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Procedia Technology 11 (2013) 1244 – 1251

Procedia Technology

The 4th International Conference on Electrical Engineering and Informatics (ICEEI 2013)

Nutritional Needs Recommendation Based on Fuzzy Logic

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Abstract

People have daily optimal energy needs, and most people careless about food's calories suitability for their health, because usually people do not calculate food's calories they want to eat. Fuzzy logic has the ability to model this problem, in the way helping people to calculate suitability between food calories and user's profile. The inference models that are used in this work are TSK to assess daily calories need, and Tsukamoto to assess calorie which is contained in food which has inconsistency in calorie information. The conclusion is that calorie need problem can be modelled using fuzzy inference model and satisfied calorie value range.

Keywords: fuzzy logic, fuzzy inference model, calories assessment, food calories, Takagi Sugeno Kang, Tsukamoto

1. Introduction

Everyone needs certain amount of nutrition daily in order to preserve the healthiness state. Unfortunately, sometimes people forget to pay attention on their daily nutritional intake. This behavior often leads to health disorder such as overweight, obese, or malnutrition. As an example, 7.2% Indonesian male categorized as overweight, and 10.4% for female [1]. From this point, there is a need to have convenient way to keep monitor daily calories intake.

The easiest way to measure calories from a food is to take a look at nutrition fact which is usually printed on the food package. On the other hand, there are food with no package such as restaurant or homemade food. The fact for

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doi:10.1016/j.protcy.2013.12.320

this unlabeled food is that the calories information can be various between one to another. From this situation, there is also a need to assess food information from the value of uncertainty and inconsistency of calorie information. Fortunately, few soft computing models are developed within fuzzy set theory [2], such as Takagi Sugeno Kang (TSK) and Tsukamoto. This research apply TSK fuzzy inference system (FIS) order 1 to give daily calorie needs assessment, then combined with Tsukamoto FIS to assess food calorie from unlabeled food. With these two assessments, ones can decide whether food's calories that are about to eat are suitable for their health or not. This fuzzy system uses Android operating system in smart phone. The consideration to use smart phone is because the using of smart phone is growing so rapidly. Nielsen researched that smart phone user in Indonesia reached 19% from all of smart phone user in 2012 [3]. This condition described that a lot of people using Android, so that this condition can give advantages in the way that system can be used widely.

Nomenclature

x	crisp value of a domain in fuzzy variable
$\mu(x)$, α	membership degree from x crisp value
Z	defuzzy fication result with crispvalue

2. Theories and Terminologies

2.1. Measuring Daily Calories

Calorie is used as a measurement for energy unit. Calorie is often used to measure energy which is contained in food in Kcal (kilo calories) unit. People has minimum calorie need called basal metabolic rate, or often called BMR. BMR is affected by body surface area, sex, blood circulation, and other internal body activities. Standard of BMR is 1 calorie per kilogram body weight per hour (1 Cal/kg/hour).

Daily calories need which is mentioned before can be various between one people to another. This daily calories depend on someone's physiological condition. Those physiological are sex, weight and height. Daily calories can be measured by knowing the following [5]:

2.1.1. Body Mass Index (BMI)

Body mass index is usually used to categorize whether people is skinny, normal, overweight, or obese. These BMI can be yielded with following equation:

$$BMI = (Body\ Weight\ (Kg))/(Height\ (meter)^2) \tag{1}$$

2.1.2. BMI Categories

To categorize whether someone is skinny, normal, or overweight, it can use BMI formula as mentioned in (1), then the result is compared to the threshold in Table 1.

Table 1. Body Mass Index Threshold

Status	Category	Threshold
Skinny	High level of malnutrition	< 17,00
Thin	Low level of malnutrition	17,00 – 18,50
Normal	Ideal	>18,50 – 25,00
Overweight	Low level of overweight	> 25,00 – 27,00
Obesity	High level of overweight	> 27,00

2.1.3. Ideal Body Weight

Ideal body weight also become one parameter to obtain daily calories need. Ideal body weight can be measured with equation (2). Ideal BMI can be seen on Table 1 which state normal status.

$$Ideal\ Body\ Weight = (Height(meter))^2 \ \times ideal\ BMI \tag{2}$$

2.1.4. Basal Metabolic Rate (BMR)

Having ideal body weight, basal metabolic rate can be obtained with following equation:

$$BMR = 1\ Kcal\ \times Ideal\ Body\ Weight\ \times 24 \tag{3}$$

2.1.5. Measuring Daily Energy

Daily energy can be measured as described in equation (4). Where physical activity value can be seen on Table 2, and weight adjustment is a constant that has a value of (-500) when people want to reduce body weight, (+500) when people want to increase body weight, and (0) when people want to preserve current body weight.

$$Daily\ Calories = Physical\ activity\ \times BMR + Weight\ adjustment \tag{4}$$

Table 2. Activity Level

Activity	Male	Female
Very Light	1,30	1,30
Light	1,65	1,55
Moderate	1,76	1,70
Heavy	2,10	2,00

2.2. Fuzzy Logic

Fuzzy logic is a concept that is improvement from Boolean / crisp logic whose set does not use {0, 1} but [0, 1], if the set member is represented by real number between 0 and 1. The following section will describe about theory and terminologies in fuzzy logic. [6]

2.2.1. Membership Function

Membership function shows a degree of membership in a variable. For example, a boy with age of 15 years old can be has a membership degree of 0.4 in domain of children, and in the same time, age of 15 years old can also be has a membership degree of 0.2 in domain of adult. Membership has value between 0 and 1, and can be yield from curve representations. In this work, there are three representations which are used to obtain membership degree. They are linear increase, linear decrease, and triangle representation. One crisp value is mapped to one membership degree.

2.2.2. Linear Increase Representation

This representation describes as a line which escalates from value of 0 until maximum reach 1 on the axis that represents membership value, and can be written as:

$$\mu(x) = \begin{cases} 0\,;\ x \le a \\ \frac{(x-a)}{(b-a)}\,;a < x \le b \end{cases} \tag{5}$$

2.2.3. Linear Decrease Representation

This representation describes as a line that decline from maximum value of 1 until reach 0 on the axis that represent membership value, and can be written as:

$$\mu(x) = \begin{cases} \frac{(b-x)}{(b-a)}\,;a \le x < b \\ 0\,;\ x \ge b \end{cases} \tag{6}$$

2.2.4. Triangle Representation

Basically, triangle representation is an escalating and declining linear curve in one curve, and written on equation (7), where a is a left limit value, and b is a right limit value.

$$\mu(x) = \begin{cases} 0\,;x < a\ dan\ x \ge c \\ \frac{(x-a)}{(b-a)}\,;a < x \le b \\ \frac{(c-x)}{(c-b)}\,;\ b < x < c \end{cases} \tag{7}$$

2.2.5. Fuzzy Inference System (FIS) Model

Generally, flow from Fuzzy Inference System is a set of input, *fuzzyfication*, inference, *deffuzyfication*, then get the output, as described in Fig. 1. Fuzzy inference models which are used in this work are Takagi-Sugeno-Kang (TSK) and Tsukamoto.

TSK model is a fuzzy inference system which uses mathematical equation as a consequent:

$$IF\ (X_1\ IS\ A_{1i}\ \bullet\ X_2\ IS\ A_{2i}\ \bullet \ldots \bullet\ X_m\ IS\ A_{mi})\ THEN\ y_i = g_i(X_1, X_2, \ldots, X_3) \tag{8}$$

Symbol • noted operation such as AND or OR. Basically, this TSK model has two models; they are order-0 and order-1. For TSK FIS model order-0, $g_i(X_1, X_2, \ldots, X_3)$ which is stated in the consequent, is in order-0 form, such as $y_i = k$ where k is a constant. While order-1 is in order-1 form, such that $y_i = \mathrm{a_{0i}} + \mathrm{a_{1i}x_1} + \mathrm{a_{2i}x_2} + \ldots + \mathrm{a_{mi}x_m}$.

Defuzzyfication method that is used in TSK is called weighted average, and can be written as:

$$Z_0 = \frac{\sum_{i=1}^{n} \mu(x)_i . Z_i}{\sum_{i=1}^{n} \mu(x)_i} \tag{9}$$

While Tsukamoto FIS has implication form as following:

$$IF\ (X_1\ IS\ A_{1i}\ \bullet\ X_2\ IS\ A_{2i}\ \bullet \ldots \bullet\ X_m\ IS\ A_{mi})\ THEN\ (Y_1\ IS\ K_{1i}\ \bullet\ Y_2\ IS\ K_{2i}\ \bullet \ldots \bullet\ Y_m\ IS\ K_{mi}) \tag{10}$$

Where Y_m is a consequent variable, and K_{mi} is variable's value in natural language. *Defuzzyfication* method that is used in Tsukamoto FIS also using weighted average which is written on equation (9).

3. Daily Calorie Need Calculation and Food Calorie Assessment Methods

To obtain daily calorie need and calorie assessment can be calculated as described in Fig. 2 at Appendix A. Detailed information about this Fig. 2 is explained in 3.1 and 3.2.

3.1. Input User Profile and Food Choice

The proposed model has several steps to follow in order to obtain daily calorie needs and food calorie assessment. The first step is by entering user profile. User profile defined as user's body weight, height, age, and sex. This user profile is used as parameters to perform first fuzzy using TSK to obtain daily calorie needs. This daily calorie needs take a part as a reference to decide whether food's calorie which will be eaten is suitable or not.

Food's choice is used to obtain calorie assessment for all of the food which will be eaten by user. As mentioned in introduction, the value of calorie of one particular food can be so various. Thus, fuzzy logic models those varieties or inconsistency. Fuzzy logic in this system gets maximum and minimum value of carbohydrates, proteins, fats, and calories of each food's choice from database, then *fuzzyfy* it. Then, the *fuzzyfied* value is stored in system as a fuzzy set.

3.2. Inference and Output Recommendation

Inference process is a step to combine fuzzy domain from each rule in system. There are two famous ways to combine those domains, or often called implication function; they are product and maximum method. Product method is a method to find proportion of a fuzzy domain using dot product. Meanwhile, maximum method is simply adds every fuzzy domain. Since FIS that are used in this method are TSK and Tsukamoto, the method that is used is the maximum one; because weighted average calculates maximum fuzzy domains. To further clarify this calculation, there will be given an example of using fuzzy logic to yield recommendation in the following part.

Assumed a man named X has the following profile:

- Height : 170 cm = 1.7 meters
- Weight : 51 kilo grams
- Sex : male
- Age : 22 years old

The food that X wants to eat is a fried chicken which has 660 kcal, and contains 100 grams of carbohydrate, 20 grams of protein, and 20 grams of fat, as mentioned in Department of Health in Indonesia. From existing database, fried chicken has maximum calorie value of 690 kcal, 25 grams of fat, 20 grams of protein, and 140 grams of carbohydrate; meanwhile the minimum value of calorie is 640 kcal, 15 grams of fat, 20 grams of protein, and 90 grams of carbohydrate. Assumed there are two rules in the system as follows:

[R1A] IF age = "adult" AND bmi_category = "thin" THEN recommendation = 1 x (Height x Height x 19.0) x 24 x 1.65 + 500

[R2A] IF age = "adult" AND bmi_category = "normal" THEN recommendation = 1 x (Height x Height x 21.0) x 24 x 1.65

[R1B] IF carbohydrate = "high" AND protein = "medium" AND fat = "high" THEN calories = "high"

[R2B] IF carbohydrate = "low" AND protein = "low" AND fat = "medium" THEN calories = "medium"

First, this calculation needs BMI value to obtain categories as mentioned in equation (1). BMI = $51 / (1.7)^2 \approx 17.65$ which is categorized as thin. Next step for this case is calculating daily calorie needs by referring to R1A and R2A. From those rules above, can be obtained daily calorie needs as describes in Fig. 3 at Appendix A. Where a_1 is a membership degree for adult, a_2 is for BMI categories, and z is a consequent value with corresponding equation each rule. Following section will calculate membership degree and consequent values from each rule.

- Rule 1 A

$$\alpha_1 = \min\{\mu(x_1), \mu(x_2)\}$$
$$\alpha_1 = \min\left\{\frac{30-22}{30-13}, \frac{18-17.65}{18-15}\right\}$$
$$\alpha_1 = \min\{0.47, 0.12\} = 0.12$$

$$Z_1 = 1 \times height^2 \times 19 \times 24 \times 1.65 + 500$$
$$Z_1 = 1 \times 1.7^2 \times 19 \times 24 \times 1.65 + 500$$
$$Z_1 \approx 2674.44$$

- Rule 2 A

$$\alpha_2 = \min\{\mu(x_1), \mu(x_2)\}$$
$$\alpha_2 = \min\left\{\frac{30-22}{30-13}, \frac{17.65-17}{20.5-17.65}\right\}$$
$$\alpha_2 = \min\{0.47, 0.23\} = 0.23$$

$$Z_2 = 1 \times height^2 \times 21 \times 24 \times 1.65$$
$$Z_2 = 1 \times 1.7^2 \times 21 \times 24 \times 1.65 \approx 2403.32$$

The next step is *defuzzyfy* using weighted average as mentioned in equation (9).

$$Z_0 = \frac{\sum_{i=1}^{2} \alpha_i . Z_i}{\sum_{i=1}^{2} \alpha_i} = \frac{0.12 \times 2674.44 + 0.23 \times 2403.32}{0.12 + 0.32} \approx 1985.67$$

So, in one day, X needs 1985.67 kcal to fulfill his calories need. Then, the next step is to calculate calories of fried chicken, and can be described in Fig. 4 at Appendix A.
The next step is to *defuzzyfy* using weighted average as mentioned on (9).

$$Z_0 = \frac{\sum_{i=1}^{2} \alpha_i . Z_i}{\sum_{i=1}^{2} \alpha_i} = \frac{0.20 \times 650 + 0.20 \times 663}{0.20 + 0.20} = 656.5$$

From calculation above, the estimation of the total calories of fried chicken is 656.5 kcal. From this point, this food calorie can be compared with daily calorie needs as a reference whether food calorie is suitable for X's need or not.

4. Related, Future Work, and Recommendation

There are several related works to this fuzzy logic application. One of them is a research that has been done by Sri Kusumadewi, originally titled "Sistem Inferensi Fuzzy (Metode TSK) Untuk Penentuan Kebutuhan Kalori Harian" [1], or Fuzzy Inference System (TSK Method) to Determine Daily Calories Need. The output of the system is a real number which is represents people's daily calories need using fuzzy logic.

Suggestion for future of this system is that fuzzy logic can be combined with neural network and genetic algorithm in order to get system more adaptive [4].

5. Conclusion

- Fuzzy logic can be used to model information inconsistency in food calorie and assessing daily calorie needs
- Fuzzy logic is a method which obtain a value that is acceptable in a predicted range
- Tsukamoto model can effectively assess food calories

Appendix A. List of Figures

A.1. Fuzzy Step Model

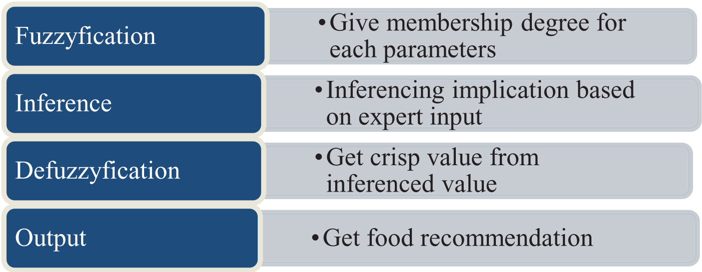

Fig. 1. Fuzzy Inference Model

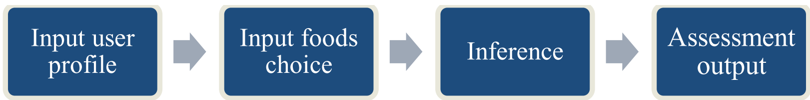

Fig. 2. Recommendation Calculation Method

A.2. Fuzzyfications and Inferences

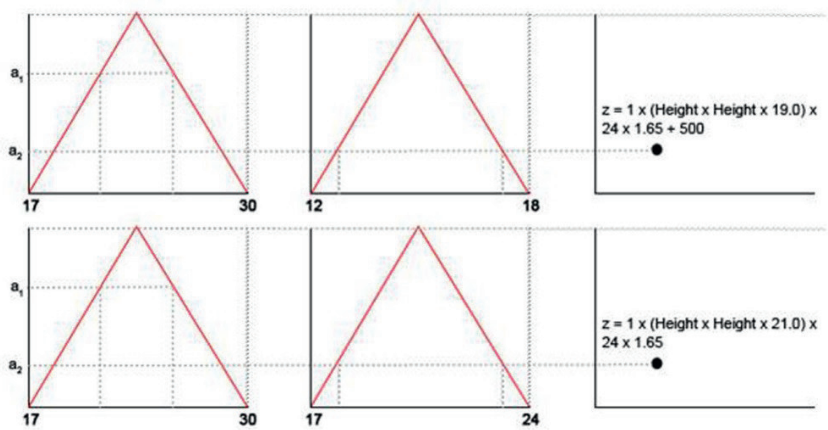

Fig. 3. Fuzzyfication and inference to obtain daily calorie needs

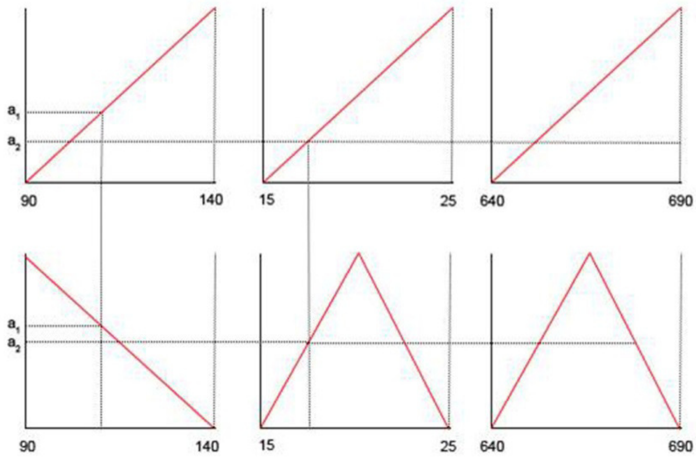

Fig. 4. Fuzzyfication and inference to obtain food calorie assessment

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