The Accuracy Of Fuzzy Sugeno Method With Anthropometry On Determination Natural Patient Status

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Abstract. Anthropometry is one of the processes that can be used to assess nutritional status. In general anthropometry is defined as body size in terms of nutrition, then anthropometry is reviewed from various age levels and nutritional levels. Nutritional status is a description of the balance between nutritional intake with the needs of the body individually. Fuzzy logic is a logic that has a vagueness between right and wrong or between 0 and 1. Sugeno method is used because in the process of calculating nutritional status so far is still done by anthropology. Currently information technology is growing in any aspect, one of them in the aspect of calculation with data taken from anthropometry. In this case the calculation can use the Fuzzy Sugeno Method, in order to know the great accuracy obtained. Then the results obtained using fuzzy sugeno integrated with anthropometry has an accuracy of 81.48%.

Keywords: Anthropometry, Nutrition Status, Fuzzy Sugeno

1. Introduction

Anthropometry is one of the processes that can be used to assess nutritional status. In general anthropometry is defined as body size in terms of nutrition, then anthropometry is reviewed from various age levels and nutritional levels. Anthropometry is very commonly used to measure nutritional status for various imbalances between protein-generated energy [20]. From a nutritional point of view has been much expressed by experts, one of them is [1] revealed that:

"Nutritional anthropometry is the measurement of the variations of the physical dimensions and the gross composition of the human body at different age levels and degree of nutrition".

Fuzzy Inference System (FIS) is one part of fuzzy logic. This FIS can make reasoning like a human being. FIS requires numbers as inputs and then translates them into linguistic terms such as small, medium, and large. There are several types of FIS namely Mamdani, Sugeno and Tsukamoto. Mamdani and Sugeno methods are two methods that researchers often use in their research, but Mamdani and Sugeno methods have their respective advantages and disadvantages. The advantages of the Mamdani method is that this method is more intuitive and the way it works is more like a human. However FIS Mamdani has a problem in terms of computing. While the Sugeno method is more adaptive in terms of optimization, computing is more efficient especially in terms of nonlinear dynamic systems [5,4,3]. Sugeno method is used because in the process of calculating nutritional status so far is still done in anthropometry, so there is still a level of error in the calculation. Currently information technology is growing in any aspect, one of them in the aspect of calculation with data taken from anthropometry. In this case the calculation can use the Sugeno Method, which can anticipate errors with the rules - rules that will input.
The research is done by the calculation using Fuzzy Sugeno method with data taken from anthropometry in the determination of nutritional status of the patient, so it can give accurate result in determining nutritional status.

2. Fuzzy Logic
In his journal [2] said that fuzzy logic is a powerful concept for nonlinear handling, different timing, and adaptive systems. This allows the use of linguistic values of variables and improper relationships for system modeling behavior. The seminal ideas of fuzzy logic applied to systems modelling and control can be found in the early papers of Zadeh in the 1960s and 1970s [15,16]. There are many interpretations of fuzzy modelling. For instance, a fuzzy set is a fuzzy model of human concept. In other words, fuzzy models consist of linguistic explanations about the system behaviour and deals with fuzzy modelling of a plant for control [9,16,17,18,19]. Just as modern control theory, a fuzzy controller can be designed based on a fuzzy model of a plant if the fuzzy model can be identified [12]. In this research is to assess the nutritional status of patients using fuzzy sugeno method which is generally done with anthropometry. With the aim of how much accuracy Fuzzy Sugeno with Anthropometry on the determination of nutritional status of patients, so it can provide benefits that on fuzzy sugeno also can be done assessment of nutritional status of patients.

3. Sugeno Fuzzy Inference
The Sugeno fuzzy model, also known as the TSK fuzzy model, was proposed by [9,10] in an effort to develop an systematic approach to generate fuzzy rules from a given input–output data set. A typical fuzzy rule in Sugeno fuzzy model has the form

\[ \text{If } x \text{ is } A \text{ and } y \text{ is } B \text{ then } z = f(x,y) \]

where A and B are MFs in the antecedent part, while \( z = f(x,y) \) is a linear function in the consequent part. Usually \( f(x,y) \) is polynomial in the input variables x and y but it can be any function as long as it can appropriately describe the output of the model within the fuzzy region specified by the antecedent of the rule. When \( f(x,y) \) is a first-order polynomial, the resulting fuzzy inference system is called a first-order Sugeno fuzzy model which was proposed in [12,10,9]. When \( f(x,y) \) is a constant, it is zero-order Sugeno fuzzy model, which can be considered as a special case of Mamdani fuzzy model, in which the consequent of each rule is specified by a fuzzy singleton or by a pre-defuzzified consequent or a special case of Tsukamoto fuzzy model in which the consequent of each rule is specified by an MF of a step function.

Moreover, a zero-order Sugeno fuzzy model is functionally equivalent to a radial basis function network under certain minor constraints [13,14]. The output of zero-order Sugeno fuzzy model is a smooth function of its input variables as long as neighbouring MFs in the antecedent have enough overlap.

4. Anthropometry
The term anthropometry [8] in his book comes from "anthro" which means man and "metri" which means size. Anthropometry by [6,7] is a collection of numerical data related to the physical characteristics of the human body, its contribution, shape and strength and the application of the data to design problem handling. Body Mass Index (BMI) is a simple tool to monitor the nutritional status of adults, especially those related to deficiency and overweight. BMI use only applies to adults over 18 years of age and is not applicable to infants, children, adolescents, pregnant women, and athletes.

The formula for calculating BMI is as follows:

\[ \text{BMI} = \frac{\text{Weight (kg)}}{\text{Height (m)} \times \text{Height (m)}} \]

Based on the formula issued by [11], that category of Body Mass Index threshold for Indonesia as follows:
Table 1. BMI limit threshold category for Indonesia

| Nutritional Status | BMI (kg/m²) |
|--------------------|-------------|
| Very Thin          | < 17.0      |
| Thin               | 17.0-18.4   |
| Normal             | 18.5-25.0   |
| Fat                | 25.1-27.0   |
| Very Fat           | > 27.0      |

Body Mass Index released in the table above, then the nutritional status of a person based on the information below:
1) If the nutritional value <17.0, then the nutritional status is very thin
2) If the nutritional value is 17.0-18.4, then the nutritional status is thin
3) If the nutritional value is 18.5-25.0, then the nutritional status is normal
4) If nutritional value 25.1-27.0, then the nutritional status is fat
5) If the nutritional value> 27.0, then the nutritional status is very fat

5. Fuzzy Membership Function
The fuzzy set and the membership function of the variable weight, height, and nutritional value are represented as follows:

a. The Fuzzy Set of Weight Variables
In the weight variable is defined three fuzzy set, namely LIGHT, NORMAL, and WEIGHT. The fuzzy set image for the weight variable is shown in Figure 1.

![Figure 1. The weight fuzzy set](image)

Where the horizontal axis is the input value of the variable weight, while the vertical axis is the membership level of the input value.
With membership function is as follows:

\[
\mu_{\text{Light}} = \begin{cases} 
1; & x \leq 40 \\
\frac{55-x}{55-40}; & 40 \leq x \leq 55 \\
0; & x \geq 55 
\end{cases} 
\]  

(1)

\[
\mu_{\text{Normal}} = \begin{cases} 
0; & x \leq 45 \\
\frac{x-45}{55-45}; & 45 \leq x \leq 55 \\
1; & x \geq 65 
\end{cases} 
\]  

(2)

\[
\mu_{\text{Weight}} = \begin{cases} 
1; & 70 \leq x \leq 80 \\
\frac{x-55}{70-55}; & 55 \leq x \leq 70 \\
0; & x \leq 55 
\end{cases} 
\]  

(3)
b. The Fuzzy Variable Height Set of Bodies
In the variable height is defined three fuzzy set, namely LOW, NORMAL, and HIGH. The representation of the fuzzy set for the height variables is shown in Figure 2.

\[ \mu_{\text{Low}} = \begin{cases} 1 & ; \quad x \leq 1.5 \\ \frac{1.65-x}{0.15} & ; \quad 1.5 \leq x \leq 1.65 \\ 0 & ; \quad x \geq 1.65 \end{cases} \]  

\[ \mu_{\text{Normal}} = \begin{cases} 0 & ; \quad x \leq 1.5 \\ \frac{x-1.5}{0.15} & ; \quad 1.5 \leq x \leq 1.65 \\ \frac{1.75-x}{0.1} & ; \quad 1.65 \leq x \leq 1.75 \\ 1 & ; \quad x \geq 1.75 \end{cases} \]  

\[ \mu_{\text{High}} = \begin{cases} 0 & ; \quad x \leq 1.6 \\ \frac{x-1.6}{0.15} & ; \quad 1.6 \leq x \leq 1.75 \\ 1 & ; \quad x \geq 1.75 \end{cases} \]  

Where the horizontal axis is the input value of the variable height, while the vertical axis is the membership level of the input value.

With membership function is as follows:

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\[ \mu_{\text{Low}} = \begin{cases} 1 & ; \quad x \leq 1.5 \\ \frac{1.65-x}{0.15} & ; \quad 1.5 \leq x \leq 1.65 \\ 0 & ; \quad x \geq 1.65 \end{cases} \]  

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\[ \mu_{\text{High}} = \begin{cases} 0 & ; \quad x \leq 1.6 \\ \frac{x-1.6}{0.15} & ; \quad 1.6 \leq x \leq 1.75 \\ 1 & ; \quad x \geq 1.75 \end{cases} \]  

c. The Fuzzy Set of Nutritional Value Variables
The fuzzy set of nutritional values is obtained by the classification of the Body Mass Index (BMI), which is represented by the fuzzy set. In the nutritional value variables are defined five fuzzy set, namely VERY THIN, THIN, NORMAL, FAT, VERY FAT. The fuzzy set of images for the nutritional value variable is shown in Figure 3.

Information:
VT : Very Thin
THIN
NRL: Normal
FAT
VF : Very Fat
Based on Figure 3, the horizontal axis is the input value of the nutritional value variable, while the vertical axis represents the membership level of the input value. With membership function is as follows:

\[ \mu_{\text{Very Thin}} = \begin{cases} 1; & x \leq 16 \\ 17 - x; & 16 \leq x \leq 17 \\ 0; & x \geq 17 \end{cases} \] 

(7)

\[ \mu_{\text{Thin}} = \begin{cases} 0; & x \leq 16 \\ x - 16; & 16 \leq x \leq 17 \\ 1; & 17 \leq x \leq 17.5 \\ 18.5 - x; & 17.5 \leq x \leq 18.5 \\ 0; & x \leq 17.5 \end{cases} \] 

(8)

\[ \mu_{\text{Normal}} = \begin{cases} 0; & x \leq 24 \\ x - 24; & 24 \leq x \leq 25 \\ 1; & 25 \leq x \leq 26 \\ 27 - x; & 26 \leq x \leq 27 \end{cases} \] 

(9)

\[ \mu_{\text{Fat}} = \begin{cases} 0; & x \leq 26 \\ x - 26; & 26 \leq x \leq 27 \\ 1; & x \geq 27 \end{cases} \] 

(10)

\[ \mu_{\text{Very Fat}} = \begin{cases} 0; & x \leq 26 \\ x - 26; & 26 \leq x \leq 27 \\ 1; & x \geq 27 \end{cases} \] 

(11)

6. Fuzzy Rules
By category in BMI, the following rules may be established:

| No | Weight | Height | Value       | Status   |
|----|--------|--------|-------------|----------|
| 1  | 40     | 1.5    | 17.77777778 | Thin     |
| 2  | 40     | 1.65   | 14.69237833 | Very Thin|
| 3  | 40     | 1.75   | 13.06122449 | Very Thin|
| 4  | 55     | 1.5    | 24.44444444 | Normal   |
| 5  | 55     | 1.65   | 20.20202020 | Normal   |
| 6  | 55     | 1.75   | 17.95918367 | Thin     |
| 7  | 70     | 1.5    | 31.11111111 | Very Fat |
| 8  | 70     | 1.65   | 25.71166208 | Fat      |
| 9  | 70     | 1.75   | 22.85714286 | Normal   |

7. Rule Evaluation and Accuracy
After the rule is formed, then evaluated the rule to see the results obtained from the fuzzy sugeno and anthropometry methods. And after the evaluation rule is done, then the next to evaluate the level of accuracy taken from anthropometry data.
Table 3. Rule evaluation results and accuracy

| Data | Patient Status | Nutritional Value | Nutritional Status | Sugeno Status | Statement |
|------|----------------|-------------------|--------------------|---------------|-----------|
| P001 | 62             | 1.52              | 26.83518           | Fat           | 27.0713   | Very Fat | False   |
| P002 | 90             | 1.65              | 33.057851          | Very Fat      | 24.99803  | Normal   | False   |
| P003 | 50             | 1.49              | 22.521508          | Normal        | 21.77778  | Normal   | True    |
| P004 | 89             | 1.6              | 34.765625          | Very Fat      | 27.51148  | Very Fat | True    |
| P005 | 55             | 1.64              | 20.449137          | Normal        | 19.95313  | Normal   | True    |
| P006 | 52             | 1.5               | 23.111111          | Normal        | 22.96296  | Normal   | True    |
| P007 | 63             | 1.55              | 26.222685          | Fat           | 26.91508  | Fat      | True    |
| P008 | 65             | 1.53              | 27.767098          | Very Fat      | 29.86508  | Very Fat | True    |
| P009 | 60             | 1.51              | 26.314635          | Fat           | 26.53811  | Fat      | True    |
| P010 | 48             | 1.65              | 17.630854          | Thin          | 16.18468  | Very Thin| False   |
| P011 | 67             | 1.5               | 29.777778          | Very Fat      | 31.11111  | Very Fat | True    |
| P012 | 63             | 1.5               | 28                | Very Fat      | 29.29293  | Very Fat | True    |
| P013 | 72             | 1.5               | 32                | Very Fat      | 31.11111  | Very Fat | True    |
| P014 | 58             | 1.48              | 26.479182          | Fat           | 25.92593  | Fat      | True    |
| P015 | 62             | 1.54              | 26.142688          | Fat           | 26.22731  | Fat      | True    |
| P016 | 58             | 1.65              | 21.303949          | Normal        | 20.8197   | Normal   | True    |
| P017 | 74             | 1.6               | 28.90625           | Very Fat      | 27.51148  | Very Fat | True    |
| P018 | 62             | 1.49              | 27.92667           | Very Fat      | 28.50242  | Very Fat | True    |
| P019 | 75             | 1.5               | 33.333333          | Very Fat      | 31.11111  | Very Fat | True    |
| P020 | 68             | 1.55              | 28.30385           | Very Fat      | 29.31129  | Very Fat | True    |
| P021 | 70             | 1.65              | 25.711662          | Fat           | 24.99803  | Normal   | False   |
| P022 | 68             | 1.68              | 24.092971          | Normal        | 24.47728  | Normal   | True    |
| P023 | 62             | 1.65              | 22.773186          | Normal        | 22.19013  | Normal   | True    |
| P024 | 45             | 1.5               | 20                | Normal        | 17.77778  | Thin     | False   |
| P025 | 51             | 1.6               | 19.921875          | Normal        | 19.72368  | Normal   | True    |
| P026 | 87             | 1.6               | 33.984375          | Very Fat      | 27.51148  | Very Fat | True    |
| P027 | 52             | 1.55              | 21.644121          | Normal        | 21.08881  | Normal   | True    |

Based on the above table, the overall data were 27 patients where the correct statement was 22 patients and the wrong statement was 5 patients.

8. Performance Evaluation Method

From the data table 4.2. Shows that the results obtained using fuzzy sugeno integrated with anthropometry have the following levels of accuracy:

\[
Accuracy \ rate = \frac{\sum \text{correct}}{\sum \text{data}} \times 100\%
\]

\[
Accuracy \ rate = \frac{22}{27} \times 100\% = 81,48\% \quad (12)
\]

So the accuracy level analysis in determining nutritional status based on Body Mass Index (BMI) produced by Sugeno fuzzy method has percentage of 81,48%.
Conclusions

Sugeno fuzzy method can be an alternative in determining nutritional status. Differences in the calculation of nutritional value using fuzzy sugeno and anthropometry methods. The accuracy level of fuzzy sugeno method with data taken from anthropometry of 81.48%. Procedure to obtain nutritional status is by adjusting the nutritional value that has been obtained into the function of the fuzzy set membership on the variable of nutritional value. The fuzzy set of nutritional values is obtained by the classification of the Body Mass Index (BMI), which is represented by the fuzzy set.

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