely:

1. Expertise, that is knowledge gained from training, reading, and experience. This expertise allows experts to make decisions faster and better than someone who is not an expert.
2. Expert, someone who has special knowledge, experience, and methods and is able to apply them to solve problems or give advice. An expert must be able to explain and learn new things related to the topic of the problem, if necessary must be able to restructure the knowledge obtained, and be able to solve the rules and determine the relevance of his expertise.
3. Transferring Expertise, namely transferring expertise from an expert to a computer, then transferred to other people who are not experts.
4. Inferencing, Inference is a procedure (program) that has the ability to reason. Inference is displayed in a component called an inference engine which includes procedures for solving problems. All knowledge possessed by an expert is stored on the knowledge line by the expert system. The task of the inference engine is to draw conclusions based on the knowledge base it has.
5. Rule, Most commercial expert system software is a rule-based system, i.e. knowledge is stored mainly in the form of rules, as problem-solving procedures.
6. Explanation Capability, another facility of the expert system is its ability to explain the suggestions or recommendations it provides. Explanation is done in a subsystem called the explanation subsystem (explanation). This part of the system allows the system to examine its own reasoning and explain its operations. Characteristics and capabilities possessed by expert systems are different from conventional systems.

2.4. Fuzzy Tsukamoto Method

In the 19th century until the 20th century, one of the theories, namely probability theory issued one of its roles, namely solving the problem of uncertainty, and continued to develop until 1965, until finally Lothfi A. Zadeh brought fuzzy theory, which is a theory that explains a sign that the probability theory that can be useful looks for an uncertainty. Fuzzy[7] theory has one of the main components of the other components which is very contrary to the membership function. The degree of a member of the variable x is denoted by a symbol, namely (x) . In determining the value of the membership function using the membership function approach, there are several logical reasons. Fuzzy sets are used to solve a problem including the problem of uncertainty, clarity, accuracy, lack of information seeking, and partial truth. In this Tsukamoto method, every consequence in the IF-Then must be explained with a fuzzy set that has a membership function that does not change or is monotonous [9], [12]–[14], [20]. Based on the research results from the journal, the fuzzy tsukamoto method has proven to be the right solution to be applied as an expert system tool. The application of the fuzzy method in an expert system can produce precise accuracy values and conclusions can be

drawn to make the author a reference for conducting research on diagnosing diabetes using the Tsukamoto fuzzy method.

2.5. Fuzzy Inference System

Fuzzy inference system is a system that performs reasoning with principles like humans who have the instinct to do something. An expert who has knowledge by implementing a system will be asked in the IF-THEN rule, which will use fuzzy inference on a knowledge that can be transferred into software which in turn produces the desired output. This fuzzy inference system has been successfully implemented in various fields, for example expert systems, decision analysis, and data classification.

2.6. Data Analysis Technique

Efforts to process data into information, so that it can support the main objectives in accordance with the stage of identification of disease diagnosis problems. At this stage there is some clarification of data such as various diseases. Then explain the software workflow on a web platform to diagnose Diabetes at SOETRASNO Hospital Rembang.

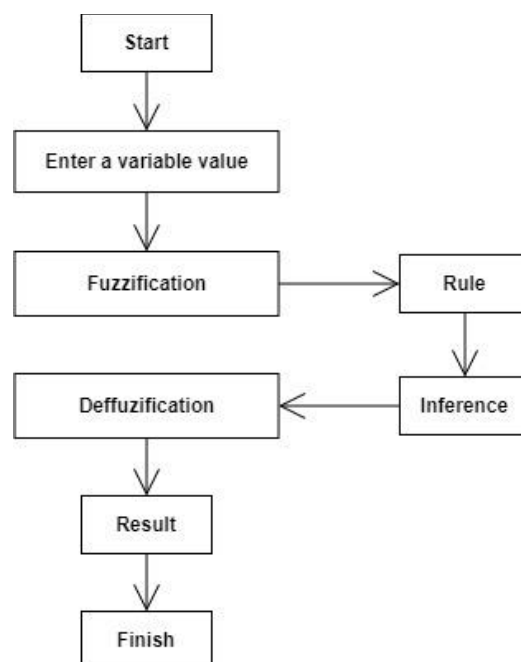


Figure 1. Research Stages

The research phase begins by summarizing the data obtained from Soetrasno Hospital Rembang with one of the specialist doctors at the hospital. The variables contained in this study were the initial symptoms felt when the patient had diabetes. After the data has gone through the summary process, then the data will be processed using the Tsukamoto Method. There are three processes contained in the Tsukamoto method, namely the process of fuzzification, inference, and continued with deffuzification. Fuzzification process has two variables, namely input and output. The input process is a symptom of the disease, and the output variable is the diagnosis. After that, the fuzzification calculation process is carried out and continued with the Inference process. The last stage is the deffuzification process. Research on Expert Systems for Detecting Diabetes is a type of explanatory research. This

method is a research method used to examine the relationship between hypothesized variables so that conclusions can be drawn about the problem at hand.

2.7. Testing Method

Tests carried out based on black box testing are experimental techniques in trying to test software that has been created or is currently being run. Blackbox testing itself is a test by silent control of the form aimed at more detailed facts. Black-box testing is possible to get software approval to create an input condition that checks the running of a form of system to be run. This test is carried out by providing input and then evaluating the resulting output. If the output obtained is in accordance with what is desired or expected, then the testing process is successful, if the testing process does not match what we want, it can be categorized as failed. This black box is a test that only shows the interface that we can see and we analyze directly in the detailed evaluation process, we can only know the input and output in black box testing.

3. RESULTS AND DISCUSSION

3.1. Data Analysis and Discussion

At the data analysis stage, this is an important part because the data that comes from the experts/experts are collected and then a program will be created that can run like the expert. The research variable in this thesis is the diagnosis of whether the user has diabetes or not based on the calculation of the probability value of the symptoms entered using the Tsukamoto fuzzy method. The hypothesis in this study is to create an expert system to determine the diagnosis of whether you have diabetes or not.

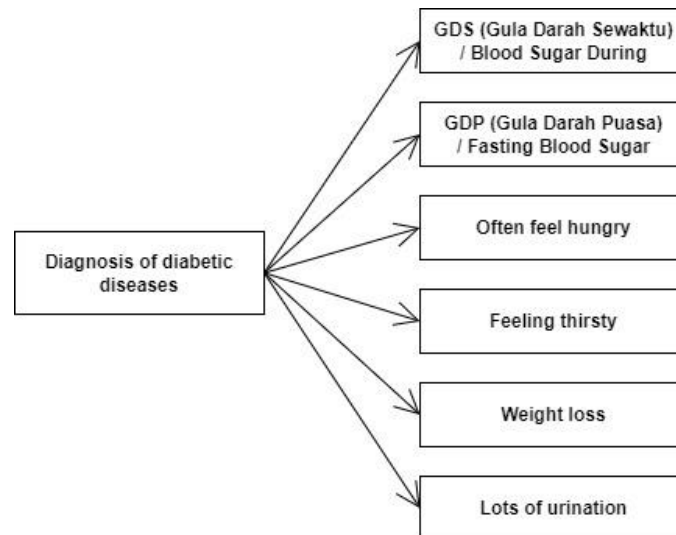


Figure 2. Criteria for symptoms of diabetes

From the results of interviews obtained by the author with experts/experts on diabetes, the symptoms of Diabetes, from the main symptoms and classic symptoms and also provide solutions for handling what should be done if detected or not. Below will explain the symptoms that occur along with the rating of each criterion:

1. Blood Sugar During

Table 1. Weighting Blood Sugar Levels While

Range	Information
<90mg/dl-190mg/dl	Normal
>190mg/dl-≤220mg/dl	High

$$\mu_{\text{Normal}} = \begin{cases} 1, x \leq 90 \\ \frac{220 - x}{220 - 90}, 90 \leq x \leq 220 \\ 0, x \geq 220 \end{cases} \quad (1)$$

$$\mu_{\text{High}} = \begin{cases} 0, x \leq 90 \\ \frac{x - 90}{220 - 90}, 90 \leq x \leq 220 \\ 1, x \geq 220 \end{cases} \quad (2)$$

Checking blood sugar on time is a glucose test at that time. Generally, blood sugar checks are carried out during an emergency. The normal value of Temporary Blood Sugar (GDS) is based on the consensus on the Management and Prevention of Diabetes in Indonesia in 2015, that is, if the results of the check are between <100mg/dl – 190mg/dl, it is normal or pre-diabetes. And if the examination is between >190mg/dl – 200mg/dl, it is a high diagnosis and diagnosed with diabetes.

2. Fasting Blood Sugar

Table 2. Weighting Fasting Blood Sugar Levels

Range	Information
<100mg/dl-125mg/dl	Normal
125 mg/dl->=126mg/dl	High

$$\mu_{\text{Normal}} = \begin{cases} 1, x \leq 100 \\ \frac{126 - x}{126 - 100}, 100 \leq x \leq 126 \\ 0, x \geq 126 \end{cases} \quad (3)$$

$$\mu_{\text{High}} = \begin{cases} 0, x \leq 100 \\ \frac{x - 100}{126 - 100}, 100 \leq x \leq 126 \\ 1, x \geq 126 \end{cases} \quad (4)$$

Fasting blood sugar check is a normal blood sugar test that is done before eating. In this test, the public is expected to know normal sugar levels after doing strenuous activities every day. The results of the fasting blood glucose test show that the glucose in the blood is from <100mg/dl – 125mg/dl including the Normal fasting glucose value. Meanwhile, 125mg/dl - >=126mg/dl is a high value and is at risk for diabetes.

3. Often Feel Hungry

Table 3. Weighting Levels often Feel Hungry

Range	Information
1 – 4	Normal
5 – 10	Abnormal

$$\mu_{\text{Normal}} = \begin{cases} 1, & x \leq 1 \\ \frac{10-x}{10-1}, & 1 \leq x \leq 10 \\ 0, & x \geq 10 \end{cases} \quad (5)$$

$$\mu_{\text{Abnormal}} = \begin{cases} 0, & x \leq 1 \\ \frac{x-10}{10-1}, & 1 \leq x \leq 10 \\ 1, & x \geq 10 \end{cases} \quad (6)$$

One of the classic characteristics of someone with diabetes is often feeling hungry. This is due to high insulin levels and excessive consumption of carbohydrates. Giving the range here is divided into two, namely, 1-4 if you feel hungry often with normal levels. While 5-10 with abnormal levels.

4. Feeling Thirsty (Dehydration)

Table 4. Dehydration Weighting

Range	Information
1 – 4	Normal
5 – 10	Abnormal

$$\mu_{\text{Normal}} = \begin{cases} 1, & x \leq 1 \\ \frac{10-x}{10-1}, & 1 \leq x \leq 10 \\ 0, & x \geq 10 \end{cases} \quad (7)$$

$$\mu_{\text{Abnormal}} = \begin{cases} 0, & x \leq 1 \\ \frac{x-10}{10-1}, & 1 \leq x \leq 10 \\ 1, & x \geq 10 \end{cases} \quad (8)$$

In addition to feeling often hungry, excessive thirst is one of the classic characteristics experienced by diabetics. These symptoms appear because the patient requires a lot of fluids. Giving the range here is divided into two, namely, 1-4 if you feel thirsty with normal levels. While 5-10 with abnormal levels.

5. Weight Loss

Table 5. Weighting of Weight Loss

Range	Keterangan
1 – 4	Normal
5 – 10	Abnormal

$$\mu_{\text{Normal}} = \begin{cases} 1, x \leq 1 \\ \frac{10-x}{10-1}, 1 \leq x \leq 10 \\ 0, x \geq 10 \end{cases} \quad (9)$$

$$\mu_{\text{Abnormal}} = \begin{cases} 0, x \leq 1 \\ \frac{x-10}{10-1}, 1 \leq x \leq 10 \\ 1, x \geq 10 \end{cases} \quad (10)$$

Weight loss when not on a diet is one of the classic characteristics of diabetics. This happens because insufficient insulin production makes the body take in another source of energy, namely protein. Giving range here is divided into two, namely, 1-4 if the BB with normal levels. While 5-10 with abnormal levels.

6. Lots of Urination

Table 6. Weighting The Amount of Urination

Range	Keterangan
1 - 4	Normal
5 - 10	Abnormal

$$\mu_{\text{Normal}} = \begin{cases} 1, x \leq 1 \\ \frac{10-x}{10-1}, 1 \leq x \leq 10 \\ 0, x \geq 10 \end{cases} \quad (11)$$

$$\mu_{\text{Abnormal}} = \begin{cases} 0, x \leq 1 \\ \frac{x-10}{10-1}, 1 \leq x \leq 10 \\ 1, x \geq 10 \end{cases} \quad (12)$$

Excessive urination is one of the symptoms of people with diabetes, because sugar levels are too high. Ideally blood sugar will be filtered by the kidneys and reabsorbed by the blood. But it's too high so the kidneys can't absorb all the sugar. Giving the range here is divided into two, namely, 1-4 if the BAK is with normal levels. While 5-10 with abnormal levels.

3.2. Fuzzification Method Calculation

3.2.1. Fuzzification

This fuzzification aims to change the input data from firm to fuzzy. In the research that the author made, there are several variables to detect diabetes. The formation of fuzzy sets is used to define firm input values. This fuzzification process is carried out based on: GDS, GDP, Frequent Hunger, Dehydration, Weight Loss, Lots of urination.

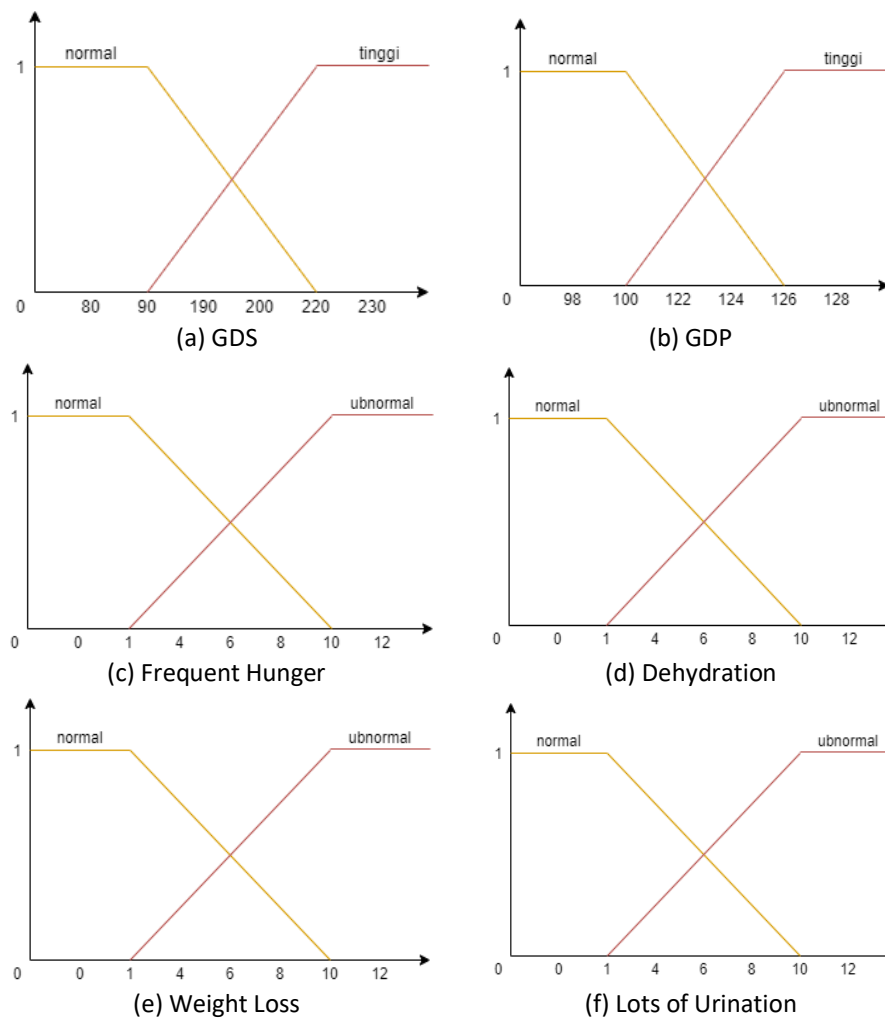


Figure 3. Fuzzification Graph of six variables

If given an input of Temporary Blood Sugar (GDS) 200, Fasting Blood Sugar (GDP) 120, often hungry 7, thirsty 6, Weight loss 5, Urinating a lot 4. Then the first step as shown in Figure 4.



Figure 4. Identification Flow

3.2.2. Inferensi

Table 7. Inference Process

no	IF	VARIABLE INPUT (AND)					THEN	INPUT VARIABLES
		Blood Sugar During	Fasting Blood Sugar	Often Feeling Hungry	Dehydration	Weight Loss		Lots of Urination
1		HIGH	HIGH	ABNORMAL	ABNORMAL	ABNORMAL	ABNORMAL	POSITIF DM
2		HIGH	LOW	NORMAL	ABNORMAL	NORMAL	NORMAL	POSITIF DM

3		HIGH	HIGH	ABNORMAL	NORMAL	ABNORMAL	ABNORMAL		POSITIF DM
4		HIGH	LOW	NORMAL	NORMAL	NORMAL	NORMAL		POSITIF DM
5		HIGH	HIGH	ABNORMAL	ABNORMAL	ABNORMAL	ABNORMAL		POSITIF DM
6		LOW	LOW	NORMAL	ABNORMAL	NORMAL	NORMAL		NEGATIF DM
7		LOW	HIGH	ABNORMAL	NORMAL	ABNORMAL	ABNORMAL		PRA-DM
8		LOW	LOW	NORMAL	NORMAL	NORMAL	NORMAL		NEGATIF DM
9		LOW	HIGH	ABNORMAL	ABNORMAL	ABNORMAL	ABNORMAL		PRA-DM
10		LOW	LOW	NORMAL	ABNORMAL	NORMAL	NORMAL		NEGATIF DM

In this step, the reasoning is done by finding the degree of membership of each variable and checking using the specified rule. In the following, the author will apply some of the rules used to find solutions to existing problems.

3.2.3. Defuzzification

This step changes the fuzzy output to a crisp value based on a predetermined membership.

$$\text{defuzzification: } \frac{\sum_{i=1}^n \alpha_{\text{predikat } i} * z_i}{\sum \alpha_{\text{predikat}}} \quad (13)$$

3.3. Accuracy Test

If given an input of Temporary Blood Sugar (GDS) 200, Fasting Blood Sugar (GDP) 120, often hungry 7, thirsty 6, Weight loss 5, Urinating a lot 4. Then the first step is:

1. Fuzzyfication

$$\text{Blood Sugar During : Normal} = \frac{b-x}{b-a} = \frac{220-200}{220-90} = 0,15, \text{ High} = \frac{x-a}{b-a} = \frac{200-90}{220-90} = 0,84.$$

$$\text{Fasting Blood Sugar : Normal} = \frac{b-x}{b-a} = \frac{126-120}{126-100} = 0,23, \text{ High} = \frac{x-a}{b-a} = \frac{120-100}{220-90} = 0,76.$$

$$\text{Often Feeling Hungry : Normal} = \frac{b-x}{b-a} = \frac{10-7}{10-1} = 0,33, \text{ Abnormal} = \frac{x-a}{b-a} = \frac{7-1}{10-1} = 0,67.$$

$$\text{Dehydration : Normal} = \frac{b-x}{b-a} = \frac{10-6}{10-1} = 0,44, \text{ Abnormal} = \frac{x-a}{b-a} = \frac{6-1}{10-1} = 0,56.$$

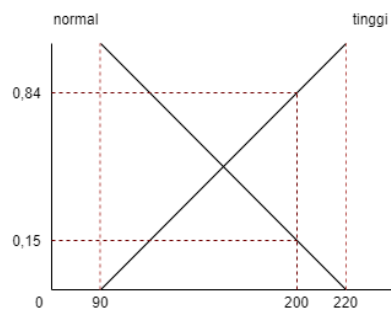
$$\text{Weight Loss : Normal} = \frac{b-x}{b-a} = \frac{10-5}{10-1} = 0,56, \text{ Abnormal} = \frac{x-a}{b-a} = \frac{5-1}{10-1} = 0,44.$$

$$\text{Lots of Urination : Normal} = \frac{b-x}{b-a} = \frac{10-4}{10-1} = 0,67, \text{ Abnormal} = \frac{x-a}{b-a} = \frac{4-1}{10-1} = 0,33.$$

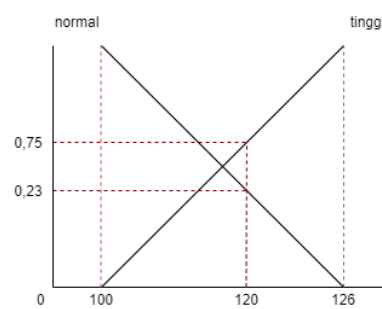
1. Fuzzyfication

- R1 = If GDS is high and GDP is high and Often hungry is abnormal and thirst is abnormal and bb is abnormal and BAK is abnormal then positive DM. $\alpha_{\text{predikat } 1} = \min (0,84 , 0,76 , 0,67 , 0,56 , 0,44 , 0,33) = 0,33$. $\delta = \frac{x-a}{b-a} = 0,33$ then $x = 4,95$.
- R2 = If GDS is high and GDP is low and often hungry is normal and thirst is abnormal and BB is normal and BAK is normal then positive DM. $\alpha_{\text{predikat } 2} = \min (0,84 . 0,23 , 0,33 , 0,56 , 0,56 , 0,67) = 0,23$. $\delta = \frac{x-a}{b-a} = 0,23$ then $x = 43,45$.
- R3 = If GDS is high and GDP is high and is often abnormally hungry and thirsty normal and BB is abnormal and BAK is abnormal then positive DM. $\alpha_{\text{predikat } 3} = \min (0,84 , 0,76 , 0,67 , 0,44 , 0,44 , 0,33) = 0,33$. $\delta = \frac{x-a}{b-a} = 0,33$ then $x = 44,95$.

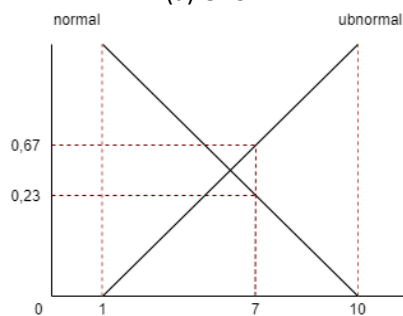
- R4 = If GDS is high and GDP is low and often hungry is normal and thirst is normal and BB is normal and BAK is normal then Positive DM. $\alpha_{predikat\ 4} = \min(0,84, 0,76, 0,67, 0,56, 0,44, 0,33) = 0,23$. $\delta = \frac{x-a}{b-a} = 0,23$ then $x = 43,45$.
- R5 = If GDS is low and GDP is low and Often hungry is normal and thirst is abnormal and BB is normal and BAK is normal then negative DM. $\alpha_{predikat\ 5} = \min(0,15, 0,23, 0,33, 0,56, 0,56, 0,67) = 0,15$. $\delta = \frac{b-x}{b-a} = 0,15$ then $x = 37,75$.
- R6 = If GDS is low and GDP is high and often hungry is abnormal and thirst is normal and BAK is abnormal then negative DM. $\alpha_{predikat\ 6} = \min(0,15, 0,76, 0,67, 0,44, 0,44, 0,33)$. $\delta = \frac{b-x}{b-a} = 0,15$ then $x = 37,75$.
- R7 = If GDS is low and GDP is low and often hungry is normal and thirst is normal and weight is normal and BAK is normal, thrn is negative DM. $\alpha_{predikat\ 7} = \min(0,15, 0,23, 0,33, 0,44, 0,56, 0,67)$. $\delta = \frac{b-x}{b-a} = 0,15$ then $x = 37,75$.
- R8 = If GDS is low and GDP is high and often hungry is abnormal and thirst is abnormal and BB is abnormal and BAK is abnormal then Positive DM. $\alpha_{predikat\ 8} = \min(0,15, 0,76, 0,67, 0,56, 0,44, 0,33) = 0,15$. $\delta = \frac{x-a}{b-a} = 0,15$ then $x = 42,25$.
- R9 = If GDS is low and GDP is low and SL is normal and thirst is abnormal and BB is normal and BAK is normal then negative DM. $\alpha_{predikat\ 9} = \min(0,15, 0,23, 0,33, 0,56, 0,56, 0,67) = 0,15$. $\delta = \frac{b-x}{b-a} = 0,15$ then $x = 37,75$.



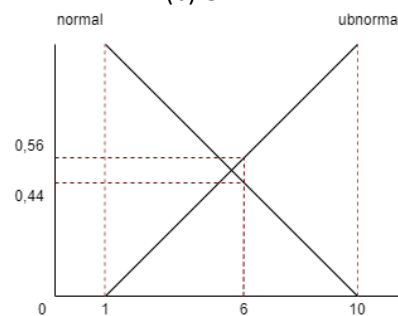
(a) GDS



(b) GDP



(c) Frequent Hunger



(d) Dehydration

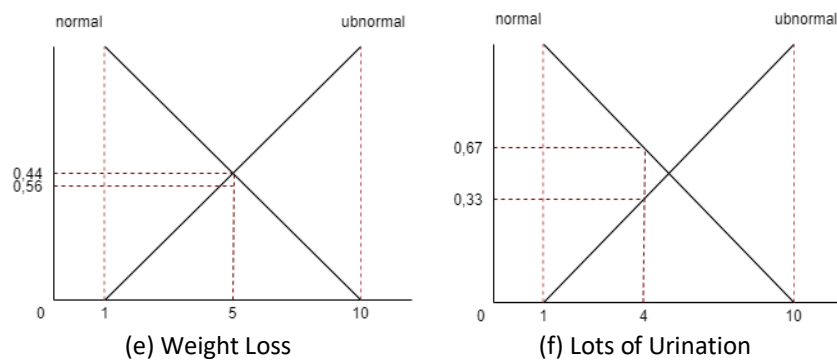


Figure 5. Fuzzification Graph of six variables over an example process

2. Deffuzification

$$Z = \frac{(\alpha 1. \delta 1) + (\alpha 2. \delta 2) + (\alpha 3. \delta 3) + (\alpha 4. \delta 4) + (\alpha 5. \delta 5) + (\alpha 6. \delta 6) + (\alpha 7. \delta 7) + (\alpha 8. \delta 8) + (\alpha 9. \delta 9)}{\alpha 1 + \alpha 2 + \alpha 3 + \alpha 4 + \alpha 5 + \alpha 6 + \alpha 7 + \alpha 8 + \alpha 9}$$

$$= \frac{14,8335 + 9,9935 + 14,8335 + 9,9935 + 5,6625 + 5,6625 + 5,6625 + 6,3375 + 5,6625}{1,87}$$

$$= \frac{78,6415}{1,87}$$

$$= 42,05 = 42 \text{ (Then the result of the diagnosis is positive).}$$

The program calculation test is used to find out whether the application is valid or not. Testing the validity of the program calculations with the results of manual calculations. Furthermore, in this test, the accuracy level of the application will be sought by using several input data taken from data samples. The results of the test with several inputs by applying the calculation of the Tsukamoto fuzzy method. It can be seen in the table below:

Table 8. Table of the results of applying the calculation of the Fuzzy Tsukamoto method

No	INPUT						OUTPUT	
	Blood Sugar During	Fasting Blood Sugar	Often Feeling Hungry	Dehydration	Weight Loss	Lots of Urination	Expert	System
1	200	120	7	6	5	4	Positive	Positive
2	90	100	6	3	1	2	Negative	Negative
3	90	90	1	1	1	1	Negative	Negative
4	170	90	3	3	1	1	Positive	Positive
5	256	107	5	6	8	7	Positive	Positive
6	106	90	1	1	1	1	Negative	Negative
7	270	128	6	8	8	9	Positive	Positive
8	220	123	5	5	6	6	Positive	Positive
9	190	121	5	5	4	6	Positive	Positive
10	201	117	6	5	5	7	Positive	Positive
11	234	128	5	5	7	6	Positive	Positive
12	200	129	4	5	3	7	Positive	Positive
13	90	95	3	2	1	2	Negative	Negative
14	186	90	2	1	1	1	Positive	Positive
15	200	106	6	3	5	4	Positive	Positive
16	150	127	1	1	1	1	Negatif	-

17	225	111	3	3	2	3	Positif	Positif
18	100	108	3	2	2	2	Negatif	Negatif
19	180	109	1	2	2	1	Positif	Positif
20	175	105	2	2	2	2	Positif	Positif
21	185	126	2	2	2	2	Positif	Positif
22	211	125	3	4	4	5	Positif	Positif
23	211	120	4	3	5	5	Positif	Positif
24	216	127	5	4	4	7	Positif	Positif
25	197	90	2	3	3	4	Positif	Positif
26	195	127	2	3	3	3	Positif	Positif
27	227	124	4	5	3	7	Positif	Positif
28	165	90	3	2	1	2	Positif	Positif
29	180	119	2	1	1	1	Positif	Positif
30	199	125	6	3	5	4	Positif	Positif
31	206	128	1	1	1	1	Positif	Negatif
32	186	107	3	3	2	3	Positif	Positif
33	184	90	1	1	1	1	Positif	Positif
34	177	128	3	3	1	1	Positif	Negatif
35	120	111	4	3	3	2	Negatif	Negatif
36	118	108	1	1	1	1	Negatif	Negatif
37	90	109	2	2	1	1	Negatif	Negatif
38	178	105	1	1	2	4	Positif	Positif
39	155	124	2	2	2	3	Positif	Positif
40	203	126	4	4	3	3	Positif	Positif
41	216	119	6	8	8	9	Positif	Positif
42	219	125	2	2	2	2	Positif	Positif
43	223	123	3	4	5	5	Positif	Positif
44	145	100	2	2	1	1	Negatif	Negatif
45	130	105	1	1	2	4	Negatif	Negatif
46	125	98	2	2	2	3	Negative	Negative
47	140	90	2	2	2	2	Negative	Negative
48	112	128	2	2	2	2	Positive	Positive
49	109	100	3	4	4	5	Negative	Negative
50	105	105	4	3	2	2	Negative	Negative

The results of the accuracy tests that have been carried out in this study are 94%. The accuracy test uses 11 test data in the form of symptom input values along with the diagnosis of the disease. The calculation of accuracy is carried out with the formula Amount of correct data/Amount of test data multiplied by 100%, so $47/50 \times 100\% = 94\%$. From the test results above, it can be concluded that the program is running well.

4. CONCLUSION

Based on the results of the research that has been done on the expert system for diagnosing diabetes using the web-based fuzzy Tsukamoto method. An expert system for diagnosing diabetes can be designed and implemented. An expert system for diagnosing heart disease can be implemented using the fuzzy Tsukamoto method by going through five main processes, namely fuzzyfication, determining the alpha-predicate of each rule, calculating the z-value of each rule, multiplying z by the alpha predicate by the rule, then calculating the fuzzyfication by dividing the number of alphas. predicate times z by the number of alpha predicates. The value will determine whether the user is detected with diabetes. Testing the accuracy rate reaches 94%, which means that the program is running well. To improve Fuzzy's

performance, in further research, this system can be developed by adding information about detailed symptoms and types of diabetes to increase knowledge base knowledge. This system can be developed by adding parameters from the symptoms experienced so that the results of the system can be more accurate. This system can be developed by adding a menu that can connect with experts and consult online.

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