Evaluation of Menu Planning Capability Based on Multi-dimensional 0/1 Knapsack Problem of Nutritional Management System

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Abstract—**Recently lifestyle-related diseases have become an object of public concern, at the same time people have been more health conscious. As an essential factor bringing on the lifestyle-related diseases, we assume that the knowledge circulation on dietary habit has not worked properly. This paper focuses on everyday meals close to our life, and proposes a well-balanced menu planning system as a preventive measure of lifestyle-related diseases. The system is developed by using the Internet technology, and it provides multi-user service and menu information sharing capability like social networking service (SNS). The system works on Web server built by Apache (HTTP server software), MySQL (DataBase Management System) and PHP (Scripting language for dynamic Web pages). For the menu planning, a genetic algorithm is applied by understanding this problem as multidimensional 0/1 knapsack problem.**

Keywords: Lifestyle-related diseases, Menu planning, Apache, PHP, MySQL, Genetic algorithm, Multidimensional 0/1 knapsack problem

1 Introduction

It has been widely known that dietary habit is closely related with individual's health, but recently erratic dietary habit has been a huge social issue in Japan. Growth of eating-out opportunities due to changes in the social environment including the increase of double-income household has been noted to be one of the factors for the erratic dietary habit and explosion of lifestyle-related diseases, and the number of troubled people for dietary habit has been expected to be still increasing yearly. In the past several years, there has been a growing people's awareness for disease prevention and health enhancement, such as government's health promotion measures [1]. Concretely speaking, to construct service-producing industries meeting the diversified health needs, there has been considerable researches through the public offering of areal consortium by Ministry of Economy, Trade and Industry. For example, some researches have shown the efforts of body information management support using IT, and the one has providesd an advanced healthcare support using artificial intelligence technology [2]. We can also see various approaches about nutritional components and foods to enhance one's health, and healthcare support systems using network and database technology that have been worked by not only private but also public sectors [3][4]. Especially some private companies have been just beginning to implement the diversity of services because the supplement of contents about healthcare information is thought to improve the company's competitiveness.

Today's Health and safety trend about the foods people eat is a major business opportunity for private companies. The private-led services can provide excellent services, but in many cases, the consumers might be required expensive usage fee. On the other hand, there are some cheaply-available services, but most of these prevent continuous usage because the services need much labor and troublesome operations to input body, biological or nutritional information. Thought an increasing number of researches about food and healthcare using IT have been reported, many of them are on the assistance of nutritional experts, and they often get customers to measure one's body information that is just time-consuming works. Forcing people to manage body and diet information is thought to make the long-term usage difficult.

To accomplish each one's own goal with continuous exercise, it is regarded as important to provide a system to decrease distress. This paper assumes that creating an enjoyable environment for customers is the best way to achieve the great result. Therefore this paper focuses on the development of interactive functionality such as information-sharing capabilities as an effective solution to support continuous nutritional management without user's labors. This paper also places the insufficiency of handing down food's traditional knowledge caused by

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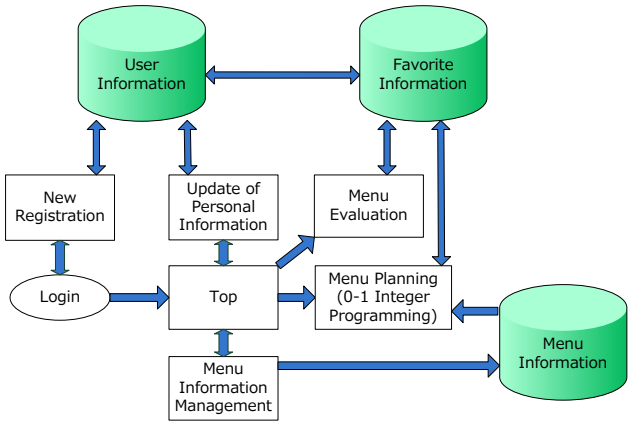

Figure 1: Outline of Well-Balanced Menu Planning System

trand toward the nuclear family as a possible cause of filestyle-related diseases. This paper considers that the avobe difficulties can be solved by using Web technology including collective intelligence and mathematical programming, so a well-balanced menu planning system with information-sharing capabilities is developed. The outline of well-balanced menu planning system is shown in Figure 1. The system in this paper has nutritional component database by reference to Standard tables of food composition in Japan [5], and it closely coordinated with all of menu information registered by customers. By using these data, the system can provide various capabilites such as nutritional information management of ingredients, calorie calculation of each menu, and menu planning support. The menu planning capability can give a well-balanced menu (combination of some dishes) while satisfying each individual's favorites, and the problem can be formulated by multidimensional 0/1 knapsack problem. From now some efficient algorithms for this problem have been proposed [6]. This paper considers that the menu planning should have randomness, so focuses on the solution with genetic algorithm [7] because of its probabilistic behavior. This paper uses genetic algorithm which is modeled by multidimensional 0/1 knapsack problem [8].

2 Related Works

This section shows some typical Japanese websites and softwares as the examples of usual efforts providing food information with database and Internet technology, and refers some remarkable researches.

At first, "Food composition datase" is published on the Internet which has been performed as part of "Experimental study on development and usage of food composition database" promoted by competitive research funding of Japan Science and Technology Agency. [9]. This website has provided nutritional information retrieval services for many ingredients up to 1882 items given by the

Table 1: Ingredients (Foods) on Database

No.	Group of food	The number of foods
1	Cereal	143
2	Potatos and starch	40
3	Sugar and sweets	23
4	Beans	73
5	Nuts and seeds	37
6	Vegetables	326
7	Fruits	156
8	Mushrooms	36
9	Algae	47
10	Fish and seafood	388
11	Meats	244
12	Eggs	20
13	Dairy	52
14	Oils and fats	22
15	Sweets and Snacks	120
16	Beverages	55
17	Seasonings and spices	84
18	Processed foods	16
19	Others	
20	Water	
	Sum of the foods	1882

standard tables of food composition in Japan [5]. Next as a representative example of private-sector corporation effort, Ezaki-Glico Co., Ltd., a Japanese confectionery company manufacturing the traditional Glico caramel candy as well as Pocky, has also developed a nutrition navigator system on the Internet, and been disclosed it without cost. The system provides nutrition information of 1878 common foods, so by using the system we can precisely measure each nutritional component in real time and without difficulty. However, the capability of system has only add up numerical value of each ingredient due to the simple design, so we cannot make own original menu with nutrition information.

As academic outcomes, Hasegawa et al. have developed a nutrition management system using camera-equipped cell-phone [10]. With this system, users can get nutritional advices from a dietician by sending picture images of everyday meals. The system is of great utility, on the other hand the system requires much running costs including labor cost of dieticians. We can see many systems with the similar service, but the effectiveness might depend on the expert's knowledge. As an example using Web technology, Itoh has proposed a design and construction for calorie calculating database integrated with Apache, PHP, MySQL, and XML [11].

As other instances of academic outcomes, many researches have shown the menu planning based on mathematical programming, and the reference [12] is one of interesting effort where the developed system was to a practical level by using linear programming consisting of

nutritional intake as constraint, minimization of cost as objective function. In [12], S. Garille et al. reviewed Stigler's diet problem, its impact on linear programming and operations research, and determined minimum cost dishes using updated nutritional and cost data. For the menu planning problem, an approach equally-typical with linear programming is integer programming. J. Balintfy et al. aimed the minimization of cost, cooking time, and others by representing the selection of dish as 0 (rejection) or 1 (acceptance) for one menu [13]. The effort also showed the analytical representation of food preference in a separable non-linear program to yield the serving frequencies of dishes in menu for a finite time horizon, and the scheduling problem dealing with dish assignments to menus and days consisting of several transportation problems linked by weekly nutritional constraints. As a effort considering fuzziness in nutritional components, Kurashige et al. have discussed a menu planning modeled by fuzzy mathematical programming [14].

The researches above-mentioned have planned only one menu by considering the nutritional balance and the affinity between some dishes, and in addition they has not provided the capability of information sharing among the various users.

As examples of knowledge sharing about foods, we can take "Cookpad"[15] and "Foods Supporter"[16]. The Cookpad is one of the Japan's biggest Internet website on recipes, and has posted more than three hundred thousand recipes registered by users. Each user can freely refer, register, and publish recipe information without charge, so there are many simple and practical recipes actually cooked by homemakers. The Cookpad has also some capabilities such as to bookmark recipes cooked by other users, and to add a new recipe cooked by reference to other recipes that is strongly linked to the usual data. The number of recipes has still continued to increase because Cookpad has given an enjoyable and useful environment for users to register, and in addition, the information sharing might be more and more promoted along with the increase in the number of recipes. The Foods Supporter is a nutrient calculation software with health management features running on standard PC. The software is stand-alone program, but it provides some useful capabilities such as registration of one's original menu, graphical representation of nutrient balance. This paper aims a system combining advantages of these systems such as "information sharing" and "menu planning".

3 Menu Planning

3.1 Input Data

To plan each menu with the information of nutritional components, the system in this paper uses 1882 items listed with the standard tables of food composition in Japan (Table1), and each ingredient (food) is classified into 18 groups. The number of ingredients according to the group is shown in Table1, and 44 kinds of nutritional components are managed by the system.

3.2 Formulation

The main focus of this paper is information sharing about recipes, and presentation of nutritional components for each menu. This paper thinks that there might not be major problem even the menu planning is with only basic technique, so provision of the menu user wants is realized by formulating multidimensional 0/1 knapsack problem (Integer Programming).

Integer Programming (Integer linear programming) is about ways to solve optimization problems, and is in a special case of linear programming in which all variables are required to take on discrete or integer values only. In contrast to linear programming, which can be solved efficiently in the worst case, integer programming problems are in many practical situations (those with bounded variables). 0/1 integer programming is the special case of integer programming where variables are required to be 0 or 1 (rather than arbitrary integers), and the problem is also classified as NP-hard [17].

This paper relates the acceptance and rejection of each dish x to 0 and 1 to determine one menu, so the menu planning problem is formulated as follows.

Maximize

$$\sum_{i=1}^{n} c_i x_i, \tag{1}$$

Subject to

$$\sum_{j=1}^{m} a_{ij}^{l} x_i \leq b_j, \tag{2}$$

$$\sum_{k=1}^{l} a_{ik}^{h} x_i \geq g_j, \tag{3}$$

$$x_i \in \{0,1\}, i = 1,2,\cdots,n,$$
$$B = \{b_j | 1,2,\cdots,m\}, G = \{g_k | k = 1,2,\cdots,l\},$$

where i is dish number for the total number of dishes n scored by each user, j is negative and k is positive nutritional component number for 44 kinds of nutritional components managed by database. c_i is satisfaction value of i, a_{ij}^{l} is intake of j in i such as salt, calorie, and fat, and b_i is limit value of recommended daily intake of j. Similarly, a_{ik}^{h} is intake of k such as vitamin, calcium, and fiber. This paper uses a genetic algorithm (GA) to solve this problem [8].GA is known as powerful search methods in a complex search space. The reason this paper uses GA is shown following. Usually, the approximation algorithm can obtain only a fixed solution. But GA can obtain a certain amount of random solution, besides GA can obtain the solution which was excellent to some extent. If a system is developed into an interactive system,

reexamination of an evaluation value will be attained in GA. There are much the publication and the result of research about the interactive system using GA.

3.3 Genetic Operators

To solve multidimensional 0/1 knapsack problem with genetic algorithm, each individual (chromosome) is usually represented by a binary 0/1 string of length n. For handling $m + l$ constraints in the problem of this paper, the most straightforward technique is to transform the constrained problem into an unconstrained problem by penalizing infeasible solutions, namely, penalty term is added to the objective function for any violation of the constraints [18]. At the same time, Sakawa et al. proposed a double string representation and decoding algorithm for eliminating infeasible solutions, and the effectiveness was shown. This paper follows genetic algorithms (decoding method and fitness)with double strings proposed by Sakawa et al. to obtain a menu with each user's satisfaction [8].

In this paper, each individual has the same number of chromosomes as the dishes stored on database, and each chromosome has binary information of 0 and 1 that corresponds to the selection of dish, namely each individual represents one menu. Each individual has also summation of each user's evaluation value for selected dishes as fitness value, so an individual with maximum fitness value is obtained as solution value after repeating generation alternations previously-determined by this system's administrator.

1) Reproduction

This paper adopts elitist expected value selection which is a combination of elitism and expected value selection.

2) Crossover Operator

To generate desirable offsprings without changing the double string structure, this paper uses the crossover method, PMX.

3) Mutation Operator

This paper adopts mutation of bit reverse type for the lower string of a double string.

4 System Structure

In this system, Apache is used for Web server software. Web application development language is PHP and MySQL is used for the database management system. These are the open sources corresponding to a multiplatform. In addition, there is the word LAMP(Linux, Apache, MySQL, "P" language), it is the combination of popular technology. Therefore, the document is very fulfilling. These features are one of the reasons using this technology. In this research, a setup of the character code in a Web server is unified into UTF-8. Moreover, when describing PHP application, the file is saved in UTF-8 form. The character code of the standard in the Windows is Shift-JIS. However, garbled characters is taken into consideration in a setup of PHP.

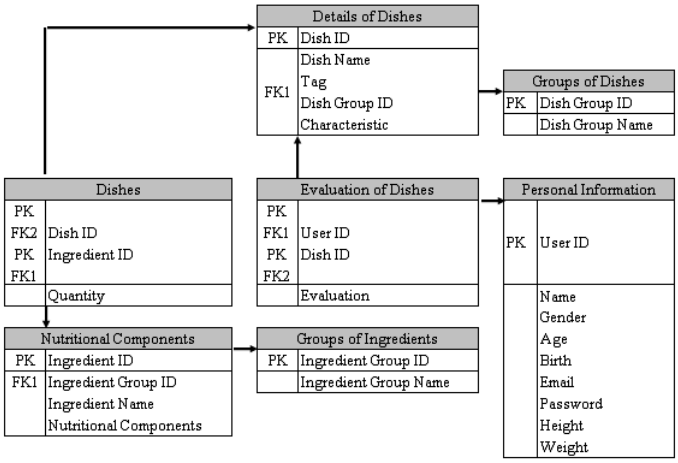

Figure 2: Table structure

4.1 Database Design

The database of this system stores the data of approximately 300 dishes consisted of some ingredients. For example, one dish in this system, "curry and rice" is composed of 19 kinds of ingredients such as carrot, potato, and onion, and each ingredient has about 40 kinds of nutrition. The system is designed for multi-user environment, so the system has evaluation values for dishes with respect to each user. The tables on the database are normalized as shown in Figure 2. Normalization is a technique for designing relational database tables to minimize duplication of information and, in so doing, to safeguard the database against certain types of logical or structural problems, namely data anomalies. In Figure 2, "PK" represents primary key which is a candidate key to uniquely identify each row in a table, and "FK" represents foreign key which identifies a column or a set of columns in one (referencing) table that refers to a column or set of columns in another (referenced) table.

As shown in Figure2, the table of "Details of Dishes" consists of Dish ID, Dish name, Tag, Dish Group ID and Characteristic. The table of "Groups of Dishes" consists of Dish Group ID (there are 6 dish groups) and Dish Group Name, and Dish Group ID corresponds with the Dish Group Name. Concretely, Dish Group Name are staple rice, staple noodles, staple baked, soup, main dish and subsidiarily. For example, a group name is a main dish when Dish Group ID is 1. The table of "Nutritional Components" consists of Ingredient ID, Ingredient Group ID, Ingredient Name, and Nutritional Components (there

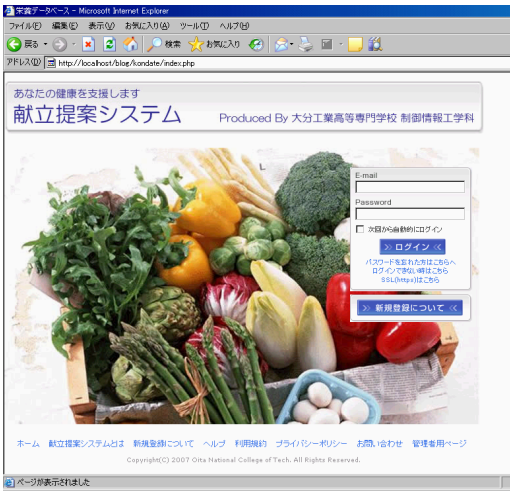

Figure 3: Login Form

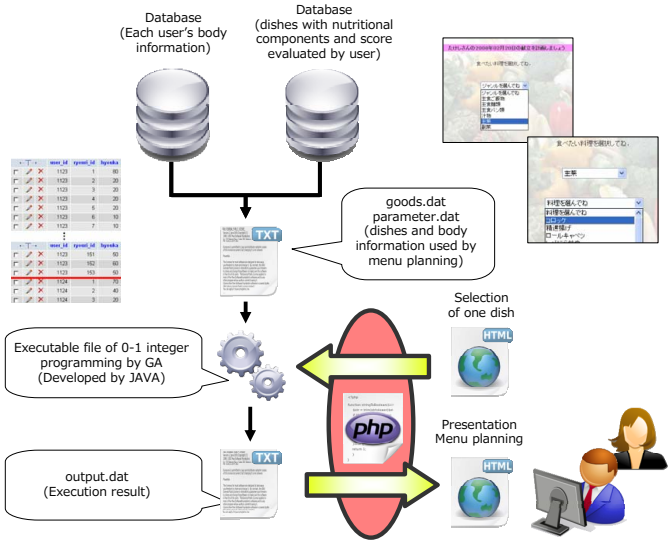

Figure 4: Details of Menu Planning

are 45 kinds of nutritional components). The table of "Groups of Ingredients" consists of Ingredient Group ID and Ingredient Group Name (there are 6 groups). The table of "Dishes" consists of Dish ID, Ingredient ID, and Quantity. The table of "Personal Information" consists of User ID and several personal data corresponding to User ID, and some data, for example, Height and Weight are required in order to calculate a user's BMI, and Email and Password are used for a each user's login. The table of "Evaluation of Dishes" consists of User ID, Dish ID, and Evaluation.

4.2 User Interface

The system in this paper consists of three functions, the initial input (login form), the selection of processing options (main form), and the decision support (menu planning form), which are classified from the standpoint of processing subject. This section shows how these functions are implemented. As an example of developed system, the top page (index.php) is shown in Figure 2) which provides initial registration of user's own information (login ID, password, and body information) and login to the main form. The main form has the menu selection, the management of profile information, the menu evaluation, the menu planning, and so on (BMI calculation, withdrawal, logout).

This system needs registration to properly reflect each user's preference for menu planning, and feature expansion about information sharing. If "initial registration" is clicked on a top screen, it will move to "regist.php" to offer the input form of initial registration. After the registration, new user ID is attached automatically. The user ID corresponding to this name is always delivered using GET method while using this system (user ID is always displayed on a URL). "Gender" and "Age" are used in order to change the amount of nutrition, and "Height" and "Weight" calculate BMI. A E-mail address and a password are used when the user logs into the system, and when the registration button is pushed, it will move to the completion screen of registration. It is not allowed to directly access the main page which is displayed after the registration by using "session".

The menu evaluation form (hyouka1.php) provides the input form to score each user's preference as numerical value for 150 dishes, and these values are used as parameter by the problem shown in Equation (1). The score is prepared at 10 intervals from 10 to 100, and these values are managed in "Evaluation table". In this form, default value is 50 expressing neither like nor dislike. Also, this system gives details information of dishes for each user by "look.php" which shows configuration of each dish such as cooking ingredients, its quantity, and its nutritional components to realize each user's exact decision support.

Table 2: A Result of Menu Planning

Dish	Energy	Classification
Croquette	435	Main dishes
Sauteed leek and liver	129	Main dishes
Fry an eggplant	123	Sub main dishes
Okra adn pickled ume	25	Sub main dishes
Garlic-fried pork	118	Main dishes
Beef and Asparagus fry	370	Main dishes
Chicken meat Saute	156	Main dishes
Pork cutle sandwich	576	Dietary staple

4.3 Menu Planning

Details of the menu planning capability are shown in Figure 4. The proposal of the menu is realized by the system

which calls up the executable file of exe form from the script of PHP. The program of the genetic algorithm created by C++ was compiled, and it has changed into exe form. An executable file is in the place which cannot be directly called up from the exterior. A PHP script has two functions. One of the functions is the information acquisition from a database. Another is creation of the input file of an executable file. Moreover, the executable file is called up while making out input file creation. The called up executable file outputs an execution result by text format. A PHP script reads the text file and outputs a plan result to a screen. The procedure is shown in described below.

First, a user chooses the proposal of a menu from a main menu. After choosing, the selection screen of a dish to eat is displayed. The call of this screen and a database are accessed. Then, cooking names, the nutritional information contained in cooking, and a user's cooking evaluation value are received. The nutritional information of cooking has some information. The information are the name of material, energy of material, the amount of nutritive substances and Energy to a quantity. For example, one of the materials of a croquette is a potato. The energy per 100g of a potato shows 76. A croquette uses 150g of potatoes. Therefore, energy shows 114 as a calculation result. And user's evaluation information is acquired. The evaluation of a croquette is 80 points. A text file is created by these information. This text file is constituted by nutritional information, evaluation, cooking ID, a cooking name, and classification. This file is used as an input file of the executable file of a genetic algorithm. "435 80 1 croquette main dish" is shown by the example of a croquette. It means that this is 435kcal, 80 points, and cooking ID=1, and a classification is a main dish. The above parameter is used. A user's degree of satisfaction looks for the solution which becomes the maximum. An execution result is outputted after repeating the set-up generation number. In the output file as an execution result, each line supports each generation. The chromosome with the highest adaptive value is outputted to the file in each generation. The each object has a chromosome by the number of menus for a plan.

All are expressed by 0/1. Moreover, val and cost are displayed at each generation's right end. The val is a degree of satisfaction which is the adaptive value with the best solution of an individual. The cost is energy. If val carries out renewal of a generation, the degree of satisfaction will increase. This is for the local minimal value convergency of a genetic algorithm. As the final stage, PHP script reads an output file and displays the result of a menu plan on a screen. For example, the adaptive value of an individual is 380. The individual has seven chromosomes of "1". It means the menu which consisted of seven dishes. The execution result of a menu plan is usually displayed within in 1 second. Therefore, we can say that we have provided the user with the dialog in real time.

Table 3: Cross table of examinee's evaluation

	Class	Meats	Greens	Grains
Score	150	50	50	50
10	13	3	8	2
20	18	4	11	3
30	13	4	4	5
40	15	5	4	6
50	13	4	1	8
60	17	3	10	5
70	22	8	6	8
80	22	9	5	8
90	9	5	1	3
100	7	5	0	2

5 Results and Discussion

The employment experiment was conducted in order to check the performance of a system. A user's information is a 20 years-old male's student. 30 menu proposals were performed to this user. There are two important purposes. The 1st purpose is to fill the amount of required nutrition. The 2nd purpose is to create the menu in consideration of the user's taste. This experiment evaluates for two purposes. A user's feature is as follows. A user likes a meat dish and doesn't like legumes. However, a user likes the processed goods which use legumes. A user has a favorite thing and a disagreeable thing in vegetables. A user likes rice bowl dishes, breads, noodles, etc. A user does not like the meat dish in which disagreeable vegetables are contained. A user inputs evaluation of each dishes before an experiment. Here, we classified the dishes registered into the database. There are three kinds of classifications. They are grain, meat, and vegetables. A cross tabulation shows the evaluation and three classifications which were given by the user. A result is shown in Table3.

The following thing understands Table3. The percentage of the dish of 10-50 points is 48%. The percentage of the dish of 60 points - 100 points is 52%. It turns out that the dish is divided into the half. Evaluation of 50 less points is divided almost similarly. There are many vegetable disesh at evaluation of 20 points. Then, it turns out that a user does not like vegetables. 60-80 points have increased about evaluation of 60 more points. There are many 60 more rates of a meat dishes and a grain dishes. The user's taste is shown. The reason with many vegetable dish was investigated in the dish of 60 points. It turned out that it is a dish using the meat and the vegetables like sauteed leek and liver. From the 1st experiment, the average of a degree of satisfaction is 271.3 and the average of items is 4.71. The relation and its approximation straight line of the number of items contained in a menu

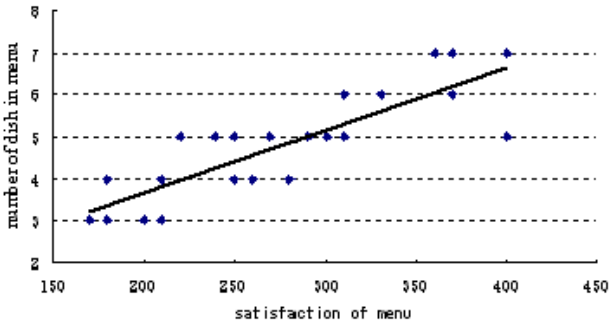

Figure 5: The relation between satisfaction and items

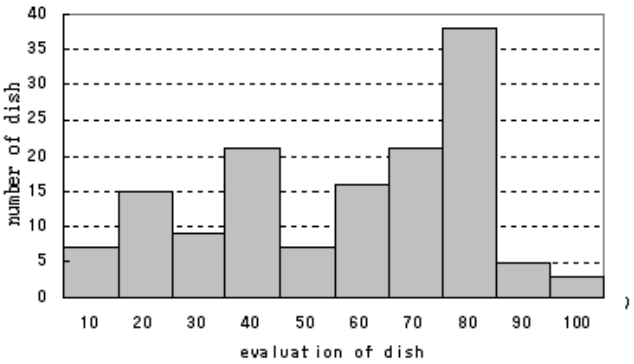

Figure 6: The relation between evaluation and items

and the degree of satisfaction of a menu are shown in Figure5. It became clear from this result that a degree of satisfaction tends to increase in proportion to items. The average of the dish included in a menu was 57.3. This value is a larger value than 50 showing average value. The result was able to propose the menu in consideration of the user's taste. And the frequency distribution of the mark of the dish included in all the proposed menus was pressed. Frequency distribution is shown in Figure6. The proposed menu is understood that there are most dishes with evaluation of 80 points. In order to make the degree of an evaluating point intelligible, the relation between cumulative elative frequency and survey frequency was expressed with the pareto graph. Many dishes in onsideration of taste are proposed. However, the dish which a user does not like is also proposed. As the cause, the menu shows low evaluation of a user's satisfaction and the menu shows high evaluation of nutritive alue. Therefore, it is thought that the menu of low evaluation was proposed. Then, We think that average evaluation 57.3 was obtained.

This is shown clearly.Figure7 can compare two evaluations. Relative frequency shows evaluation of the dish by a user, and evaluation of the dish used for the menu.

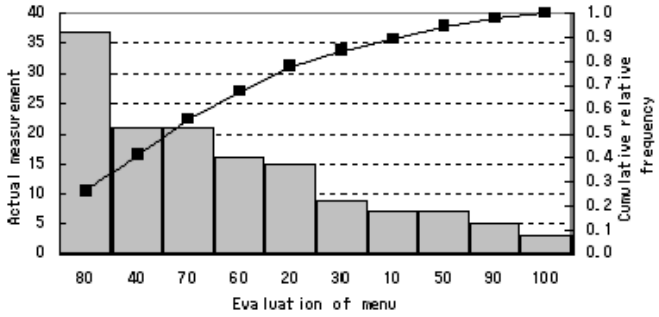

Figure 7: Pareto chart

From the result of Figure7, the increase in a dish with evaluation of 40 points and 80 points is shown. The menu proposal which had a user's taste taken into consideration is possible. However, also proposing the menu a user hates was shown. In order to know the reason for proposing a disagreeable menu, we investigated the dish of the proposed menu. The dish of 80 points has proposed the dish containing many meat and good nutritional balance. he dish of 40 points has proposed the dish containing many vegetables and good nutritional balance. The menu with good nutrition fills constraints of nutrition. Therefore, it is shown that the menu with good nutrition is often contained in a menu. Dish has especially high evaluation and the dish with good nutritional balance are included in a menu by high probability. On the contrary, dish has low evaluation and the dish with bad balance of nutritional information is not included in a menu. Dish has high evaluation and the bad dish of nutritional balance is not included in a result. For example, it is junk food, such as a hamburger.

6 Conclusions and Future Works

This paper developed a system with the capabilities of information sharing and menu planning, as one of the corrective strategy to improve the dietary life closely-related with one's health. The major definition of "menu planning" is to determine the dishes and its quantity by considering selectable nutritional intake, but this paper addressed only the combination of existing dishes as menu planning, and aimed to plan well-balanced menu. The menu planning capability provided one day's menu filled with some nutritional constraints by using a genetic algorithm. The capability also achieved menu planning of great variety, which is realized by the characteristic of solution, probabilistic search. From the results of experiment through test installation, it was confirmed that many menus consisted of dishes strongly-preferred by user. However, it was also confirmed that dishes with well nutritional balance were selected with high probability for the menu even though the menu was not so preferred by user. This paper thinks that such the dish

should be consumed to satisfy nutritional intake, and the user must eat such the dish for one's health regardless of user's preference. However, dishes with low score (not preferred by user) and poorly balanced, and unhealthy dishes with high score and poorly balanced such as junk-food, were hardly selected for the menu. From the results, This paper thinks that it is certainly possible to plan well-balanced menus responding more to user's preference by ensuring enough users and menu information through the actual operation of this system, which will be attained by the reorganization and the selection promoted by information sharing between enough users.

As future works, firstly we will develop the capability to create three menus (breakfast, lunch, and dinner), and secondly will expand the feature of menu planning to formulate the problem in several days such as one week. Moreover, the capability of menu planning will be improved by the consideration of compatibility between dishes, food allergy, and clustering based on user's characteristics.

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References

[1] Health, Labour and Welfare Ministry, "Special topic of lifestyle-related diseases prevention," http://www.mhlw.go.jp/bunya/kenkou/seikatsu (In Japanese).

[2] S. Izumi et al., "Design and Implementation of an Ontology-based Health Support System," *Technical report of IEICE SS*, Vol.106, No.523, pp.19-24, 2007 (In Japanese).

[3] H. Kubo, "Development of individualized health management system based on Kansei information of food preference," *Research report on research and development grant*, 2006 (In Japanese).

[4] Y. Fujii et al., "Development of Evaluation System of Nutrient Balance using Perl," *Proc. of PC Conference*, pp.401-405, 2006 (In Japanese).

[5] Ministry of Education, Culture, Sports, Science and Technology, "Standard tables of food composition in Japan, fifth revised and enlarged edition," 2005 (In Japanese).

[6] G. Dahl and N. Foldnes, "LP based heuristics for the multiple knapsack problem with assignment restrictions," *Annals of Operations Research*, Vol.146, No.1, pp.91-104, 2006.

[7] P. C. Chu and J. Beasley, "A genetic algorithm for the multiconstraint knapsack problem," *Journal of Heuristics*, Vol.4, No.1, pp.63-86, 1998.

[8] M. Sakawa et al., "Genetic algorithms with double strings for 0-1 programming problems," *European Journal of Operational Research*, Vol. 144, Issue. 3, pp.581-597, 2003.

[9] Japan Science and Technology Agency, "Food composition datase," http://fooddb.jp/ (In Japanese).

[10] S. Hasegawa et al., "Application of the Mobile Nutrition Assessment System to Nutrition Management Education," *Information Processing Society of Japan, 06*, pp.41-46, 2006 (In Japanese).

[11] M. Itoh, "A Design and Construction for Calorie Calculating Database Integrated with Web Technologies," *Research Report of Aichi Institute of Technology*, No.40 B, 2005 (In Japanese).

[12] S. Garille and S. Gass, "Stigler's Diet Problem Revisited," *Operations Research*, Vol.49, No.1, pp.1-13, 2001.

[13] J. Balintfy et al., "A mathematical Programming System for Preference and Compatibility Maximized Menu Planning and Scheduling," *Mathematical Programming*, Vol.15, No.1, pp.63-76, 1978.

[14] K. Kurashige et al., "Creation of the menu using fuzzy mathematical programming" *Journal of the Operations Research Society of Japan*, pp.96-97, 2006 (In Japanese).

[15] COOKPAD Inc., "Cookpad," http://cookpad.com/ (In Japanese).

[16] Editorial committee of tables of food composition, "Foods Supporter - Nutrient calculation software," *Hitotsubashi-shuppan*, 2007 (In Japanese).

[17] A. Schrijver, "Theory of Linear and Integer Programming," *Wiley Blackwell*, 1998.

[18] Z. Michalewicz, "Genetic Algorithms + Data Structures = Evolution Programs," *Springer-Verlag, Berlin*, 1996.