Fuzzy-Based Application Model and Profile Matching for Recommendation Suitability of Type 2 Diabetic

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Abstract—Diabetes Mellitus (DM) is a metabolic disease characterized by hyperglycemia due to insulin secretion abnormalities and a global health threat. DM has several types, namely type 1, 2, gestational, and other types. Type 2 diabetes patients have the largest number in the world. DM therapy can be done in 2 (two) ways: improving lifestyle and administering drugs. The problems and risks in recommending drugs are essential in the patient's healing process because they are likely to take medicine for life. Approximately 260,000 patients with type 2 diabetes experienced medication errors in 2017. The doctor's mistake in recommending drugs causes a long healing process and costs more. Recommending drugs requires pharmacological knowledge, and not all hospitals have pharmacologists. Several researchers have researched recommendations for antidiabetic drugs, but no studies have yet been found that discuss recommendations for combination antidiabetic drugs for type two to determine dosage and frequency. The number of medications used is 6 to 7, with many parameters to 8. The latest endocrinology guidelines for 2020 state that in recommending antidiabetic drugs, not only 6 to 7 participants, but still need to maintain other aspects. Therefore, this study aims to build an expert system model with a new approach in recommending antidiabetic drugs with more complete parameters and recommend dosage and frequency. The model developed uses the Fuzzy Profile Matching method. Fuzzy is used to calculate the suitability between the patient's condition and the type of antidiabetic drug. Profile Matching is used to calculate the core factor and secondary factor to obtain each drug's total value. The dose was calculated using the FIS Tsukamoto for inputting low dosage, and high dosage calculated the weighted average value. Determination of frequency using the IF-Then function. Model evaluation is done by comparing recommendation data from doctors. The results of the evaluation of the model obtained an accuracy of 90%. This system will reduce medical personnel errors in recommending antidiabetic drugs that can positively impact patients' time, the healing process, and costs. This study provides knowledge that antidiabetes drugs' determination requires many parameters, while other studies used only 4 to 8. This study also provides an overview of the dosages of drugs that drug companies can produce. Usually, the company only makes low and high dosage. This study shows that creating multiple drug dosage is more efficient for patients.

Keywords—Model evaluation; diabetic type 2; fuzzy Tsukamoto; profile matching; drugs; dosage; frequency.

I. INTRODUCTION

Diabetic Mellitus (DM) Type 2 is a group of metabolic diseases with hyperglycemia characteristics that occur because of an abnormality receptor insulin that lasts long also affects its secrecy. DM type is classified into 4 (four) groups, namely Type 1 DM, type 2 DM, gestational DM, and other type DM \cite{1}\cite{2}. Blood glucose levels are expressed as diabetic, among others, with a rate of $HbA1c > 6.5\%$ (mmol/L) \cite{3}. Until today DM is still one of the global health threats. Epidemiological research indicates the tendency to increase the incidence rate and prevalence of type 2 Diabetic Mellitus in various parts of the world\cite{4}. The majority of DM is predicted to grow 3 (three) times in 2030. This increase has been expected by the World Health Organization (WHO) that the year 2030 will reach 21.3 million\cite{1}, and Predicted from the International Diabetic Federation (IDF) in 2045 will reach 16.7 million \cite{3}.

DM can occur in patients accompanied by other diseases. DM therapy can be done 2 (two) to improve the lifestyle and Drug Administration \cite{2}. Treatment of medications using Oral and Insulin types \cite{5}. Commonly used oral drugs are types of Sulfonylurea, Glinide, Biguanide, Tiazolidin, Alpha
Glucose inhibitors, GLP-1, SGLT-2, DPP-4, while for Insulin there are Lispo, Aspar, Glulysine and Faster Aspar [6]. The goal of therapy in DM is to reduce hyperglycemia symptoms, reduce the onset and development of complications, reduce mortality, and improve life quality [6]. Antidiabetic drugs usually pay attention to age, comorbidities, risk of hypoglycemia, and many other factors [7].

Efforts to manage DM still have obstacles in terms of service and health financing [4]. It should be noted that health workers in carrying out their work require high pharmacological accuracy and knowledge [8]. Around 260,000 patients with diabetes experienced medication errors in 2017 [8]. Ignorance and negligence of action to the patient will have an impact on patient safety. One thing that must be considered is the procedure for administering injectable and oral drugs. Giving injection drugs is more at risk of causing hypoglycemic conditions that are dangerous for patients. In addition to economic wastage, irrational drug use patterns can decrease treatment services quality, increase drug side effects, influence treatment failure, and increase insulin resistance [9]. Cases in various health institutions were found to be incorrectly given unnecessary drug combinations. The selection of an appropriate oral hypoglycemic drug is crucial to the success of diabetic therapy, depending on the severity and condition of the patient. Oral hypoglycemic pharmacotherapy can be done using one drug or a combination of two types of drugs [7].

Sub-therapeutic drug administration results in ineffective drug therapy. Drug administration with excessive dosage results in hypoglycemic effects and the possibility of toxicity [10]. Inappropriate use of Insulin often results in hypoglycemia and can lead to weight gain. Unwanted drug effects can occur in long-term use, such as lipodystrophy or loss of fat tissue at the injection site, and allergic reactions can occur, including edema [11]. Treatment must be started as early as possible to prevent or slow the progression of beta-cell failure in people with impaired glucose tolerance [4].

Several researchers have conducted research that discusses antidiabetic drug recommendations. In the study showed Rung-Ching Chen et al. [12], the drug recommendations used the SWRL technique with 6 (six) types of antidiabetic drugs Metformin, DPP4, Sulfonylurea, Glinide, Thiazolidinedione, Alpha-Glucosidase (AGI) with 6 (six) parameters of HbA1c, Hypoglycemia, Renal, Heart, BMI, and liver. This research was developed with the Fuzzy method that can display the results of drug recommendations based on the most appropriate level of choice [13]. Drug recommendations are also carried out using Fuzzy-TOPSIS with 7 (seven) types of drugs and 8 (eight) parameters [14]. In 2018 Fuzzy, combined with MULTIMOORA with input data scoring, recommended antidiabetic drugs using 8 (eight) parameters. Several researchers have researched recommendations for antidiabetic drugs, but no studies have yet been found that discuss recommendations for combination antidiabetic drugs for type two to determine dosage and frequency. The number of medications used is 6 to 7, with many parameters 5 to 8. The latest endocrinology guidelines for 2020 state that in recommending antidiabetic drugs, not only 6 to 7 participants, but still need to maintain other aspects such as glucagon secretion (Cell Alpha Pancreas), insulin secretion (Cell Beta), glucose fat, glomerular filtration, muscle glycogen and contraindications with pregnant or nursing women and infections [15]. Drug recommendations must be adapted to the patient’s condition or variables to avoid errors and drug side effects. The number of patient variables has the main and second variables [16]; therefore, the Profile Matching (PM) method is very appropriate because it has a Core Factor and Secondary Factor calculations.

The problem and the risk of recommending drugs are essential in helping patients to maintain health services quality [10]. This research supports this research; this study aims to build an expert system model with a new approach to recommending antidiabetic drugs with more complete parameters and recommend dosage and frequency. The model developed uses the Fuzzy Profile Matching method. Fuzzy is used to calculate the suitability between the patient’s condition and the type of antidiabetic drug. Profile Matching is used to calculate the core factor and secondary factor to obtain each drug’s total value. Model evaluation is done by comparing recommendation data from doctors. A safe treatment system needs to be developed and maintained to ensure that patients receive good drug services due to the increasingly varied drugs and the increasing number of drugs and types of antidiabetic drugs [17]. This study’s results can be used as an alternative to help paramedics. Young doctors recommend the right dosage and frequency of medicines to improve the quality of health services, accelerate the healing process, and reduce medical costs.

II. MATERIALS AND METHOD

The application of the suitability of antidiabetic drugs to the patient’s health condition was developed by illustrating the proposed model’s architecture. The development of the model consists of 2 (two) main parts, namely the development knowledge base and development environment presented in Fig. 1 model was developed from the drug suitability model [16].

A. Development Stages

The first development from the expert consultation stage and the result is presented in Figure. 2. Expert consultation was carried out by specialists in internal medicine, diabetes, and pharmacology to obtain parameters and knowledge base. The next step is the process of matching antidiabetic drugs to the patient’s condition using a membership curve. The next
match's result was calculated by the core and secondary factors using the Profile Matching method. In addition to the type of drug, for determining the dose using Tsukamoto FIS. The stages of development can be seen in Fig. 2.

Fig. 2 Stages of model development

B. Expert Consultation

Based on consultations with internists and pharmacologists, as well as a review of several works of literature [5], [18], [19], [4], there are 17 (seventeen) parameters that influence determining the delivery of antidiabetic type 2 drugs. In addition to considering the patient's health parameters, the drug's efficacy and price are presented in Table I.

| TABLE I | INPUT PARAMETERS FOR THE DETERMINATION OF ANTIDIABETIC MELLITUS TYPE 2 DRUGS |
|---|---|
| | HbA1c | Age | Body mass index | Renal | Liver | Heart | Blood pressure | Hypoglycaemia Cell of beta |
| % | year | kg/m² | mg/dl | µ/L | pg/ml | mm/Hg | % | % |
| P10 | P11 | P12 | P13 | P14 | P15 | P16 | P17 |

Brief description of each patient's health parameters that influences in determining the type 2 antidiabetic drug administration:
- HbA1c (hemoglobin A1c) is a protein containing iron in red blood cells. High or low HbA1c levels will affect drug administration. Intake of HbA1c by prickng a needle in a vein in the arm. Normal levels of Hba1c <6.5% [2]
- Age is taken from the year of birth. Age>60 years old and <60 years old is young. The age of the patient will determine the choice of drug type because not all ages can be given the same drug [1]
- BMI is taken from body weight and height [20]. Kadar normal BMI <25. If someone has a BMI>25, then the drug to be given is different from patients who have a BMI <25kg/m²[20]
- Renal is the level of kidney health obtained based on laboratory tests with the Enzymatic method performed on patients by calculating creatinine levels [21]. Patients with kidney patients need special attention from doctors [18]
- The liver is SGPT (Serum Glutamic Pyruvic Transaminase) level is an abundant enzyme in the liver. Normal levels of 7-56 micro per liter of serum (µ/L) [22].
- Heart health uses the value of B-type natriuretic peptide (BNP) is a hormone produced by the heart. The BNP hormone (NT-proBNP) is a non-active hormone released from the same molecule that has BNP [23]
- Hypoglycemia is a condition when the body's blood sugar levels are too low. Hypoglycemia normal <50% mmol/L [5]. Provision of antidiabetic drugs pay attention to the effects of hypoglycemia [24]
- Beta cells (β cells) are cells found in pancreatic islets that synthesize and secrete Insulin. Beta cells account for about 50-70% of cells in the islet of the pancreas in the human body [25]
- Pancreatic Alpha Cells are cells that function to produce glucagon hormone. This hormone increases blood sugar levels, breaks down the liver reserves in the liver, and then carries it to the blood. Alfa cells account for around 25% of the island of Langerhans [22]
- Free fatty acid (FFA) is the content of free fatty acids in the body that cause cholesterol that can affect drug administration. Normal levels of 30-50 FFA%[4]
- Muscle glycogen is a type of sugar polysaccharide that is stored in liver cells and body muscle cells. Glycogen data is obtained by converting glucose levels obtained from food [22]
- Glomerular filtration is the average rate of blood filtration that occurs in the glomerulus in ml/min units [26]
- Pregnancy/lactating is the condition of the patient's history of being pregnant or breastfeeding. Some anti-diabetic drugs have contraindications with this condition [10]
- Infection is the condition of the patient who has a wound or postoperatively. Patients who are experiencing disorders should not be given drugs Sulfonilurea, Glinide, Biguanide, and SGLT-2 [18]
- Efficacy is the level of effectiveness of the drug [18]
- Cost is the cost of purchasing drugs. Determination of the price of medicines taken from the guidelines for the treatment of type 2 diabetes [5]

C. Expert System Knowledge Base

The parameters used are made in the form of a knowledge base for each parameter's degree of compatibility with the type of antidiabetic drugs. The knowledge base is presented in Table II. Almost all type 2 diabetic drugs should not be given to DMT2 patients with impaired liver or kidney function, liver, high blood pressure, and severe heart problems. Patients with T2DM aged ≥60 years and overweight (BMI) should be aware of the onset of hypoglycemia. There are types of contraindicated drugs in patients with impaired renal function with LFG ≤ 30 mL[4]. Also, drug administration needs to be considered for pregnant or breastfeeding patients and have infections [10].
TABLE II
Knowledgebase For The Suitability Of Anti-Diabetic Drugs [5], [18], [19], [4]

| Type            | HbA1c | Age (years) | BMI | Renal | Liver | Heart | Blood pressure | Hypoglycemia | Cell Beta Pancreas | Cell Alpha | Free Fatty Acid | Muscle Glycogen | Filtration Glomerulus | Pregnancy/Lactating | Infection | Efficacy | Cost |
|-----------------|-------|-------------|-----|-------|-------|-------|----------------|--------------|--------------------|------------|-----------------|------------------|-----------------------|---------------------|-----------|----------|------|
| Biguanide       | >6.5  | 17-60       | 25-35 | >1.2  | <56   | <100  | >90            | >50          | >50%               | <20%       | >50%            | <1%              | >30                   | No                   | No        | High     | Low  |
| Sulfonylurea    | >7.0  | <60         | <25  | <1.2  | <56   | >100  | >140           | <50          | >50%               | <20%       | >50%            | <1%              | >30                   | No                   | No        | High     | Low  |
| Glucose         | >7.5  | >60         | >25  | >0.55 | <56   | >100  | >140           | <50          | >50%               | <20%       | >50%            | <1%              | >30                   | Yes                  | No        | High     | Low  |
| Thiazolidinedione Alpha Glucose | >7.0   | >60        | >25  | >0.55 | <56   | <100  | <140           | >50          | >50%               | <20%       | >50%            | <1%              | >30                   | Yes                  | Yes       | Low      | High |
| GLP-1           | 7.0   | >55         | >25  | >1.2  | >56   | >100  | >140           | >50          | >50%               | <20%       | >50%            | <1%              | >30                   | Yes                  | Yes       | High     | Low  |
| SGLT2           | >9    | >55         | >25  | >1.2  | >56   | >100  | >140           | >50          | >50%               | <20%       | >50%            | <1%              | >45                   | Yes                  | No        | Middle   | High |
| DPP-4           | 7.0   | <55         | >18.5| >1.2  | <56   | >100  | >140           | >50          | >50%               | <20%       | >50%            | <1%              | >30                   | Yes                  | Yes       | High     | Low  |
| Insulin         | >9    | >13         | <25  | 0.55-1.2 | >56   | >100  | >140           | <50          | >50%               | <20%       | >50%            | <1%              | >30                   | Yes                  | Yes       | High     | Low  |

D. Fuzzy Membership Functions

Based on the knowledge base in Table II, they then made in the form of curves and fuzzy logic membership functions for each parameter with the suitability of the type of antidiabetic drug. Curves and membership functions of the kind of antidiabetic drug Biguanide are shown in Table III.

TABLE III
Curves and Membership Functions for Biguanide Drugs

| Parameters       | Curve | Membership function |
|------------------|-------|---------------------|
| HbA1c (%)        | µ(x)  | x ≤ 5.5 |
|                  |       | 5.5 < x ≤ 6.5 |
|                  |       | 6.5 < x ≤ 7.0 |
| Age (years)      | µ(x)  | x ≤ 10 |
|                  |       | 10 < x ≤ 20 |
| Weight (BMI)     | µ(x)  | x ≤ 30 |
|                  |       | 30 < x ≤ 40 |
| Hypoglycemia     | µ(x)  | x ≤ 15 |
|                  |       | 15 < x ≤ 30 |
| Renal            | µ(x)  | x ≤ 10 |
| Liver            | µ(x)  | x ≤ 40 |
| Heart            | µ(x)  | x ≤ 10 |
| Blood pressure   | µ(x)  | x ≤ 80 |
|                  |       | 80 < x ≤ 100 |
| Cell of beta     | µ(x)  | x ≤ 45 |
| Cell of alpha    | µ(x)  | x ≤ 25 |

Free Fatty Acid  
µ(x) = \frac{1}{1 + \frac{x-55}{50}}

Muscle Glycogen  
µ(x) = \frac{1}{1 + \frac{x-55}{50}}

Filtration  
µ(x) = \frac{1}{1 + \frac{x-25}{25}}

Pregnancy/Lactating  
µ(x) = \frac{1}{1 + \frac{x-30}{30}}

Infection  
µ(x) = \frac{1}{1 + \frac{x-30}{30}}

Efficacy  
µ(x) = \frac{1}{1 + \frac{x-30}{30}}

Cost  
µ(x) = \frac{1}{1 + \frac{x-30}{30}}

TABLE IV
Calculation Value Membership Functions

| Id   | Parameters | Data | Value of membership |
|------|------------|------|---------------------|
| 1    | HbA1c      | 6.9  | 1                   |
| 2    | Age        | 62   | 0.6                 |
| 3    | BMI        | 24   | 0.84                |
| 4    | Renal      | 2.3  | 1                   |
| 5    | Liver      | 54   | 1                   |
| 6    | Hearts     | 98   | 1                   |
| 7    | Blood pressure | 138 | 1                  |
| 8    | Hypoglycemia | 60  | 1                   |
| 9    | Cell of beta | 67  | 1                   |
| 10   | Cell of alpha | 19  | 1                   |
| 11   | Free fatty acid | 45  | 1                   |
| 12   | Muscle glycogen | 2.6 | 0.2                |
| 13   | Filtration glomerulus | 33  | 1                  |
| 14   | Pregnant/lactating | No  | 1                   |
| 15   | Infection  | Yes  | 0                   |
| 16   | Efficacy   | High | 1                   |
| 17   | Price      | Low  | 1                   |

Membership functions need to be made for the types of antidiabetic drugs Sulfonylurea, Gludin, Thiazolidinedione, Alpha-Glucosidase, GLP-1, SGLT2, DPP4, and Insulin need to be made. Based on the membership function in Table III,
the value of each parameter is then calculated. Table IV displays the membership values for each parameter with the type of antidiabetic drug Biguanide.

**E. Core Factor and Secondary Factor**

Parameter grouping is divided into 2 (two), namely Core Factor (CF) and Secondary Factor (SF). Core Factor is the leading parameter group where the determination of the type of drug given is very dependent on the parameters in this group, whereas a Secondary Factor is a parameter group that does not have a strong influence on the determination of the type of drug given to patients [27].

**TABLE V CLASSIFYING PARAMETERS CF AND SF**

| Core Factor (CF) | Secondary Factor (SF) |
|-----------------|-----------------------|
| Age (P2)        | HbA1c (P1)            |
| Renal (P4)      | BMI (P3)              |
| Liver (P5)      | Blood pressure (P7)   |
| Heart (P6)      | Cell alpha (P10)      |
| Hypoglycemia (P8)| Free fatty acid (P11) |
| Cell beta (P9)  | Muscle glycogen (P12) |
| Filtration glomerulus (P13) | Efficacy (P16) |
| Pregnant/lactating (P14) | Price (P17) |
| Infection (P15) |                       |

Calculate the value of CF using a formula:

$$ CF = \frac{\sum_{i=1}^{NC} CF_i}{NC} $$  \hspace{1cm} (1)

CF = The average value of the core factor
NC = Total number of core factor values
IC = Number of items CF value

$$ SF = \frac{\sum_{i=1}^{NS} SF_i}{NS} $$  \hspace{1cm} (2)

SF = The average value of the secondary factor
NS = Total number of secondary factor values
IS = Number of secondary factor items

Based on the grouping of core factors and the subsequent factors calculated the average value:

The value of the average core factor parameters
$$ CF = \frac{0.6+1+1+1+1+1+1+1+1+1+1+0}{11} = 0.84 $$

The value average secondary factor parameters
$$ SF = \frac{1+0+0+1+1+1+1+1+0+2+1+2}{12} = 0.88 $$

The grouping core factor's value average value multiplied the weight of 75%, and the secondary factor bore with a weight of 25%. The result of the core factor and secondary factor weights are then added to get a matching value:

$$ Total = (Weight \ CF \times CF) + (WeightSF \times SF) $$  \hspace{1cm} (3)

Total = (0.75 \times 0.84) + (0.25 \times 0.88) = 0.63 + 0.22 = 0.85

Results calculate of the value 0.85 indicate that the patient "P1" if given the class of antidiabetic medicine Biguanide has suitable (0.85 / 1) x 100% = 85% and for the second medicine 76% that Alpha-glucose, the medications are given can be combined, the show is Table VI.

**TABLE VI DRUG SUITABILITY CALCULATION RESULTS**

| Id  | Type        | Value | Level |
|-----|-------------|-------|-------|
| 1   | Sulfonylurea| 0.56  | 7     |
| 2   | Glinide     | 0.55  | 8     |
| 3   | Biguanide   | 0.85  | 1     |
| 4   | Thiazolidinedione| 0.71 | 5 |
| 5   | Alpha-Glucosidase| 0.76 | 2 |
| 6   | GLP-1       | 0.73  | 3     |
| 7   | SGLT2       | 0.52  | 9     |
| 8   | DPP-4       | 0.60  | 6     |
| 9   | Insulin     | 0.72  | 4     |

This model can evaluate the suitability of the patient's condition with various types of antidiabetic drugs.

**F. Dosage and Frequency Drug**

The dose and frequency of drug administration are very influential in the therapeutic effect of the drug. Giving excessive dosage, especially for drugs with a narrow range of therapy, will be very at risk of side effects. Conversely, a too small dose will not guarantee the achievement of less than optimal therapeutic levels [17].

**TABLE VII TYPE, DOSAGE, AND FREQUENCY DRUGS [18][4]**

| Id | Type        | Drugs            | Dosage     | Frequency (Ones/Day) |
|----|-------------|------------------|------------|----------------------|
| 1  | Sulfonylurea| Glibenclamide    | 2.5 - 20mg/dl | 1-2 |
| 2  | Glinide     | Gliclazide       | 40 - 320mg/dl  | 1-2 |
| 3  | Biguanide   | Metformin        | 500 - 3000mg/dl | 1-3 |
| 4  | Thiazolidinedione| Pioglitazone| 15 - 45 mg/dl | 1-2 |
| 5  | Alpha-Glucose| Acarbose        | 100 - 300mg/dl | 2-3 |
| 6  | GLP-1       | Liraglutide      | 0.6 - 1.8mg/dl  | 1-2 |
| 7  | SGLT2       | Dapagliflozin    | 5 - 10 mg/dl  | 1-2 |
| 8  | DPP-4       | Sitagliptin      | 50 - 100mg/dl | 1-2 |
| 9  | Insulin     | Lispro           | 0.1 - 1Unit/Kg| 1-2 |

**G. The domain of Medicine Dosage**

Determination of the dose using the parameters in Figure 4 (a). Each parameter becomes an input variable, divided by 2 (two) in linguistic and domain variables. The environment's output is a dose calculated using Tsukamoto's FIS to calculate a more appropriate dosage.
Table VIII
DOMAIN PARAMETERS FOR DETERMINES DRUGS DOSAGE

| Id | Parameters | Linguistic Variable | Domain | Output (Dosage) |
|----|------------|---------------------|--------|-----------------|
| 1  | HbA1c      | Normal              | 0-9    |                 |
|    |            | Abnormal            | 6.5-12 |                 |
|    |            | Young               | 0-65   |                 |
| 2  | Age        | Old                 | 60-100 | Low             |
|    |            | Young               | 0-65   |                 |
| 3  | BMI        | Low                 | 0-27   | [0-600]         |
|    |            | High                | 24-30  |                 |
| 4  | Renal      | Normal              | 0-1.5  | High            |
|    |            | Abnormal            | 1.2-3.0| [500-1000]      |
| 5  | Liver      | Normal              | 0-100  | 1000            |
|    |            | Abnormal            | 40-100 |                 |
| 6  | Hypoglycemia| No                  | 0-70   |                 |
|    |            | Yes                 | 50-120 |                 |

Table IX
THE DOSAGE DOMAIN OF THE DRUG IS BIGUANIDE

| Type    | Drugs   | Dosage (mg/dl) | Domain |
|---------|---------|----------------|--------|
| Biguanide| Metformin| 500 - 1000     | 0-600  | 500-1000       |

Based on Table IX. The next step is to make a curve for each parameter presented in Fig. 3-5, and the output curves for drug dosages are shown in Fig. 6.

H. Fuzzy Implication Rules for Dosage
Monotonous fuzzy rules are used as a basis for fuzzy implication techniques. The number of practices used is calculated based on the number of criteria and sub-criteria [28]. The parameters used are 6 (six) as HbA1c, Age, BMI, Renal, Liver, Hypoglycemia, and sub-criteria of each criterion are 2 (two), so the number of rules use is $2^6 = 64$ rules. Examples of the use of practices as follows:

```
[R13] If HbA1c= Normal and Age=Young and BMI=High and Renal=Abnormal and Liver=Normal and Hypoglicemia=No Then Low dosage;
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[R29] If HbA1c= Normal and Age=Old and BMI=High and Renal=Abnormal and Liver=Normal and Hypoglicemia=No Then Low dosage;
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[R30] If HbA1c= Abnormal and Age=Young and BMI=Low and Renal=Normal and Liver=Normal and Hypoglicemia=Yes Then High dosage;
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[R45] If HbA1c= Abnormal and Age=Young and BMI=High and Renal=Abnormal and Liver=Normal and Hypoglicemia=No Then High dosage;
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```
[R61] If HbA1c= Abnormal and Age=Old and BMI=High and Renal=Abnormal and Liver=Normal and Hypoglicemia=No Then Low dosage;
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```
[R64] If HbA1c= Abnormal and Age=Old and BMI=High and Renal=Abormal and Liver=Abnormal and Hypoglicemia=Yes Then Low dosage;
```

Then value $z$ calculation will be performed to look for output using FIS Tsukamoto from each rule given explicitly (crisp) based on $\alpha$-predicate (fire strength). In this calculation, not all $\alpha$ and $z_{1-64}$ rules are displayed. The final result is obtained using a weighted average. Examples of the use of practices as follows:

\[
\alpha\text{-predicate}_{13} = \mu_{HbA1c\ Normal} \land \mu_{Age\ Young} \land \mu_{BMI\ High} \land \mu_{Renal\ Abnormal} \land \mu_{Liver\ Normal} \land \mu_{Hypoglicemia\ No}\ Then\ Low\ dosage;
\]

\[
\alpha\text{-predicate}_{29} = \mu_{HbA1c\ Normal} \land \mu_{Age\ Old} \land \mu_{BMI\ High} \land \mu_{Renal\ Abnormal} \land \mu_{Liver\ Normal} \land \mu_{Hypoglicemia\ No}\ Then\ Low\ dosage;
\]

\[
\alpha\text{-predicate}_{61} = \mu_{HbA1c\ Abnormal} \land \mu_{Age\ Old} \land \mu_{BMI\ High} \land \mu_{Renal\ Abnormal} \land \mu_{Liver\ Normal} \land \mu_{Hypoglicemia\ No}\ Then\ Low\ dosage;
\]

\[
\alpha\text{-predicate}_{64} = \mu_{HbA1c\ Abnormal} \land \mu_{Age\ Old} \land \mu_{BMI\ High} \land \mu_{Renal\ Abnormal} \land \mu_{Liver\ Abnormal} \land \mu_{Hypoglicemia\ Yes}\ Then\ Low\ dosage;
\]

\[
Z_{13} = \text{High} - (\alpha_{13} \ast (\text{High-Low}))
\]

\[
= 3000 - (0.5 \ast (3000-500))
\]

\[
= 1750
\]

\[
\alpha\text{-predicate}_{29} = \mu_{HbA1c\ Normal} \land \mu_{Age\ Old} \land \mu_{BMI\ High} \land \mu_{Renal\ Abnormal} \land \mu_{Liver\ Normal} \land \mu_{Hypoglicemia\ No}\ Then\ Low\ dosage;
\]

\[
\alpha\text{-predicate}_{61} = \mu_{HbA1c\ Abnormal} \land \mu_{Age\ Old} \land \mu_{BMI\ High} \land \mu_{Renal\ Abnormal} \land \mu_{Liver\ Normal} \land \mu_{Hypoglicemia\ No}\ Then\ Low\ dosage;
\]

\[
\alpha\text{-predicate}_{64} = \mu_{HbA1c\ Abnormal} \land \mu_{Age\ Old} \land \mu_{BMI\ High} \land \mu_{Renal\ Abnormal} \land \mu_{Liver\ Abnormal} \land \mu_{Hypoglicemia\ Yes}\ Then\ Low\ dosage;
\]

\[
Z_{29} = \text{High} - (\alpha_{29} \ast (\text{High-Low}))
\]

\[
= 3000 - (0.2 \ast (3000-500))
\]

\[
= 2500
\]
\[ Z_{30} = \text{High} - (\alpha_{30} \times (\text{High-Low})) \]
\[ = 3000 - (0.2 \times (3000-500)) \]
\[ = 2500 \]
\[ \alpha_{45} = \text{High} - (\alpha_{45} \times (\text{High-Low})) \]
\[ = 3000 - (0.16 \times (3000-500)) \]
\[ = 2600 \]
\[ \alpha_{61} = \text{High} - (\alpha_{61} \times (\text{High-Low})) \]
\[ = 3000 - (0.16 \times (3000-500)) \]
\[ = 2600 \]

I. Determining Dosage

After a combination of forming rules, the next step is doing a calculation to get the value of defuzzification by adding the rules to regulations 64 to get the weighted average values (Weight Average)

\[ z \text{ (Dosage)} = \frac{F_2 \times G_2}{F_6 \times G_6} = \frac{F_{15} \times G_{15}}{F_{25} \times G_{25}} = \frac{F_{35} \times G_{35}}{F_{45} \times G_{45}} = \frac{F_{55} \times G_{55}}{F_{65} \times G_{65}} \]

Based on the name of the drug Metformin with the lowest dose of 500 ml/dl and the highest dosage of 3000 ml/dl in Table XI, based on the results of the system recommendations for the correct dosage given by patients as many as 2160 mg/dl.

J. Determine Drugs Frequency

The low frequency of use will result in a healing process and have an extended usage interval frequency of drug use that can cause side effects that can worsen the patient's condition. The dose should consider the HbA1c level <8% to determine the drug dosage and frequency [18]; we need proper consideration in determining the dosage and frequency. The frequency of administration of antidiabetic drugs using IF-Then about HbA1c levels shown in Table XIII.
Else
If HbA1C > 9 Then Frequency = Middle
Else
Frequency = low;
End;

K. Expert System Application

This application uses fuzzy-profile matching, which was built using the Pascal programming language with the Delphi IDE. The application interface can be seen in Fig. 8.

Fuzzy logic calculates the value of the match between the patient’s condition with the type of drug and profile matching as an inference to display the total amount of each kind of medication. The dose was calculated using the FIS Tsukamoto for inputting low dosage, and high dosage calculated the weighted average value. Determination of frequency using the IF-Then function. Doctors or medics will use this application by inputting several parameters, and the system will display the match values of each antidiabetic drug. Also, the system can communicate as well as the frequency of administration of the appropriate medication

L. Comparison with Existing System

Table XIV shows the differences between several studies of antidiabetic drug recommendations with this study. The difference between this study and previous research is that this study uses more complex parameters to recommend the type of drug and its name. Also, being able to calculate the dosage and frequency based on parameters so that the dose and frequency are more precise and consider the price and efficacy of the drug.

III. RESULTS AND DISCUSSION

A. Recommendation Doctor with System

The data used were 20 test data taken from patients' medical record data at the Bumi Waras Hospital in Bandar Lampung, Lampung, Indonesia, in 2019. Medical record data were calculated using the ordinal scale 1 and 0, as shown in Figure 9, in mapping the suitability of the patient’s condition with antidiabetic drugs. The calculation uses a database query by creating a table; then, the selection is based on each patient's condition stored in the view. Data in the next statement is calculated using a query formula to get the total. The results of the query calculation in Figure 10

Calculations using an ordinal scale have weaknesses because they do not produce flexible values to affect the quality of drug recommendations [16]. For example, antidiabetic Sulfonylurea is used for ≤60 years. If calculated using an ordinal scale, patients who are 61 years old cannot be given the type of Sulfonilurea drug, even though up to 65 years of age can still be given the medication. Therefore we need a more flexible calculation using Fuzzy logic [16].

Compared with Ordinal scale calculations, the application of fuzzy logic produces drug recommendations that approach the dataset; this is because fuzzy logic can provide flexible values to provide better anti-diabetic drug recommendations. Based on the number of recommended first-line antidiabetic drugs, Biguanide (Metformin), while for the second-line Insulin. This is according to management guidelines for type 2 Diabetes Mellitus [18].
B. Evaluation of drugs administration

In Antidiabetic drug recommendations, the accuracy of the system is crucial [33]. The course will display all the results, and the doctor will choose the best based on expertise. Evaluate the suitability of drug recommendations based on the system, and the doctor, True Positive (TP) is used, which means the doctor approves the recommended drug. The dataset (DS) is the total amount of data, the formula shown in Table XVII. The first stage of testing compares drug recommendations using the Ordinal scale, and the second stage will be carried out to compare drug recommendations using fuzzy logic. The results of drug recommendations using the Ordinal scale can be seen in Table XVI.

TABLE XVI

| Parameter     | Definition                                                                 |
|---------------|-----------------------------------------------------------------------------|
| True positive rate (TP) | The system recommends, and the doctor agrees                              |
| Dataset (DS)  | The total amount of record                                                  |

**Accuracy** = \( \frac{TP}{DS} \)

\( \text{Accuracy} = \frac{\text{Total number of recommended drugs}}{\text{Total Dataset}} \times 100\% \) (4)

**TABLE XVII COMPARISON OF ACCURACY ORDINAL SCALE AND FUZZY**

| Scale | First medicine | Second medicine | Average |
|-------|----------------|-----------------|---------|
| Ordinal | Medicine 1 | Medicine 2 | Medicine 2 |
| 11/20 | 100% | 9/20 * 100% | 47.5% |
| Fuzzy | 18/20% | 100% | 90% |

The recommendation to use Fuzzy does not have much difference with the dataset doctor. The difference lies in the number of Biguanide recommendations that the dataset recommends as many as 14, but the system only recommends 12. Based on the accuracy value calculation, the fuzzy logic application has better accuracy, with an average difference of 43%. The application of fuzzy logic was high-speed and lower cost in recommending reliable drugs [26].

IV. Conclusion

Based on the description, explanation, and testing that have been done, we get a few conclusions. This study
applied antidiabetic drugs’ suitability based on the patient’s health condition using the Profile Matching and Fuzzy Logic methods. Based on the evaluations Fuzzy Logic can recommend antidiabetic drugs that are better than using the Ordinal scale. In addition to the recommendation of the type of medicine, the system can also recommend the dosage and frequency of using Tsukamoto’s FIS so that it is more precise and reduces the errors of medical staff in recommending drugs and can have a positive impact on patients in terms of time, the healing process, and lower costs. This study provides knowledge that antidiabetic drug determination requires as many as 17 parameters, while other courses only use 4-8 parameters. This study also describes the number of drugs that drug companies can produce. Usually, companies only make low and high dosage. This research shows that creating various dosages of the drug is more efficient for patients. However, this research still needs to be reviewed and continued considering that it still has some weaknesses and shortcomings from the dataset to the number of parameters.

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