Development of Menu Planning Support System with Nutritional Database Using Genetic Algorithm

Tomoko Kashima *, Shimpei Matsumoto †and Hiroaki Ishii ‡

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 a 0-1 integer programming. For the menu planning, a genetic algorithm is applied by understanding this problem as a multidimensional 0-1 integer programming.**

Keywords: Lifestyle-related diseases, Menu planning, Genetic algorithm, 0-1 integer programming, Web technology

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. 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 [1]. 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 [2][3]. 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 provide excellent services, but in many cases, the consumers are 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 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

*Tomoko Kashima is with the Department of Information and Physical Sciences, Graduate School of Information Science and Technology, Osaka University, 2-1 Yamada-oka, Suita, Osaka 565-0871 Japan; Tel: +81-6-6879-7868(ext.3641); Fax: +81-6-6879-7871; Email: t.kashima@ist.osaka-u.ac.jp

†Shimpei Matsumoto is with the Department of Computer and Control Engineering, Oita National College of Technology, 1666 Oaza-Maki, Oita City, Oita 870-0152 Japan; Tel/Fax: +81-97-552-7421; Email: smatsu@oita-ct.ac.jp

‡Hiroaki Ishii is with the Department of Information and Physical Sciences, Graduate School of Information Science and Technology, Osaka University, 2-1 Yamada-oka, Suita, Osaka 565-0871 Japan; Tel: +81-6-6879-7868(Direct); Fax: +81-6-6879-7871; Email: ishii@ ist.osaka-u.ac.jp

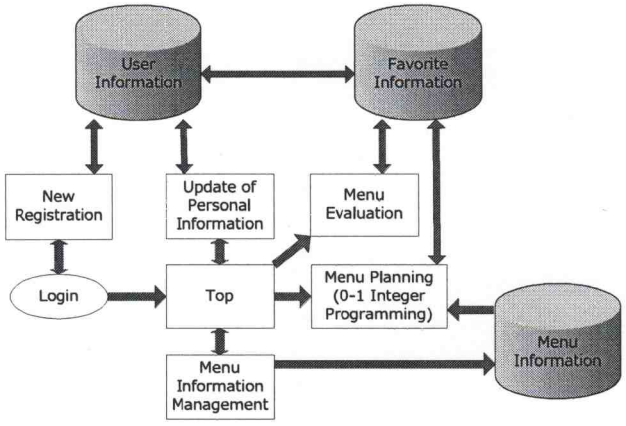

Figure 1: Outline of Well-Balanced Menu Planning System

to support continuous nutritional management without user's labors. This paper also places the insufficiency of handing down food's traditional knowledge caused by 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 is with nutritional component database by reference to the standard tables of food composition in Japan, fifth revised and enlarged edition 2005, 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 propose a well-balanced menu (combination of some dishes) while satisfying each individual's favorite by using genetic algorithm which is modeled by multidimensional 0-1 integer programming [4].

2 Usual Efforts

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

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.This website has provided nutritional information retrieval services for many ingredients up to 1882 items given by the standard tables of food composition in Japan fifth revised and enlarged edition 2005. Next as a representative example of

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

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 [5]. With this system, users can get nutritional advices from a dietician by sending a 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 another instance, Kurashige et al. have discussed a menu planning modeled by fuzzy mathematical programming [6]. As an example using Web technology, Itoh has proposed a design and construction for calorie calculating database integrated with Apache, PHP, MySQL, and XML [7]. These researches has 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" and "Foods Supporter"[8]. 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 (see Table 1), and each ingredient (food) is classified into 18 groups. The number of ingredients according to the group is shown in Table 1, 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 0-1 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) NP-hard. 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.

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 [4]. GA is known as powerful search methods in a complex search space. The reason this paper uses GA is to deal with the extension of this problem such as addition of constraints, and consideration of fuzziness for nutritional components.

3.3 Genetic Operators

To solve 0-1 multidimensional programming problems through genetic algorithms, each individual (chromosome) is usually represented by a binary 0-1 string of length n. For handling $m + l$ constraints in the multidimensional 0-1 knapsack 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 [9]. 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 [4].

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.

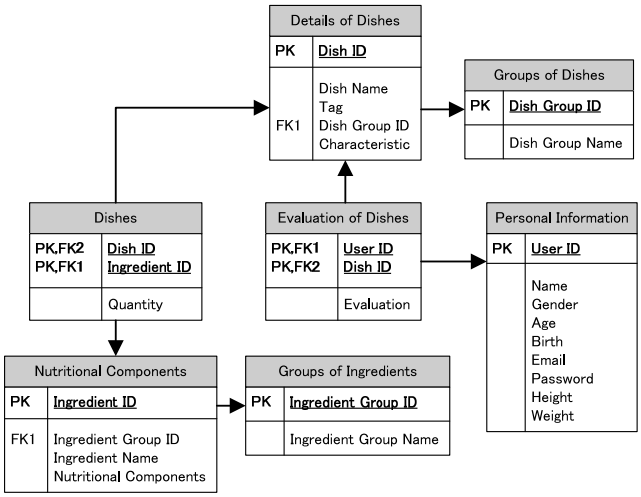

Figure 2: Table structure

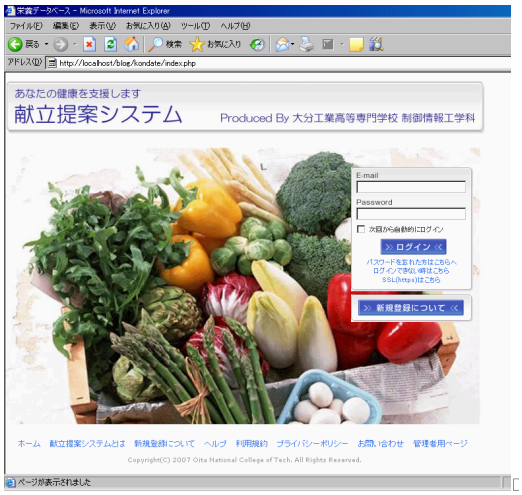

Figure 3: Login Form

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 multi-platform. 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.

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 Figure 2, 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 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.

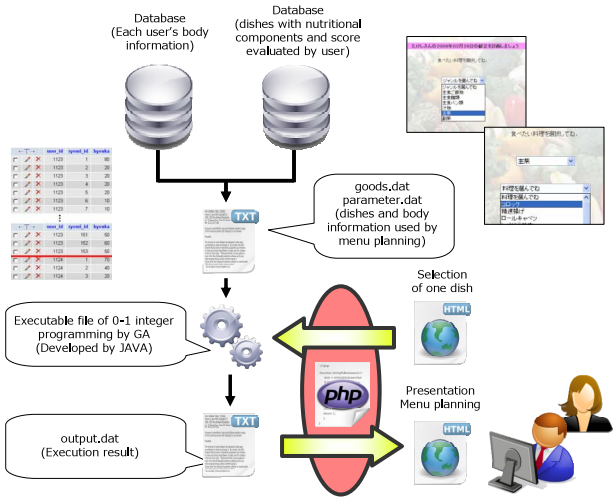

Figure 4: Details of Menu Planning

料理	エネルギー	分類
コロッケ	435	主菜
レバにら炒め	129	主菜
揚げなす	123	副菜
オクラの梅肉あえ	25	副菜
もやしと豚肉のにんにく炒め	118	主菜
アスパラと牛肉のオイスター炒め	370	主菜
にんにくの茎とささ身のソテー	156	主菜
カツサンド	576	主食パン類

総カロリーは 1932(1497+435)になりました.
総満足度は 380になりました.
メインへ戻る

Figure 5: A Result of Menu Planning

4.2 User Interface

The menu proposal system consist of 3 functions. The functions are early selection function (top screen), arrangement select function (main screen) and menu proposal function. Here, this system's functions are shown how the function of the system is mounted. The top page (index.php) of this system (see Figure 3), there are initial registration of user information and login. The user can log in, after initial registration.

We need user registration. Because registration is important for making a user's taste reflect in a result and managing information appropriately. If "initial registration" is clicked on a top screen, it will move to regist.php which offers an initial registration function. The regist.php is shown in Figure 13. When registering, a user ID is attached automatically. The user ID corresponding to this name is always delivered using a GET method, when using a system. Therefore, the name corresponding to ID is displayed on a screen. Sex and age are used in order to change the amount of nutrition. Height and weight calculate BMI. A mail address and a password are used when logged in from a top screen. If items other than height and weight are blanks, an error message is displayed and it cannot register. The inputted information is registered into a database. If a registration button is pushed, it will move to the completion screen of registration (regist_f.php). The screen shows that user information is registered correctly by phpMyAdmin screen.

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. A database is accessed when this screen calls up. The nutritional information contained in all the cooking and dishes is acquired. The nutritional information contained in cooking catch. User's cooking evaluation catch. 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. An execution result is shown in Figure 5. Here, 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. It is shown in Figure 6. Moreover, val and cost are displayed at each generation's right end. It is the adaptive value and energy with the best solution of an individual. 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, a PHP script reads an output file and displays the result of a menu plan on a screen. In the output result of Figure 6, the adaptive value of the best solution is 380. The result is shown in Figure ??. When adaptive value looks at the individual of 380, there is seven chromosomes of "1". We can understand consisting of seven dishes from this result. The execu-

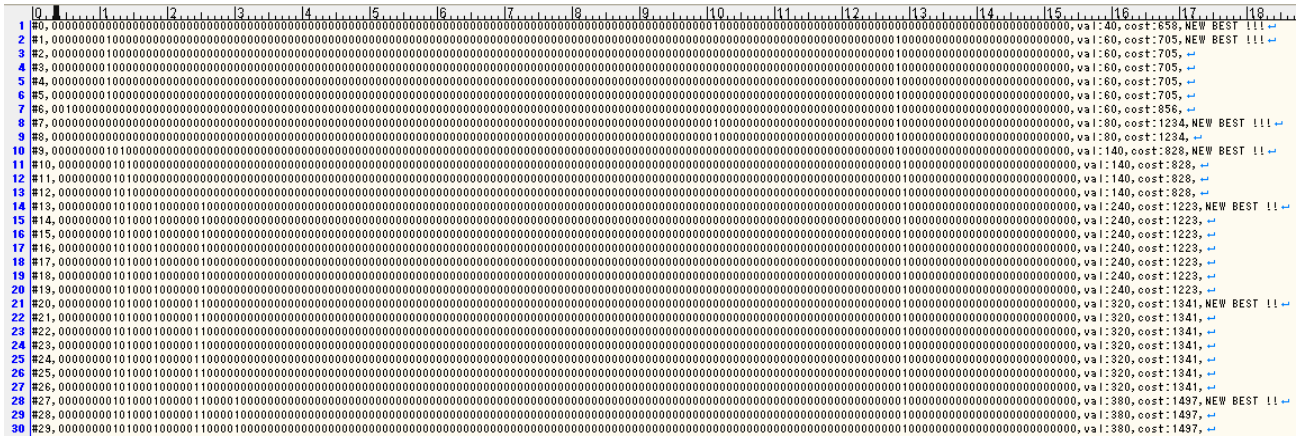

Figure 6: Output File of Generation Alternations

tion 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.

5 Conclusions and Future Works

This paper developed a system with the capabilities of information sharing and menu planning. The system is one of the corrective strategy of eating habits. The menu planning capability used a genetic algorithm. A menu fills required nutrition. Moreover, various menu creations were realized. The probable element is realized for realization. An experimental result, the dish which likes for many users was chosen. However, when the dish which filled nutritional balance, it may be chosen as a menu even if evaluation of a user is low. We think that the selected dish is a dish required in order to fill the required intake of a nutrient and the low dish of user evaluation must also be eaten for health. However, a dish with low evaluation, the bad dish of nutritional balance, and junk food are hardly chosen as the menu. Therefore, it can be said that this system is a menu plan in consideration of the user's taste. As future works, first creation of the menu of three degrees of obscuration divided into day and night in the morning. Formulation of a plan of the menu in several days, such as one etc. week. Moreover, in a menu plan, there are food eaten together, consideration of food allergy, and so on.

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References

[1] 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.

[2] H. Kubo, "Development of individualized health management system based on Kansei information of food preference," Research report on research and development grant, 2006.

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

[4] 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.

[5] 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.

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

[7] 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.

[8] Foods Supporter - Nutrient calculation software, Hitotsubashi-shuppan, 2007 (In Japanese).

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