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Determining Students' Nutritional Status Using Mamdani Fuzzy Logic Method

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A B S T R A C T

Nutritional status is a body condition as a result of food consumption or a measure of the success of nutritional fulfillment; there is a balance between the amount of nutrient intake and the amount required by the body for a variety of biological functions such as physical growth, development, activity or productivity, health maintenance, and others. Children's nutritional status is indicated by weight and height [6]. Theoretically, nutritional status can be determined based on Anthropometric standards. Fuzzy logic is a method to show problems from input to expected output [4]. The Mamdani fuzzy method is one of the methods of the fuzzy inference system. This research uses Matlab R2021b software to apply the fuzzy method

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INTRODUCTION

Nutritional problems in children (5–18 years old) are a matter of particular interest to the government. In adolescents, nutritional problems majorly impact their development as individuals; or they cannot grow optimally. Three nutrition problems that adolescents in Indonesia experience include malnutrition (stunting), micronutrient deficiency that can result in anemia, and obesity.

Nutritional status is a body condition as a result of food consumption or a measure of the success of nutritional fulfillment; there is a balance between the amount of nutrient intake and the amount required by the body for a variety of biological functions such as physical growth, development, activity or productivity, health maintenance, and others. Children's nutritional status is indicated by weight and height [6]. Theoretically, nutritional status can be determined based on Anthropometric standards.

LITERATURE REVIEW

Anthropometric standards are based on weight and height parameters consisting of four indexes, including a) weight-for-age (BB/U); b) height-for-age (TB/U); c) weight-for-length/height (BB/PB or BB/TB); d) body mass index (BMI)-for-age (IMT/U). This research uses body mass index (BMI)-for-age for children aged 5 to 18 years old. This index has five categories: a) severely thinness; b) thinness; c) normal; d) overweight; and e) obese [3].

Fuzzy logic is a method to map problems from input to expected output [4]. The fuzzy inference system is a calculation framework based on fuzzy set theory and fuzzy logic that is used in conclusion or decision-making [5]. The Mamdani fuzzy method is one of the methods of the fuzzy inference system. This research uses Matlab R2021b software to apply the fuzzy method.

METHODOLOGY

The Mamdani method is often known as the Max-Min method. This method was developed by Ebrahim Mamdani in 1975. There are four steps in this method, which are: fuzzy set's formation, implication function's application, rule's composition, and defuzzification. The application of the Mamdani fuzzy logic in this research is shown in the flowchart in Figure 1.

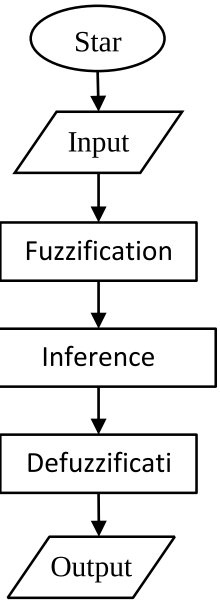

Figure 1. Fuzzy Flowchart

The explanation of the Mamdani fuzzy flowchart is as follows:

1. Input
   The inputs in this research are data variables that have a crisp value. The input data for determining nutritional status are height and weight.
2. Fuzzification
   This process is carried out to convert the input data into fuzzy variables. The aim is to allow fuzzy input to be mapped into a suitable type for the fuzzy sets. The mapping is done with the help of the membership function to determine the degree of membership.
   Graphics and formulas of fuzzification for nutritional status:
   a. One's height is categorized as short if the height is under 155 cm; one's height is categorized as normal or medium if the height is between 150 cm and 175 cm; and one's height is categorized as tall if the height is over 170 cm.

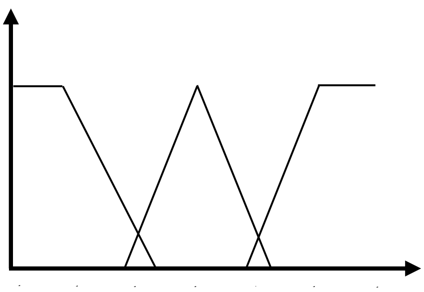

Figure 2. Height Curve

Formulas:
Short: $\frac{155-height}{155-140}$
Normal: $\frac{height-150}{162.5-150}$; $(150<height<162.5)$
Normal: $\frac{175-height}{175-162.5}$; $(162.5<height<175)$
Tall: $\frac{height-170}{180-170}$

b. One's weight is categorized as light if the weight is under 50 kg; one's weight is categorized as average or normal if the weight is between 45 kg and 75 kg; and one's weight is categorized as heavy if the weight is over 70 kg.

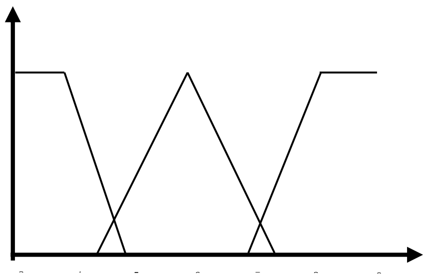

Figure 3. Weight Curve

Formulas:
Light: $\frac{50-weight}{50-40}$
Normal: $\frac{weight-45}{60-45}$; $(45<weight<60)$
Normal: $\frac{75-weight}{75-60}$; $(60<weight<75)$
Heavy: $\frac{weight-70}{80-70}$

3. Inference Engine

This is the process of converting fuzzy input into fuzzy output by applying the rules (*IF-THEN Rules*) that have been established in the fuzzy knowledge base. Table 1 shows the rule base formation for nutritional status using height and weight variables.

Table 1. Nutritional Status Rule Base

<table>
<tr><td rowspan="2" colspan="2">Nutritional Status</td><td colspan="3">Weight</td></tr>
<tr><td>Light</td><td>Normal</td><td>Heavy</td></tr>
<tr><td rowspan="2">Height</td><td>Short</td><td>R1= Normal</td><td>R2= Overweight</td><td>R3= Obese</td></tr>
<tr><td>Normal</td><td>R4=</td><td>R5=</td><td>R6=</td></tr>
</table>

		Under weight	Norm al	Over weigh t
	Tall	R7= Under weight	R8= Under weight	R9= Norm al

In the inference engine, the Min function is applied to each rule in the implication function in determining nutritional status.

a. Rule 1 = If Height (TB) short and Weight (BB) light then Nutritional Status (SG) Normal
formula: $Min\ \mu short \cap \mu light$
b. Rule 2 = If Height (TB) short and Weight (BB) normal then SG Overweight
formula: $Min\ \mu short \cap \mu normal$
c. Rule 3 = If Height (TB) short and Weight (BB) heavy then SG Obesity
formula: $Min\ \mu short \cap \mu heavy$
d. Rule 4 = If Height (TB) normal and Weight (BB) light then SG Underweight
formula: $Min\ \mu normal \cap \mu light$
e. Rule 5 = If Height (TB) normal and Weight (BB) normal then Nutritional Status (SG) Normal
formula: $Min\ \mu normal \cap \mu normal$
f. Rule 6 = If Height (TB) normal and Weight (BB) heavy then Nutritional Status (SG) Overweight
formula: $Min\ \mu normal \cap \mu heavy$
g. Rule 7 = If Height (TB) tall and Weight (BB) light then Nutritional Status (SG) Underweight
formula: $Min\ \mu tall \cap \mu light$
h. Rule 8 = If Height (TB) tall and Weight (BB) normal then Nutritional Status (SG) Underweight
formula: $Min\ \mu tall \cap \mu normal$
i. Rule 9 = If Height (TB) tall and Weight (BB) heavy then Nutritional Status (SG) Normal
formula: $Min\ \mu tall \cap \mu heavy$

One’s nutritional status is categorized as underweight if the BMI is under 18, one’s nutritional status is categorized as normal if the BMI is between 17 and 25, and one’s nutritional status is categorized as overweight if the BMI is over 23.

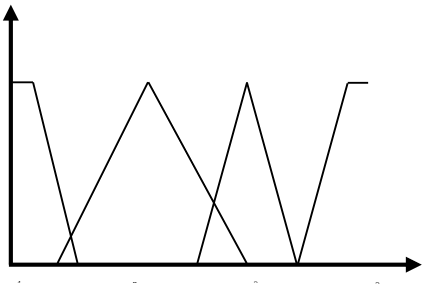

Figure 4. Nutritional Status Curve

4. Defuzzification

This process produces a value that can be calculated in the form of crisp logic; the value is under the given fuzzy set and the degree of membership. Defuzzification can be defined as a mapping process from fuzzy sets to crisp sets.

The input of the defuzzification process is a fuzzy set obtained by fuzzy rule composition. The output is a number in the fuzzy set domain, so if given a fuzzy set in a particular range, a certain crisp value must be possible to take as the output. A crisp value is obtained through the MOM method by using the domain mean that has the maximum membership value.

$$z_{MOM} = \frac{\int_{Z'} z\,dz}{\int_{Z'} dz},$$

$$\text{where } Z' = \{z; \mu_A(z) = \overset{*}{\mu}\}$$

RESULTS AND DISCUSSION

This research uses Matlab software to change the inputs, which are height and weight, to find nutritional value. The nutritional value is adjusted to the membership range in the nutritional value variable to get nutritional status as an output. This variable is formed based on the IMT classification.

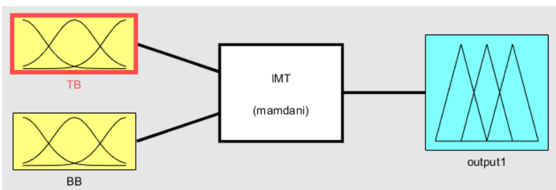

Figure 5. Fuzzy Process

The variable determination in this research can be seen in Table 2:

Table 2. Universal Set for Each Nutritional Status' Fuzzy Variable

Function	Variable	Universal Set
Input	Height	[130 190]
	Weight	[30 90]
Output	Nutritional Status	[15 30]

The fuzzy sets, along with the membership function of height, weight, and nutritional status variables, are shown in Figures 6, 7, and 8:

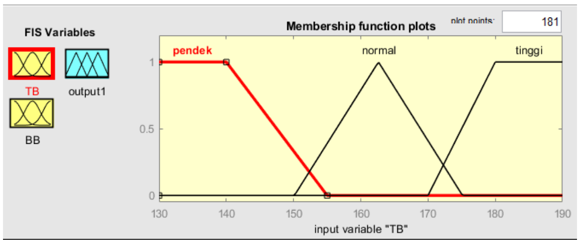

Figure 6. Membership Function of Height Input

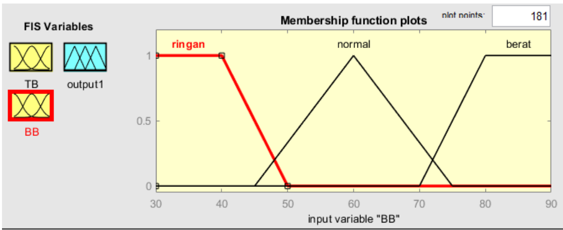

Figure 7. Membership Function of Weight Input

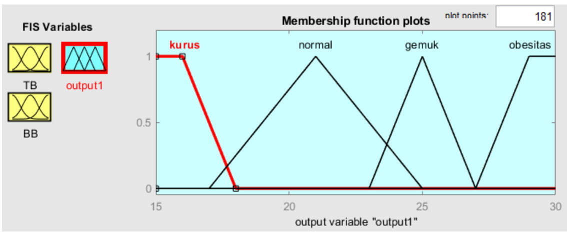

Figure 8. Membership Function Output

The details of the membership function of the fuzzy sets can be seen in Table 3:

Table 3. Function Membership Table

Function	Variable Name	Domain	Fuzzy Set	Parameter
Input	Height	[140 155]	Short	[130 130 140 155]
		[150 175]	Normal/ Medium	[150 163 175]
		[170 180]	Tall	[170 180 190 190]
	Weight	[40 50]	Light	[30 30 40 50]
		[60 75]	Normal/ Average weight	[45 60 75]
		[70 80]	Heavy	[70 80 90 90]
Output	Nutritional Status	[16 18]	Underweight	[15 15 16 18]
		[17 25]	Normal/ Average weight	[17 21 25]
		[23 27]	Overweight	[23 25 27]
		[27 29]	Obesity	[27 29 30 30]

The formation of the nutritional status rule base using height and weight variables is shown in Table 4:

Table 4. The Nutritional Status Rule Base

Nutritional Status		Weight		
		Light	Normal	Heavy
Height	Short	R1= Normal	R2= Overweight	R3= Obesity
	Normal	R4= Underweight	R5= Normal	R6= Overweight
	Tall	R7= Underweight	R8= Underweight	R9= Normal

The application of the Min function to each rule in the implication function in determining nutritional status.

a. Rule 1 = If Height (TB) short and Weight (BB) light then Nutritional Status (SG) Normal
   formula: $Min\ \mu short \cap \mu light$
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i. Rule 9 = If Height (TB) tall and Weight (BB) heavy then Nutritional Status (SG) Normal
formula: $Min\ \mu tall \cap \mu heavy$

In the defuzzification process, the output is a crisp number in the fuzzy set domain. Thus, if given a fuzzy set in a particular range, a certain value must be possible to take as the output. The defuzzification used in determining nutritional value is by using the mean method.

The data used in this research are the height and weight of the students at SMA Negeri 5 Yogyakarta. The data were obtained through a questionnaire. The research was participated in by 36 students of the X MIPA 1. An example of the assessment is shown in the following figure:

1. Student number 1, Height=174 cm and Weight=74,2 kg with Nutritional Status: Normal

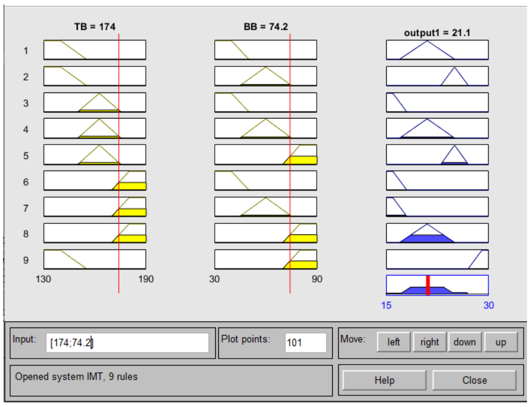

Figure 9. Result of Student Number 1

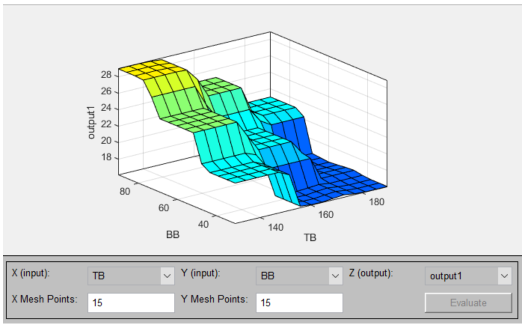

Figure 10. Graphic of Student Number 1's Result

2. Student number 2, Height=148 cm and Weight=52 kg with Nutritional Status: Overweight

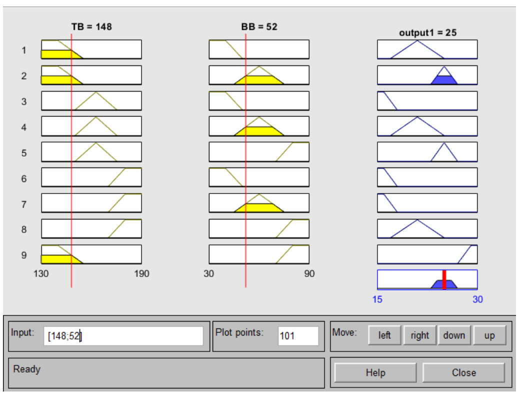

Figure11. Result of Student Number 2

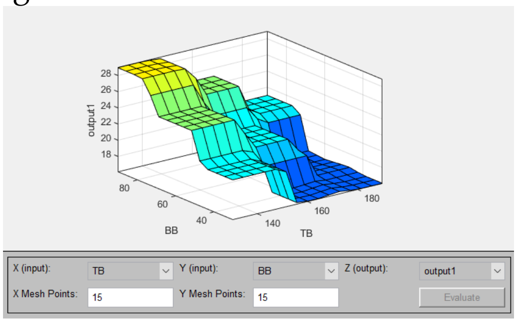

Figure 12. Graphic of Student Number 2's Result

CONCLUSIONS AND RECOMMENDATIONS

Based on the research findings, the conclusions are as follows:

1. This research used the Mamdani fuzzy inference method to calculate nutritional status by showing two variable inputs: height and weight.
2. Determining students' nutritional status is proven helpful because it can be used as a reference to monitor the growth and development of the students at SMA Negeri 5 Yogyakarta and other educational institutions.
3. It enables homeroom teachers to monitor their students' growth and development.

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