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Proposal of Well-Balanced Menu Planning by Using Fuzzy Mathematical Programming and Rough Set Theory

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Abstract— This paper addresses an well-balanced menu planning by using fuzzy mathematical programming and rough set theory. Recently, lifestyle-related disease has been assumed as a critical problem in Japan. The cause of this problem has been considered to be westernization of eating habit, nutritional imbalance and shortage of exercise. Now Japanese government has cared about this social situation, so some public health measures have been established and various researches about nutritional information and dietary balance have appeared which expects the effect of health. In this paper, well-balanced menus corresponding to each user's favorite are obtained by the rough set theory. On rough set procedure, some invisible elements are visualized by our rough set model i.e., it takes notice of the visualization of nutritional information which hid behind a user's favorite. Each user's characteristic is grasped by rough set and effective menus for each user are presented. Here one menu consists of one or more dishes with various diets, and this combination is given by the rough set. All dishes have some information, including affinity with cooking, various groups, and etc. After filling all constraints, such as the affinity of cooking, and group composition, well-balanced menus are introduced. About menu planning, this paper gives the fuzzy mathematical programming. After filling constraints such as the affinity of cooking, and the group composition, the well-balanced menus to take more nutrients are created.

Index Terms— **Information System, Fuzzy Mathematical Programming, Lifestyle- Related Disease, Well-Balanced Menu Planning, Rough Set**

I. Introduction

Recently, disorder of eating habits is serious problem in Japan. The number of the patients afflicted by lifestyle-related diseases has increased. Actually, it is said that about 80% of Japanese population older than thirties are Infected by a diseases associated with adult lifestyle habits, or are likely to get so. The deviation of nutrition, skipping a meal, etc. become remarkable by the flood of the information about diversification of a life style, the increase in a single-person household, and a meal etc., and hyper-trophy, undernutrition, overweight, and lose weight pose a problem. And the increase in a lifestyle-related disease etc. poses a problem as a result. In other words, improvement of lifestyle habit prevents these diseases from progressing. One of the typical causes of the diseases is food balance. To improve eating habits (alimentary therapy), knowledge of medicine and nutrition is required because it is very important to keep a daily calorie count and to get a balanced meal. There are many studies which are focused on health care and fuzzy database [1]-[2], and Database for using open source software [3]. For example, there are a system which interlocked the cooking recipe and the food composition value closely, a system which creates the menu which was able to take the optimal nutritional balance [4], and A system to estimate rice volume and a nutrition management system using mobile camera phones to guide subjects to improve eating habits by elucidating their dietary life-styles [5]. However, it stopped by the system which only totals the food composition value which each adopted about ingredient worth of each food. Moreover, decision-making of choosing the food which he wants to eat was not taken into consideration [6]. None of them developed functions to assist planning balanced healthy meals. And it is very difficult for a user to continue selected eating habits. Therefore, after taking a user's intention into consideration, we should consider the meal with which nutrition is filled.

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II. Well-Balanced Menu Planning

A. Lifestyle- Related Disease

Lifestyle-related disease is a generic description that covers such world-wide illnesses as cancer, heart disease and cerebrovascular disease. Those diseases are called lifestyle-related because they are closely tied to our daily habits. Lifestyle-related diseases are becoming increasingly common worldwide, involving in the metabolic syndrome.

Metabolic syndrome is a combination of medical disorders that increase the risk of developing cardiovascular disease and diabetes. It affects a large number of people, and prevalence increases with age. Metabolic syndrome is now hot topic in many academic communities. It is a common health problem in industrialized countries. Adipose tissue is currently considered not only an energy-storage organ, but also an endocrine organ producing a variety of biologically active molecules, conceptualized as adipocytokine. Obesity is recognized as a important risk factors for metabolic syndrome. Moreover it is closely associated with diseases involving circular organs, such as cardiac infarction and strokes. To prevent these illnesses, we assume that it is necessary to obtain well-balanced diet in our daily life.

B. Well-Balanced Menu Planning

Cooking menus are proposed not only in consideration of a user's taste but in consideration of the balance of nutrition. First, we extract the rule of user's favorite menu. A rough set search for what kind of attribute a user likes a menu with. The rough set theory is used to extract attributes from various-menu information. For example, the information of a fish and Japanese-style food in material is extracted. The information drawn by the rough set is added to the database of a menu. Next, the menu which maintained the balance of nutrition is considered. A menu creates the menu of one degree of obscuration combining a single article dish. It has an attribute value in all the dishes which are the targets of combination. Attribute values are the quantity of a nutrient, affinity with other dishes, various groups, etc. Constraints, such as the affinity of cooking, group composition, and liking of a user, are added. When taking the balance of a nutrient into consideration, it is difficult to coincide the actual amount of nutrition with an ideal place. It is difficult especially when taking two or more nutrients into consideration simultaneously. The feeling "about" is applied to the ideal value of the amount of nutrition. Therefore, the required amount of nutrition is expressed with a fuzzy number. The value of the membership function about each nutrient is taken in to evaluation criteria. In order to take the balance of the whole nutrient into consideration in that case, let maximization of the membership function be an objective function to a nutrient with the lowest evaluation.

III. METHOD TO EXTRACT THE RULE OF A USER'S FAVORITE MENU

A rough set asks for menus with the optimal attribute value from the many menus. The database regarding the expert's know-how is generally given in the form of the information system. The information system is a table showing the attribute value data to many objects. The definition of the traditional information system is given by Pawlak [7]-[9]. We use the theory about rough set, in order to extract the rule of a user's favorite menu. However, such a classification is based on the facts such as noise-free, importance-identical for each example, and error-free for the final rules. Therefore, we use fuzzy rough set model [10]-[12]. It is an uncertain information system to relax the traditional information system.

An uncertain information system (UIS) is defined as follows.

$$USI = (U, C, D, V, \rho, \tilde{W}) \tag{1}$$

Where U is the universe which is a non-empty finite set of objects x; C is a finite condition set of attributes; D is a finite decision set of attributes; $V = \cup_{q \in C \cup D} V_q$, and V_q is the domain of attribute q; ρ is a mapping function such that $\rho(x,q) \in V_q$ for every $q \in C \cup D$ and $x \in U$; $\tilde{W} = \cup_{x \in U} \tilde{w}_x$, and $\tilde{w}_x$ is a fuzzy number defined by membership function $\mu_{\tilde{w}_x} \to [0, 1]$, which assigns each tuple an importance (weight) factor to represents how important (weighty) is for the corresponding decision.

Let E, X be a non-empty elementary set, and a non-empty subset in the approximation space, respectively. It is defined a concept which is called relative degree of classification of the set E with respect to set X as follows:

$$\tilde{c}(E,X) = \frac{\sum_{x \in I} \tilde{w}_x}{\sum_{x \in E} \tilde{w}_x} \tag{2}$$

$$I = E \cap X \tag{3}$$

Two thresholds $\tilde{\beta}_P$, $\tilde{\beta}_N$, which are called positive threshold, negative threshold, respectively define in consideration of admissible level of misclassification, noise, and approximation precision. E is included in X, if $\tilde{c}(E,X) \geq \tilde{\beta}_P$, and E is connected nothing with X, if $\tilde{c}(E,X) \leq \tilde{\beta}_N$. $\underline{apr}_{\tilde{\beta}P}(X)$, $\overline{apr}_{\tilde{\beta}N}(X)$ respectively, are defined as

$$\underline{apr}_{\tilde{\beta}r}(X) = POS_{\tilde{\beta}P}(x) \tag{4}$$

$$\overline{apr}_{\tilde{\beta}N}(X) = U - NEG_{\tilde{\beta}N}(x) \tag{5}$$

Where,

$$POS_{\tilde{\beta}P}(x) = \bigcup\{E \in R_C^* \mid \tilde{c}(E,X) \geq \tilde{\beta}_P\} \tag{6}$$

$$NEG_{\tilde{\beta}N}(X) = \bigcup\{E \in R_C^* \mid \tilde{c}(E,X) \leq \tilde{\beta}_N\}\sqrt{a^2+b^2} \tag{7}$$

$$BND_{\tilde{\beta}P,\tilde{\beta}N}(X) = \bigcup\{E \in R_C^* \mid \tilde{c}(E,X) \geq \tilde{\beta}_P,\} \tag{8}$$

In this way, the accuracy measure of set X in the approximation space A = (U, R) is given by

$$\tilde{\alpha}(x) = \frac{\sum_{x \in \underline{apr}\tilde{\beta}P} \tilde{w}_x}{\sum_{x \in \overline{apr}\tilde{\beta}N} \tilde{w}_x} \tag{9}$$

Example, there is an information system. It is a database about a user's menu. The menus have user's favorites (Table 1). There are 6 menus. And there are three attributes of a menu.

Table1. Menus and User's favorites

	C			D
U	a1	a2	a3	favorite
m1	1	1	1	0(1.0)
m2	1	2	1	1(0.2)
m3	2	2	2	1(0.1)
m4	2	1	2	0(0.6)
m5	2	2	2	1(0.4)
m6	1	2	1	0(0.8)

Table2. Numeric expressed of attributes value.

	Attribute	0	1	2	3
a1	Kind of cooking	Japanese	European	Chinese	other
a2	Main materials	Meat	Fish	vegetable	other
a3	Cooking method	Boil	Burn	Frit	other

In the information system, U = {m1, m2, …, m8} in which each element expresses a menu. A meal is classified with attributes. Attribute set = {a1, a2, a3}. The value of attribute values and a determination values are numerically expressed, in order to make it intelligible (Table2). A expresses the kind of cooking. Japanese-style food is 0, European food is 1, and Chinese food is 2. B classifies the main materials. Meat is 0, fish is 1, and vegetable is 2. C classifies the cooking method. Boil is 0, burn is 1 and frit is 2. Others are 3 in all the items.

Sets of equivalence are as follows.

{{m1}, {m2, m6}, {m3, m5}}

$$\underline{apr}_{\tilde{\beta}P}(X) = \{m3, m5\} \tag{10}$$

$$\overline{apr}_{\tilde{\beta}N}(X) = \{m2, m6\} \tag{11}$$

The menu which has attributes value for the same attributes as lower approximation shows that a determination value is 0 inevitably. Although a determination value cannot certainly say upper approximation in 0, it can say that there is the possibility.

Contraction is a subset of the minimum attribute required since contrast is discriminable. In an example, a menu has three attributes. It comes out from an information table that asking for contraction searches for an important attribute from a user's taste. The method of asking for contraction is as follows. First, the discernment procession which makes a user's taste a determination value is created (Table 3). Since a menu 1 and a menu 2 are different determination values, they are a candidate for discernment. The attribute value from which a menu differs is a2. It is written as {a2}. In order for this meaning to distinguish a menu 1 and a menu 2, it is shown that a of an attribute is required. Next, a menu 1 and a menu 4 are the same determination values. Therefore, since it is the outside for discernment, it is written as "*". Other menus are examined similarly. In it, although a determination value differs between a menu 2 and a menu 6, all attribute values are the same. This is contradictory. The sign ϕ of an empty set is written as like.

Table3. Discernment procession

	m1	m2	m3	m4	m5	m6
m1	*					
m2	{a2}	*				
m3	{a1,a2,a3}	*	*			
m4	*	{a1,a2,a3}	{a1,a2}	*		
m5	{a1,a2,a3}	*	*	{a2}	*	
m6	*	ϕ	{a1,a3}	*	{a1,a3}	*

(a2) ∧ (a1, a2, a3) ∧ (a1, a2, a3) ∧ (a1, a2, a3) ∧ (a1) ∧ (a1, a3) ∧ (a2) ∧ (a1, a3)

A calculation result is (a1 ∧ a2) ∨ (a2 ∧ a3).Therefore, contraction is {a1, a2}, {a2, a3}.

When guessing how a new menu is evaluated by using the view of this contraction, the minimum required attribute can be searched for.

IV. Create the Menu Which Maintained the Balance of Nutrition

The menu is proposed in consideration of the balance of nutrition. The taste of the user chosen by the rough set is also taken into consideration. A solution is calculated for the optimal menu with mathematical programming. The required amount of nutrition is expressed with a fuzzy number. The value of the membership function about each nutrient is taken in to evaluation criteria. The objective function aims at maximization of the membership value of a function about a nutrient with the lowest evaluation. It is shown that a restrictions type is fixed within the limits with that all the affinities of cooking are good and the number of cooking belonging to various groups, respectively.

$$\text{maximize} \quad \lambda \tag{12}$$

$$\text{subject to} \quad 0 \le \lambda \le 1 \tag{13}$$

$$\lambda \le f_k(N_k) \tag{14}$$

$$\prod_{i=2}^{R}\prod_{j=1}^{i} \frac{4 - M_{i,j}(x_i + x_j)\left\{1 + (-1)^{(x_i + x_j)}\right\}}{4} = 1 \tag{15}$$

$$L_h \le \sum_{i=1}^{N} x_i . B_{ih} \le U_h \tag{16}$$

However, It is $x_i \in X'$ when cooking is $x_i = 1$. a1 ∈ A1', a2 ∈ A2', a3 ∈ A3' where R is the number of cooking $(1 \le i, j \le R)$. k is the number of nutrients $(1 \le k \le K)$. H is the number of group $(1 \le h \le H)$. x_i is decision variable. It is 1 if cooking is gone into a menu. It is 0 if it does not go into a menu. M_{ij} is Affinity variable. It is 0 when the affinity of Dish i and Dish j is good. It is 1 when the affinity is bad. B_{ih} is if Dish i belongs to Group h, they will be 1 and a constant which does not belong and which will be set to 0 if it becomes. Q_{ik} is quantity of the nutrient k contained in Dish i. N_k is the intake of the nutrient k expressed with the following formula.

$$N_k = \sum_{i=1}^{R} x_i . Q_{ik} \tag{17}$$

$f_k(N_k)$ is the membership value of a function at the time of the intake to N_k Nutrient k. L_h is the minimum of the number of cooking belonging to Group h. U_h is the maximum of the number of cooking belonging to Group h. X is cooking set. X' is the cooking set which eating today has determined $(X' \subseteq X)$. a1 is expressed kind of cooking Japanese. a2 is expressed main materials meat. a3 is expressed cooking method. A1', A2' and A3' is the value of user's favorite (a1 $\subseteq$ A1', a2 $\subseteq$ A2', a3 $\subseteq$ A3').

The nutrient taken into consideration is taken as energy, fat, a dietary fiber, protein, carbohydrate, and salt. The nutritional requirements contained in a dish and each dish referred to the dietary intake standard of literature and Japanese people. Moreover, the membership function to each nutrient is shown in Figures 1 - 4. The amount of nutrition needed is shown in Table 4.

In decision of a dietary intake standard, the Japanese dietary intake standard (2005 editions) is used. It is a dietary intake standard of the Japanese for a healthy individual or group. The standard of energy and the intake of each nutrient is shown for the purpose of maintenance of national health, improvement, prevention of energy or nutritional deficiency, prevention of a lifestyle-related disease, and prevention of the health disturbance by superfluous ingestion. As a dietary intake standard, one kind is set up about energy and five kinds of indices are set up about the nutrient.

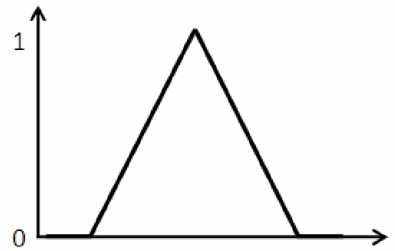

Figure 1.The membership function of energy and protein

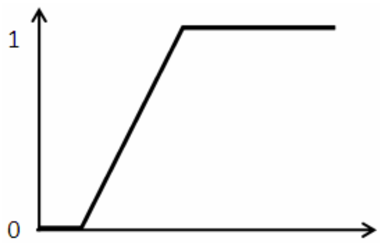

Figure 2.The membership function of a dietary fiber

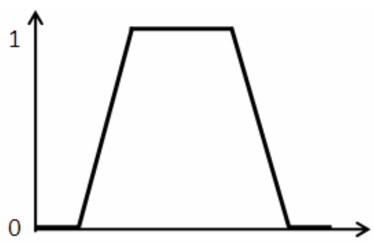

Figure 3.The membership function of lipid and carbohydrate

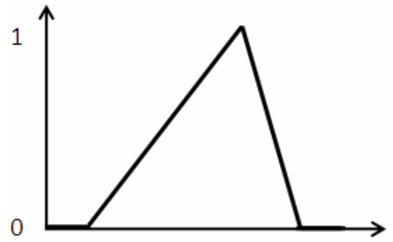

Figure 4.The membership function of salt

Table 4. The amount of nutrition

Nutrient	Below tolerance level	Fiducial point	More than tolerance level
Energy	558.6	610.9	663.3
Lipid	13.6	-	20.4
Dietary fiber	4.3	5.3	-
Protein	12.5	13.7	122.2
Carbohydrate	76.4	-	106.9
Salt	0	2.7	-

V. CONCLUSION

This paper has described fuzzy mathematical programming and the menu planning using a rough set. The element with a user's various tastes is contained. By visualizing a user's taste by this method, it can take into consideration in a menu. And after taking the user's taste into consideration, the menu which considered the balance of nutritional information can be considered.

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