Nutritional Calculating Application for Diabetes Mellitus Patients Based on Body Mass Index Using Fuzzy Logic

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***Abstract*— The number of patients with type II diabetes mellitus with its complications tends to increase from year to year as a result of uncontrolled diabetes. WHO and the Indonesian Endocrinology Association (PERKENI) predict that there will be a significant increase in the number of people with diabetes in the coming years and is predicted to continue to increase. DM in Indonesia from 8.4 million in 2000 to 21.3 million in 2030. Currently the calculation of body mass index is still done manually. Calculation of body mass index manually can certainly cause problems such as taking so long and being less efficient. One effort to prevent this problem is by designing an application that can calculate body mass index using the system. This application was built and designed with the aim of knowing the nutritional value status of diabetes mellitus patients based on body mass index. In determining the patient's nutritional value, a method is needed, one method that can draw conclusions to calculate nutritional value status with fuzzy logic based on body mass index variables which include age, height, weight, and activity. It can be concluded that the Application for Calculating Nutritional Needs for Patients with Diabetes Mellitus can display results based on Body Mass Index, with a total sample of 7 patients with type 2 diabetes mellitus. The application has also been tested for Quality of Service with a packet loss test result of 0.14% which is included in the very good category, and the delay value of 120.005 ms according to the standard is very good.**

***Keywords*— Application, Body mass index, Diabetes mellitus, Fuzzy Logic, Nutritional**

I. INTRODUCTION

Diabetes Mellitus is a chronic metabolic disease, which is characterized by an increase in blood sugar levels due to a lack of insulin, which over time can damage the body's organs [1][2]. Based on Basic Health research from 2013 to 2018 the prevalence of diabetes has increased from 6.9% to 8.5%, which means that 22.9 million Indonesians have a prevalence of diabetes [3]. According to the American Diabetes Mellitus Association (2015), Diabetes Mellitus can be classified into several types, namely, Type I Diabetes Mellitus [4], Type II Diabetes Mellitus[5], Gestational Diabetes Mellitus [6], and other Diabetes Mellitus.

Seeing that diabetes mellitus will have an impact on the quality of human resources and a significant increase in health costs, a type II diabetes mellitus control program is needed. Type II diabetes mellitus can be prevented, delayed or eliminated by controlling risk [7][8]. According to [9], type II diabetes mellitus can be prevented by implementing preventive and curative patterns.

On the other hand, in the field of technology, the development of computer science is increasing rapidly every year. For example, we found a method development model using fuzzy logic. The convenience provided by this method is the level of flexibility, meaning that this method can be implemented for various cases, one of which is to determine the number of daily calories [10]. The fuzzy inference method is divided into 3 methods with different inventors, namely the Sugeno [11][12], Tsukamoto[13][14], and Mamdani methods [1][15][16], where many applications from various cases are created and developed by implementing these methods.

II. METHOD

A. *The System Workflow*

The system starts from a literature study regarding the application of calculating the nutritional needs of patients with diabetes mellitus, fuzzy logic, and body mass index, with reference to which as learning from the research to be carried out. Then data collection, research support, and research conducted, the need for tools includes hardware and software used as a design for making systems. Furthermore, the design of application software to calculate nutritional needs for diabetes mellitus patients will be stored in the database.

Then designing and making the interface design on the program application display, this stage determines a display on the application menu used by patients. Furthermore, the implementation consists of testing the system that is made until testing the results of the design, if the test results are not successful or invalid then return to the design stage of the system design. Next is data generation and analysis, this stage is carried out to obtain data from testing. Then make conclusions on what was done from start to finish and constructive suggestions to be used as a reference for further program development. The last stage of making a report after successfully getting the data and analysis of making the overall report, as shown in Figure 1.

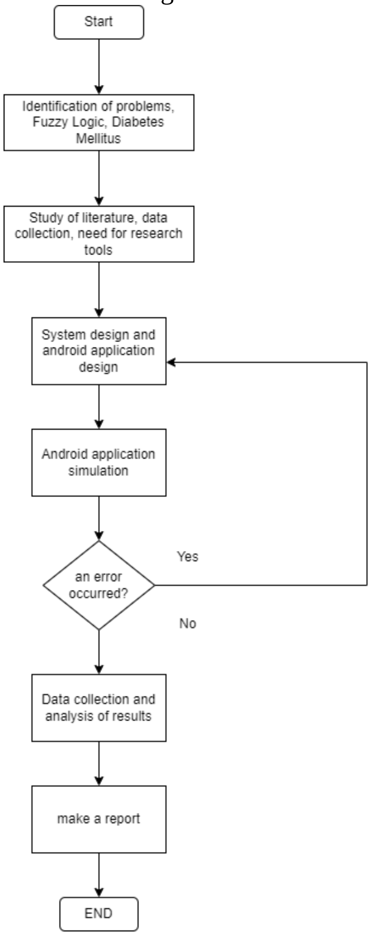

Figure 1. The System Workflow

B. Block Diagram

Patients enter the variable body mass index (BMI) as a parameter that determines nutritional needs for diabetics. The data that has been input will be processed automatically by the program. Patient data information is stored in the fire store database. The results will display the user's nutritional needs along with. food recommendations to meet the patient's daily nutritional needs, as shown in Figure 2.

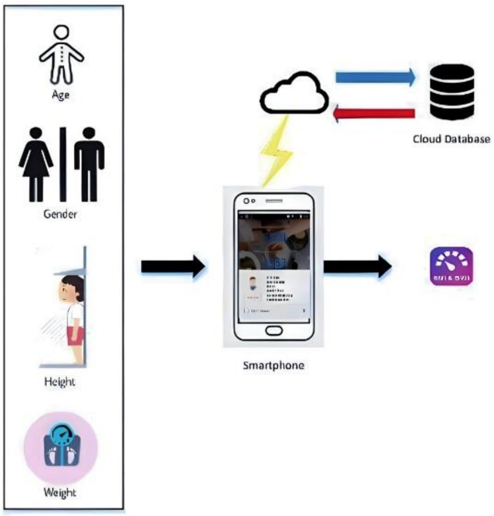

Figure 2. Block Diagram

C. DFD (Data Flow Diagram) Level 0

DFD in the application system for calculating nutritional needs in units of calories based on Android. Users register their own information to the program system. User account data information will be stored in the real-time database. The program receives and processes user personal data information. The system calculates variable data that has been inputted by the user. The system will display information on caloric needs in the form of a value to the user, as shown in Figure 3.

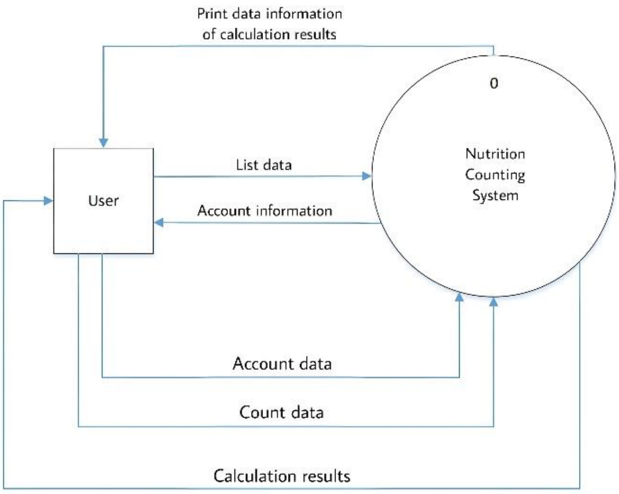

Figure 3. DFD (Data Flow Diagram) Level 0

D. Flowchart Application

Patients fill out forms that support calculation data, namely age, height, weight, and activity. The system will automatically calculate the nutritional needs that have been programmed using the fuzzy logic of the Mamdani method. Displays the results of the nutritional status of the body mass index (BMI) and the patient's caloric needs through predetermined parameters, as shown in Figure 4.

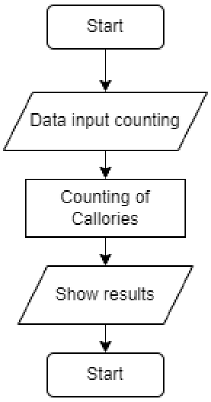

Figure 4. Flowchart Application

III. RESULT AND DISCUSSIONS

A. *Application Display Results*

Figure 5 is the initial appearance of the application which requires the user to log in when they already have an account.

Figure 5. Application Display Results

If the patient does not have an account, it is required to register an account first, as depicted in Figure 6.

Figure 6. Patient Data Filling Form

Figure 7 depicts the results of the data on this menu are not the final data results on the patient, but the stages of the registration process from the system that has been programmed. Then it will automatically display patient data

Figure 7. Patient Data Registration Results

Figure 8 depicts main page which are food recommendations according to the user's nutritional needs, at the bottom of the page there is a button "Update Food Recommendations" which will navigate the food recommendation menu to other foods that have been recommended by certain experts and sources, so that they can be used as regulatory guidelines food by the patient.

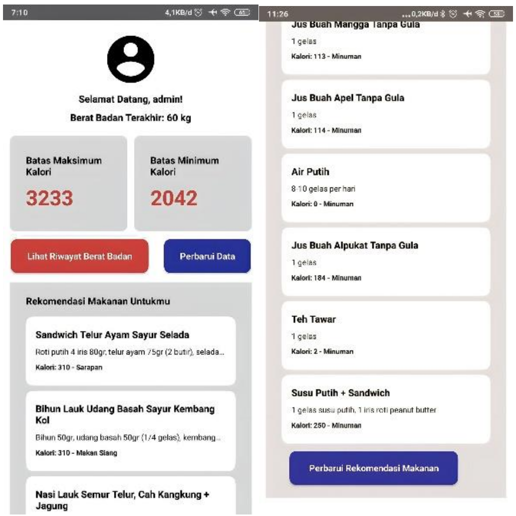

Figure 8. Results Display and Food Recommendations

The patient can view the history of his weight change, the patient can track information on his weight change, which includes the time and date of updating the information, and can also see the difference in daily calorie consumption, as shown in Figure 9.

Figure 9. Display *Weight History*

Figure 10 depicts a popup display which contains several input fields as well as two "Cancel" and "Save" buttons which have been provided to the patient to update his weight if the patient experiences a change in body weight, when the save button is pressed the system will recalculate the amount variable based output; Weight, height, gender, age, activity.

Figure 10. Display *Update Weight*

B. *Food Menu and Nutritional Needs*

TABLE I.
FOOD MENU AND NUTRITIONAL NEEDS

Time	**Food**	**Ingredient**	**Weight (g)**	**Energy (kal)**	**Protein (g)**	**Lard (g)**
Breakfast	Rice Corn	Rice Corn	100	175	4	3.99
	Rib	Rib 1 Slice	100	175	4	9
		Oil	7.5	65.25	0.8	7.35
Snack	Pastel	Pastel	45	100	2.6	7.7
Drink	Mineral Water	Water	0	0	0	0
Lunch	Rice	Rice	70	249.2	2.94	0.14
	Spicy Chicken	Chicken	40	120.8	7.28	10.6
	Cah jagung muda	Jagung muda	100	140	4.7	1.3
	Mushroom	Mushroom	25	3.75	0.95	0.15
Snack	Banana	Banana ambon	100	173.25	2.1	0.35
Drink	Mineral Water	Water	0	0	0	0
Dinner	Rice	Rice	70	249.2	2.94	0.14
	Semur telur	Telur	60	97.2	7.7	6.9
		Ketchup	25	11.5	1.43	0.15
	Cah kangkung + jagung	Kangkung	50	14.5	1.5	0.3
		Oil	7.5	65.25	0.8	7.35
		Jagung muda	100	140	4.7	1.3
Snack	Apple	Apple	100	58	0.3	0.4
Drink	Green Tea	Tea	1 Cup	2	0.2	0
Total				**1905.15**	**48,94**	**57.14**

Food consumption is given at intervals of 3 hours, the amount of food given must be finished according to the interval:

- Hour 06.30 = Breakfast + Drink
- Hour 09.30 = Snack
- Hour 12.30 = Lunch + Drink
- Hour 15.30 = Snack
- Hour 18.30 = Dinner + Drink
- Hour 21.30 = Snack

C. *Application Test of Nutritional Requirements*

TABLE II.
APPLICATION TESTING RESULTS

No.	Variabel Input					Variabel Output		
	W	H	Age	Sex	Activity	IMT	Cal. Min.	Cal. Maks.
1.	60	155	61	P	2	24,97	1218	2314
2.	66	163	54	P	1	28,07	1273	2418
3.	64	151	54	P	3	30,41	1672	3176
4.	72	177	45	L	4	22,98	1647	3129
5.	66	163	52	L	3	24,84	1460	2774
6.	55	159	47	P	2	15,08	1245	2365
7.	70	160	56	P	2	27,34	1348	2561

Information:
W = Weight
H = Height
Cal = Calorie

D. *Fuzzy Logic*

According to body weight, the horizontal axis is the input value of the weight variable, while the vertical axis is the membership level of the input value, as shown in Figure 11.

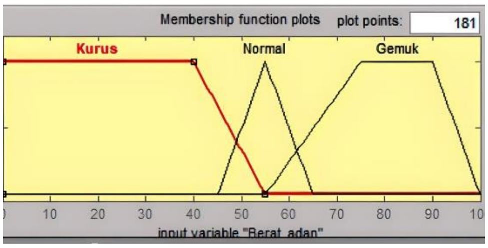

Figure 11. Assemblage of Weight

With membership function as follows:

$\mu_{thin} = \{ \frac{55-x}{15}$ 1 ; $x \leq 40$

; $40 \leq x \leq 55$

0 ; $x \geq 55$

$\mu_{Normal} = \{\frac{x-45}{10}$ 0 ; $x \leq 45$

$\frac{65-x}{10}$; $45 \leq x \leq 40$

; $55 \leq x \leq 65$

0 ; $x \geq 6$

0

$\mu_{fat} = \{\frac{x-55}{20}$; $x \leq 55$

1 ; $55 \leq x \leq 75$

; $x \geq 75$

TABLE III.
ASSEMBLAGE DOMAIN FUZZY WEIGHT

Variabel Weight	Domain Assemblage (crisp)	Domain Assemblage Fuzzy
Thin	$x \leq 40$	[0 40]
Normal	$55 \leq x \leq 65$	[30 70]
Fat	$x \geq 75$	[55 100]

According to body height, the horizontal axis is the input value of the weight variable, while the vertical axis is the membership level of the input value, as shown in Figure 12.

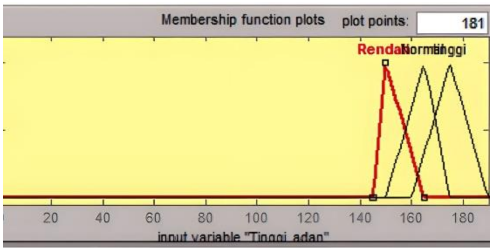

Figure 12. Assemblage of Height

With the membership function as follows:

$\mu_{low} = \{\frac{165-x}{15}$ 1 ; $x \leq 150$

; $150 \leq x \leq 165$

0 ; $x \geq 165$

$\mu_{Normal} = \{\frac{x-150}{15}$ 0 ; $x \leq 150$ atau $x \geq 175$

$\frac{175-x}{10}$; $150 \leq x \leq 165$

; $165 \leq x \leq 175$

$\mu_{height} = \{\frac{x-160}{15}$ 0 ; $x \leq 160$

; $160 \leq x \leq 175$

1 ; $x \geq 175$

TABLE IV.
ASSEMBLAGE DOMAIN FUZZY HEIGHT

Variable Height	Domain Assemblage tegas (crisp)	Domain Assemblage Fuzzy
Low	$x \leq 150$	[0 150]
Normal	$165 \leq x \leq 175$	[145 170]
High	$x \geq 175$	[175 190]

According to age, in calculating daily calories for people with diabetes mellitus, there are supporting variables used to determine the calculation, namely age, height, weight, and activity, as presented in Figure 13.

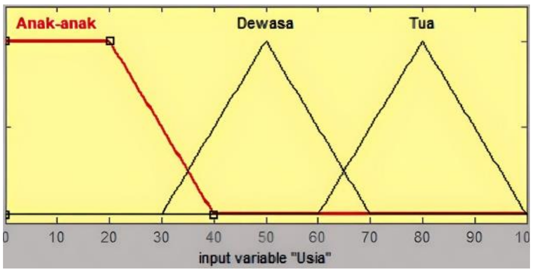

Figure 13. Himpunan Fuzzy Age

µChildren $= \{1; \frac{40-x}{20}$; $x \leq 40$

$20 \leq x \leq 40$

µAdult $= \{ \frac{x-30}{5}$; $30 \leq x \leq 35$

; $x = 35$

$1; \frac{(70-x)}{35}$; $30 \leq x \leq 70$

µElderly $= \{ \frac{x-60}{5}$; $60 \leq x \leq 80$

$1; x \geq 80$

TABEL V.
FUZZY AGE DOMAIN SET

Age variable	Crisp Domain	Fuzzy Set Domain
Children	$x \leq 40$	[0 40]
Adult	$30 \leq x \leq 70$	[30 70]
Elderly	$x \geq 80$	[60 100]

Based on Activity category, the horizontal axis is the input value of the weight variable, while the vertical axis is the membership level of the input value, as depicted in Figure 14.

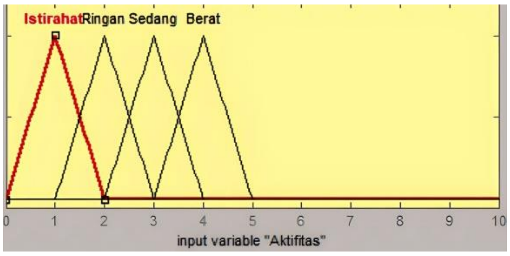

Figure 14. Assemblage Fuzzy Activity

The following is the membership function of the activity variable:

µRest $= \{ 1; \quad x \leq 1$

$\frac{2-x}{1}$; $1 \leq x \leq 2$

µMild $= \{ (x\text{-}1)$; $1 \leq x \leq 2$

1; $x = 2$

$(3\text{-}x)$; $2 \leq x \leq 3$

µAverage $= \{ \frac{x-2}{1}$; $2 \leq x \leq 3$

1; $x = 3$

$\frac{4-x}{1}$; $3 \leq x \leq 4$

µHeavy $= \{ \frac{x-3}{2}$; $3 \leq x \leq 5$

1; $x \geq 5$

TABLE VI.
ASSEMBLAGE DOMAIN FUZZY ACTIVITY

Activity variable	Crisp Domain	Fuzzy Set Domain
Rest	$x \leq 1$	[0 2]
Mild	$2 \leq x \leq 3$	[1 3]
Average	$3 \leq x \leq 4$	[2 4]
Heavy	$x \geq 5$	$[3 + \infty]$

Based on calory category, the results of the daily calorie fuzzy set are obtained based on the input variables that have been entered, the following displays the calorie requirement output:

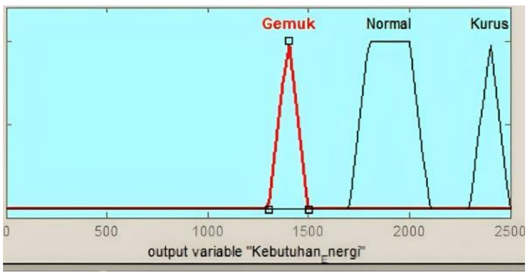

Figure 15. Assemblage Fuzzy Calories Needs

If the patient has a calorie requirement of 1300 to 1500 per day, it means that the patient is in the obese category, so he needs fewer calories to meet his nutritional needs. If the patient has a calorie requirement of 1700 to 2100 per day, it means that the patient has normal nutritional needs. patients in the thin category so that they need more calories to meet their nutritional needs, as depicted in Figure 15.

E. *Measurement of QoS (Quality of Service)*

The measurement result of Quality of Service consists of delay and packet loss parameters.

	DELAY	PACKET LOSS
1.	120.005 S	0,14 %

The number of data sent was 142 and the data received was 140. So, the packet loss assessment index was obtained as follows:

$$packet\ loss\% = \frac{(send\ data\ package - data\ package\ received)}{data\ package\ delivered} \times 100\%$$

$$packet\ loss\% = \frac{142 - 140}{142} \times 100\%$$

$$packet\ loss\% = 0{,}14\%$$

Based on the packet loss calculation value, the packet loss value is 0.14%, which is still in the very good index category.

$$Delay = \frac{Total\ of\ delay}{Total\ Number}$$

$$Delay = \frac{1.320{,}061, ms}{11}$$

$$Delay = 120{,}005$$

The average delay measurement result is 120.005 which indicates a very good index for the process of sending data from the application to the database.

IV. CONCLUSION

The implementation of the mamdani method fuzzy logic algorithm was successfully implemented in decision making on Android-based devices. In testing the application of diabetes mellitus, it has been successful in applying the PERKENI body mass index calculation formula for a sample of 7 diabetes mellitus patients. Based on the Quality of Service test, a packet loss value of 0.14% was obtained which indicated a very good index, and a delay value of 120.005 ms which indicated a very good index.

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