Mobile Decision Support System to Determine Toddler's Nutrition using Fuzzy Sugeno

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ABSTRACT

Determination of nutritional status is closely related to the determination of dietary patterns should be given to infants. Nutrition is very important role in mental, physical development, and human productivity. In this study, the system based on android is developed to determine the nutritional status of infants by using Fuzzy Sugeno. Indicator variables are age, height, circle head, and body weight according to the male or female. In this study, the results of measurements of nutritional status of children with Fuzzy Sugeno are tested by comparing the nutritional quality of the data Posyandu toddler by using anthropometric tables. The results of the evaluation measurement accuracy in this application are compared with the results of manual calculation based infant growth charts according to WHO standards. Therefore, these applications can be used to help the community in monitoring the nutritional status of children so that the growth of children is more appropriate in line with expectations.

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1. INTRODUCTION

The growth technology forces the human resource adapting this growth smartly as well. The alignment of growing technology in information industry, especially cloud computing, where the system created to be able access wherever and whenever needed with integration application by using internet. One of the application is to determine the toddler’s nutrition status which uses the android system. This application is created for parents and doctors to check on toddler’s nutrition and provide the nutrient needed. The food menu is chosen by the need by the toddler and the nutrients in the food. Choosing the right food makes the nutrition status normal, where there’s balancing between food consumption and nutrient. Fulfillment of nutrient takes an important role for mental and physical growth, and productivity. So the nutrition fulfillment must be controlled to maintain the health of growing period toddlers.

Method used to support the nutrition system on toddler is logic Fuzzy and Sugeno method. By using this method is to simplify the information of toddler’s nutrition so that the parents or doctors can make the right decision. This research is to determine the toddler’s nutrition according to height, weight, and age. But this system has not applied to an application based on computerization [1]. Author will develop this toddler’s nutrition application by using logic Fuzzy Sugeno. Fuzzy Sugeno method is the inference Fuzzy method to be represent in a form of “IF-THEN”, where the output (consequence) system not a Fuzzy compilation, but a constant or linear [2]. Indicator used in this research is an age variable, height, and weight accordingly to the gender; boy or girl. Software used to create this application is Java using Basic4Android and database SQL Lite Manager based on Android.
2. RELATED WORKS

Fidiantoro and Setiadi [3] uses the weight according to the age, height according to the age and weight according to height. The Method for evaluate the toddler’s nutrition uses fuzzy logic. Fuzzy is able to solve the complex nonlinear in order to able to view the nutrition status with member degree. Jean Christophe Buisson [4] (2008) did a research called “Nutri-Educ, a nutrition software application for balancing meals, using fuzzy arithmetic and heuristic search algorithms”. This research used a daily input meal breakdown and meal description with output balance assessment and fix or improve the meal. Programming language called combining Java and Flash/Action Script (Buissen, 2008).

Josua M. Krebez and Adnan Saout[5] conducted a research call “Fuzzy Nutrition System”. The research mentioned the Fuzzy diet analysis system with food recommendations. The proposed system is described and implemented as follows. Two methods for nutritional feedback, one fuzzy and the other crisp, are compared. A comparison is made between the usefulness of fuzzy and crisp diet data from a user’s perspective. Similarity with this research is using the same method but the difference is discussed topic, where on this system explain about Fuzzy diet analysis, but on our research explain toddler’s nutrition status and the program used is SQL Queries for database USDA SR23, but this research using Java based on Android. Petri Haimonen’s research [6] with entitled “Development of a Fuzzy Expert for Nutritional Guidance Application” discussed the Nutritional Guidance with fuzzy mandani method. This application is designed using Matlab. (Heinonen, Mannelin, Iskala, Sorsa & Junso, 2009).

Research that done by Sudirman [7] called “Classification Nutrition Analysis with Fuzzy Method C-means using application based on Android”. This application used height input, weight and gender as the research indicator with an output of toddler’s nutrition status. Programming language that used is Java based on Android. Tomy Prasetio’s research with entitled [8] “Application to diagnose Nutrition on Toddler with the Calories needed using Fuzzy Sugeno method”. On this research system, the input used such as Height/Age, Weight/Age and Height/Weight with output toddler’s nutrition status. Programming language used is Visual C++. (Prasetion, Martiana & Mubtada’i, 2011)

3. RESEARCH METHOD

Flowchart determine toddler’s nutrition system uses Fuzzy Sugeno method as shown Figure 1

![Flowchart of Toddler’s Nutrition Status Valuation](image)

Figure 1. Flowchart of Toddler’s Nutrition Status Valuation
3.1. Gathering Data  
Data in this research uses the data gathered from Clinic Silalas, West Medan 2014. Toddler’s data needed for this research include height, weight, age accordingly to the gender, either boy or girl. Toddler’s Nutrition status is specified by Minister of Health No.1995/MENKES/SK/XII/2010 about Anthropometry standard. Valuation divided into 4 category, such as; extra nutrition, good nutrition, less nutrition and poor nutrition (Dr. Lanny Lestiani S., Sp.GK as Nutrition Specialist at Medistra Hospital Medan).

3.2. Fuzzy Sugeno Method  
Fuzzy Sugeno method used for the assessment of nutritional status can be done in three stages:
1. Fuzzyfication is a process where input data tend to be certain (crips input) into the Fuzzy input. On this research, used Fuzzy variable include age, weight, height and head diameter and body mass index and also gender. Age variable divided into 5 types such as; Phase1, Phase2, Phase3, Phase4, and Phase5. Weight variable according to gender divided into 3 such as; Light, Medium and Heavy. But height variable according to gender divided into 3 such as; Short, Medium and Tall. And body mass index divided into 3 types such as; Skinny, Medium and Fat (Dr. Lanny Lestiani S., Sp.GK as Nutrition Specialist at Medistra Hospital Medan).

2. Inference Process  
Next, based on Fuzzy resulted on toddler’s nutrition status, the total indicator used on this method total 145 rules. The result of this Fuzzy rule been consulted with Dr. Lanny Lestiani S., Sp.GK as Nutrition Specialist at Medistra Hospital Medan. But nutrition status for toddler can be determined according to nutrition status such as:
a. Bad nutrition, if nutrition less than 49 (<49).
b. Less nutrition, if nutrition less than 53 and bigger than 49 (49<nutrition value<60).
c. Good nutrition, if nutrition less than 70 and bigger than 60 (60<nutrition value<70).
d. Excellent nutrition, if nutrition more than 70 (nutrition value>70).

3. Defuzzyfication using Sugeno can be converted into Fuzzy output to crips with calculation of weighted average with formula as shown Eq. (1):

\[
\text{Output(Crips)} = \frac{\sum (\text{Alpha}) \times \text{(Consequent)}}{\sum \text{Consequent}}
\]   

Where:
Alpha : output parameter of degree member  
Consequent: Number of Consequent

4. RESULTS AND ANALYSIS  
The following will be made comparison testing between Sugeno method and the results obtained by anthropometric table.

4.1. Manual Testing Sugeno Method  
In this stage, the variable input test such as:
- Age : 32  
- Height : 88  
- Weight : 13  
- Head Diameter : 48  
- Gender : Girl  
- Body Mass Index : 16.7872

Before inference needs to be found, the member value degree on each fuzzy variable, such as age as shown Figure 2, body mass index as Figure 3, head diameter as Figure 4, and nutrition as shown Figure 5.
Figure 2. Variable Fuzzy Age

| Variable | Equation |
|----------|----------|
| \( \mu_{\text{PHASE}_1}(32) \) | 0 |
| \( \mu_{\text{PHASE}_2}(32) \) | 0 |
| \( \mu_{\text{PHASE}_3}(32) \) | \( \frac{36 - 32}{36 - 24} = 0.3333 \) |
| \( \mu_{\text{PHASE}_4}(32) \) | \( \frac{32 - 24}{36 - 24} = 0.6667 \) |
| \( \mu_{\text{PHASE}_5}(32) \) | 0 |

Figure 3. Variable Fuzzy Body Mass Index

| Variable | Equation |
|----------|----------|
| BMI | \( \frac{BB}{(\frac{TB}{100}) \times (\frac{TB}{100})} \) |
| | \( = \frac{13}{(\frac{88}{100}) \times (\frac{88}{100})} \) |
| | \( = 16.7872 \) |
| \( \mu_{\text{SKINNY}(16.7872)} \) | 0 |
| \( \mu_{\text{OVERWEIGHT}(16.7872)} \) | \( \frac{17 - 16.7872}{17 - 15.5} \) |
| | \( = 0.1419 \) |
| \( \mu_{\text{NORMAL}(16.7872)} \) | \( \frac{16.7872 - 15.5}{17 - 15.5} \) |
| | \( = 0.8581 \) |

Figure 4. Variable Fuzzy Head Diameter
Head Diameter
\[ \mu_{\text{SMALL}}(48) = \frac{(48,25 - 48)}{(48,25 - 46,75)} = 0,1667 \]
\[ \mu_{\text{MEDIUM}}(48) = \frac{(48 - 46,75)}{(48,25 - 46,75)} = 0,8333 \]
\[ \mu_{\text{BIG}}(48) = 0 \]

After get a function on each member variable then the next step is to form the rule and weight by using defuzzification using Sugeno method.

**Connected Rule**

[R1] IF Age=PHASE 3 AND HeadDiameter= SMALL AND BMI=NORMAL THEN Nutrition=MEDIUM
\[ \alpha \text{-predicate} = \min( \mu_{\text{PHASE}(32)}, \mu_{\text{SMALL}}(48), \mu_{\text{NORMAL}}(16,7872)) = \min(0, 3333; 0,1667; 0,1419) = 0,1419 \]

[R2] IF Age=PHASE 3 AND HeadDiameter= SMALL AND BMI=OVERWEIGHT THEN Nutrition=EXTRA
\[ \alpha \text{-predicate} = \min( \mu_{\text{PHASE}(32)}, \mu_{\text{SMALL}}(48), \mu_{\text{OVERWEIGHT}}(16,7872)) = \min(0, 3333; 0,1667; 0,8581) = 0,1667 \]

[R3] IF Age=PHASE 3 AND HeadDiameter= MEDIUM AND BMI=NORMAL THEN Nutrition=GOOD
\[ \alpha \text{-predicate} = \min( \mu_{\text{PHASE}(32)}, \mu_{\text{MEDIUM}}(48), \mu_{\text{NORMAL}}(16,7872)) = \min(0, 3333; 0,8333; 0,1419) = 0,1419 \]

[R4] IF Age=PHASE 3 AND HeadDiameter= MEDIUM AND BMI=OVERWEIGHT THEN Nutrition=GOOD
\[ \alpha \text{-predicate} = \min( \mu_{\text{PHASE}(32)}, \mu_{\text{MEDIUM}}(48), \mu_{\text{OVERWEIGHT}}(16,7872)) = \min(0, 3333; 0,8333; 0,8581) = 0,3333 \]

[R5] IF Age=PHASE 4 AND HeadDiameter= SMALL AND BMI=NORMAL THEN Nutrition=MEDIUM
\[ \alpha \text{-predicate} = \min( \mu_{\text{PHASE}(32)}, \mu_{\text{SMALL}}(48), \mu_{\text{NORMAL}}(16,7872)) = \min(0, 6667; 0,1667; 0,1419) = 0,1419 \]

[R6] IF Age=PHASE 4 AND HeadDiameter= SMALL AND BMI=OVERWEIGHT THEN Nutrition=EXTRA
\[ \alpha \text{-predicate} = \min( \mu_{\text{PHASE}(32)}, \mu_{\text{SMALL}}(48), \mu_{\text{OVERWEIGHT}}(16,7872)) = \min(0, 6667; 0,1667; 0,8581) = 0,1667 \]

[R7] IF Age=PHASE 4 AND HeadDiameter= MEDIUM AND BMI=NORMAL THEN Nutrition=GOOD
\[ \alpha \text{-predicate} = \min( \mu_{\text{PHASE}(32)}, \mu_{\text{MEDIUM}}(48), \mu_{\text{NORMAL}}(16,7872)) = \min(0, 6667; 0,8333; 0,1419) = 0,1419 \]

[R8] IF Age=PHASE 4 AND HeadDiameter= MEDIUM AND BMI=OVERWEIGHT THEN Nutrition=GOOD
\[ \alpha \text{-predicate} = \min( \mu_{\text{PHASE}(32)}, \mu_{\text{MEDIUM}}(48), \mu_{\text{OVERWEIGHT}}(16,7872)) = \min(0, 6667; 0,8333; 0,8581) = 0,6667 \]

**Determine maximum value on nutrition**

Worst = 0
Less = 0
Medium = max(0,1419; 0,1419) = 0, 1419
Good = max(0,1419; 0,3333; 0,1419; 0,6667) = 0, 6667
More = max(0,1667; 0,1667) = 0, 1667

\[ Z = (0 x 43) + (0 x 49) + (0,1419 x 53) + (0,6667 x 60) + (0,1667 x 70) + 0 + 0 + 0,3333 + 0,6667 + 0,1667 \]
\[ = 59,1917 \]
\[ 0,9753 \]
\[ = 60,6907 \]
From the calculation above, 32 months toddler with height 88cm, weight 13kg and Head Diameter 48cm has a good nutrition. The nutrition value 60,6907.

![Figure 5. Variable Fuzzy Nutrition](image)

From the Figures 2-5, the fuzzy sugeno can be determined to be 60,6907, which is on a GOOD value.

4.2. Test Based on Anthropometry

In this stage, variable test input such as:

- Age: 32
- Height: 88
- Weight: 13
- Head Diameter: 48
- Gender: Girl

Weight / Age

\[ Z_1 = \frac{(13 - 13.1)}{(13.1 - 11.6)} \]
\[ = \frac{-0.1}{1.5} \]
\[ = -0.06667 \]

Weight / Height

\[ Z_2 = \frac{(13 - 12.1)}{(13.3 - 12.1)} \]
\[ = \frac{0.9}{1.2} \]
\[ = 0.75 \]

Height Diameter / Age

\[ Z_3 = \frac{(48 - 48.25)}{(48.25 - 46.75)} \]
\[ = \frac{-0.25}{1.5} \]
\[ = -0.16667 \]

\[ Z = \frac{(Z_1 + Z_2 + Z_3)}{3} \]
\[ = \frac{-0.06667 + 0.75 - 0.16667}{3} \]
\[ = 0.172222 \]

From the calculation above, test based on anthropology resulted 0.172222. This value is a GOOD value which between -1 and 1 according to anthropology.

4.3. Evaluation System Result

Parameter will be filled with manual calculation such as:

- Age: 8
- Height: 65
- Weight: 9
- Head Diameter: 45

Filling on the nutrition status such as:
Worst : 43
Less : 49
Medium : 53
Good : 60
More : 70

Table 1. Category Toddler’s Nutrition

| No. | Evaluation Result | Result |
|-----|-------------------|--------|
| 1   | 43 – 48           | WORST  |
| 2   | 49 – 52           | LESS   |
| 3   | 53 – 58           | MEDIUM |
| 4   | 60 – 69           | GOOD   |
| 5   | 70 above          | MORE   |

Table 1 is toddler’s nutrition category table, which shows the range evaluation result to determine the nutrition status. For example; Evaluation between 43-48 has a worst nutrition status, 49-52 has a less nutrition status, 53-58 has a medium nutrition status, 60-69 has a good nutrition status and evaluation more than 69 has an excellent or great nutrition status.

Input onto the system:

Figure 6. Calculation from Fuzzy Sugeno
After test on this system, the result shows the same as manual calculation. So this system program can prove the accuracy between system calculation and manual. The result can be seen on figure 6, the result from fuzzy sugeno method on toddler’s nutrition is 60,6907 (Good Nutrition).

4.4. Comparison Result between Clinic (Manual) with Sugeno Application

Table 2 shows the comparison evaluation result between data from clinic and fuzzy calculation using fuzzy sugeno method.

| No | Toddler Name | Age  | Date of Birth | Weight | Height | Head Diameter | Anthropometry | Nutrition Status | Sugeno Result | Nutrition Status |
|----|--------------|------|---------------|--------|--------|---------------|---------------|-----------------|---------------|----------------|
| 1  | Marisa       | 36   | 29/03/2013    | 13     | 94     | 48            | 0.47          | Good            | 53,175       | Medium         |
| 2  | Ting-ting    | 24   | 18/03/2014    | 12     | 87     | 47            | 0.15          | Good            | 63,333       | Good           |
| 3  | Kalista      | 30   | 29/09/2013    | 13     | 88     | 48            | 0.31          | Good            | 60,833       | Good           |
| 4  | Rachael      | 26   | 23/01/2014    | 13     | 87     | 48            | 0.70          | Good            | 63,333       | Good           |
| 5  | Affiniriki   | 28   | 10/12/2013    | 12     | 89     | 48            | 0.70          | Good            | 55,434       | Medium         |
| 6  | Federick     | 7    | 23/08/2015    | 10     | 68     | 45            | 1.85          | Medium         | 61,376       | Good           |
| 7  | Cyntia       | 20   | 08/08/2014    | 12     | 86     | 48            | 0.80          | Good            | 64,833       | Good           |
| 8  | Filbert      | 2    | 23/01/2016    | 5.5    | 61     | 42            | 0.42          | Good            | 56,644       | Medium         |
| 9  | hosea        | 49   | 26/03/2012    | 18     | 112    | 51            | 0.09          | Good            | 54,631       | Medium         |
| 10 | Cindy        | 54   | 15/10/2011    | 14     | 97     | 49            | 0.74          | Good            | 54,005       | Medium         |
| 11 | Kent         | 49   | 12/01/2012    | 18     | 95     | 49            | 0.99          | Good            | 65,605       | Good           |
| 12 | Sese         | 49   | 27/02/2012    | 14     | 95     | 48            | 0.70          | Good            | 53,143       | Medium         |
| 13 | Aurel        | 44   | 18/08/2012    | 12     | 96     | 48            | 1.44          | Medium         | 50,333       | Less           |
| 14 | Cesilia      | 42   | 11/10/2012    | 15     | 99     | 50            | 0.29          | Good            | 58,553       | Medium         |
| 15 | Vorencia     | 35   | 16/05/2013    | 15     | 97     | 50            | 0.77          | Good            | 62,947       | Good           |
| 16 | Hubert       | 44   | 24/10/2012    | 14     | 93     | 48            | 0.62          | Good            | 60,784       | Good           |
| 17 | Gerrison     | 50   | 27/04/2012    | 13     | 97     | 50            | 0.93          | Good            | 53,0         | Medium         |
| 18 | Chelsea      | 56   | 30/10/2011    | 14     | 109    | 49            | 1.55          | Medium         | 53,0         | Medium         |
| 19 | Rihanna      | 43   | 23/01/2014    | 13     | 94     | 48            | 1.53          | Medium         | 50,901       | Less           |
| 20 | Andre        | 57   | 30/09/2011    | 18     | 110    | 52            | 0.25          | Good            | 57,088       | Medium         |
| 21 | Michael      | 38   | 22/04/2013    | 12     | 91     | 48            | 1.30          | Medium         | 50,309       | Less           |
| 22 | andrian      | 42   | 23/12/2012    | 13     | 93     | 48            | 0.69          | Good            | 51,460       | medium         |
| 23 | Agung        | 44   | 24/10/2012    | 13     | 95     | 49            | 1.03          | Medium         | 52,720       | Less           |
| 24 | Muhammad     | 47   | 26/07/2011    | 13     | 91     | 50            | 0.65          | Good            | 60,814       | Good           |
| 25 | Agus salim   | 36   | 21/06/2013    | 14     | 97     | 49            | 0.34          | Good            | 54,005       | Medium         |
| 26 | Farel        | 54   | 29/12/2012    | 14     | 102    | 48            | 1.61          | Medium         | 49,0         | Less           |
| 27 | Steveny      | 49   | 27/05/2012    | 14     | 95     | 50            | 0.17          | Good            | 60,089       | Good           |
| 28 | Junita       | 37   | 22/05/2013    | 12     | 96     | 48            | 1.14          | Medium         | 50,333       | Medium         |
| 29 | Darliana     | 59   | 01/08/2011    | 19     | 114    | 51            | 0.17          | Good            | 55,892       | Medium         |
| 30 | Ferdinand    | 52   | 27/02/2012    | 16     | 100    | 50            | 0.12          | Good            | 60,069       | Good           |

4.5. Comparison Evaluation Result

Evaluation result gathered from clinic uses the anthropometry table to get deviation standard value of toddler’s nutrition quality. In this evaluation, the clinic uses 3 variables such as; weight, height and head diameter. Each variable connect to each other to get a comparison result of toddler’s nutrition quality based
on the variable used. Result on -1 and 1 deviation standard is Good to Medium according to fuzzy sugeno method calculation. This happen because the parameter variable is the input of fuzzy sugeno. To be more detail e, 30 samples are tested to prove the toddler’s nutrition. According to the evaluation, there’re 12 toddlers have a same result, Good Nutrition. From the 30 data, there’s 40% toddler’s data has a same output, and the other data result resemble to each other. As an example according to anthropometry, calculation resulted -1.61 where the category near less and according to sugeno calculation resulted 49 where this value number resulted worst.

Gathered outcome has each criteria based on calculation input. This calculation proves that parameter has a different calculation, eventhough different, nutrition status resemble to each other.

5. CONCLUSION

The evaluation application and comparing toddler’s nutrition survey at clinic and manual calculation with growth graphic involve 30 toddlers are conducted in this research. The category group toddler’s nutrition uses 4 categories; worst, less, medium, good. Sugeno uses 5 categories; worst, less, medium, good and excellent so Fuzzy Sugeno method has a high accuracy to determine the calculation of Age, Body Mass Index and Head Diameter. The result value of Fuzzy Sugeno is near to ideal value and same as manual method.

Calculation result does not always shows the same result because of the different method used. Even though different method used, the result value almost the same. So, fuzzy sugeno method can be an alternative method to increase the nutrition needed or the check the result on which part need to be improve for toddler’s nutrition. The result can be used to decide the daily food consumption for toddler so that the nutrition value is excellent. This method can be used to check on toddler’s growth on weight, height and head diameter.

REFERENCES

[1] Muljono, “Using Fuzzy Sugeno Method To Determine Toddler’s Nutrition Status. Techno.COM”, Volume 10 No 3, pp. 127-136, Mar 2011.
[2] Kusumadewi. Analysis Desain Sistem Fuzzy Using Tool Box Matlab. Yogyakarta: Andi, 2002.
[3] Nungki Fidianotoro, & Tedy Setiadi. Model Determine Toddler’s Nutrition Status In Clinic. Journal Bachelor Technic Information, Volume 1 No 1, pp. 367-373, Juni 2013.
[4] Buisson, J. C. Nutri- Educ, A Nutrition Software Application For Balancing Meals, Using Fuzzy Arithmetic Andheuristic Searc Algorithms. Artificial Intelligence in Medicine, Volume 1 No 1, pp. 213-227, 2008.
[5] Josua M. Kreebez, & Adnan Shabout. Fuzzy Nutrition System. International Journal of Innovative Research in Computer and Communication, Volume 1 Issue 7, pp. 1360-1371, September 2013.
[6] Heinonen, P., Mannelin, M., Iskala, H., Sorsa, A., & Juuso, E. Development of a Fuzzy Expert System for a Nutritional Guidance Application. IFSA-EUSFLAT, pp. 1685-1690, 2009, http://www.eusflat.org/proceedings/IFSA-EUSFLAT_2009/pdf/itema_1685.pdf
[7] Sudirman, Nerfita Nikentari, S., & Martaleli Bettiza, S. Analysis Classification Nutrition Status with Fuzzy C-Mean method using application based on Android. Technic Faculty UMRAH, pp. 1-9, 2013, http://journal.umrah.ac.id/wp-content/uploads/2013/08/Sudirman-090155201022.pdf
[8] Prasetio, T., Martiana, E., & Mubtada’i, N. R. Application To Diagnose Nutrition On Toddler With The Calories Needed Using Fuzzy Sugeno Method, 2001. https://www.pens.ac.id/uploadta/downloadmk.php?id=1484