Intelligent Ontological Agent for Diabetic Food Recommendation

Chang-Shing Lee*, Mei-Hui Wang, Huan-Chung Li, and Wen-Hui Chen

Abstract—Diabetes is a chronic illness that food intake affects the body's needs and insulin's ability to lower blood sugar. This paper proposes an intelligent agent, called the personal food recommendation agent, based on the ontology model for diabetic food recommendation. The agent can create a meal plan according to a person's lifestyle and particular health needs. The required knowledge is stored in the ontology model predefined by domain experts. It contains the Taiwanese food ontology and a set of personal food ontology. The personal food recommendation agent includes the ontology creating mechanism, the personal ontology filter, the food fuzzy number creating mechanism, the fuzzy inference mechanism, and the real-time recommendation mechanism. It retrieves the personal ontology and meal records to recommend a personal meal plan based on the fuzzy inference mechanism. An experimental platform has been constructed to test the performance of the agent. The results indicate that the proposed method can work effectively and alleviate the effort of a registered dietician.

I. Introduction

Diabetes Mellitus(DM) is a disorder in which blood levels of glucose are abnormally high due to either an absolute deficiency of insulin secretion, or as a result of reduced effectiveness of insulin, or both [1]. For those with diabetes, a proper diabetes diet is crucial so that the experts recommend eating a wide variety of foods, including vegetables, whole grains, fruits, non-fat or low-fat dairy products, beans, lean meats, poultry, and fish. However, each person has a unique dietary pattern so a dietician creates a meal plan depending on each case. Therefore, in order to recommend individual meal, the ontology is a good idea for building a personal dietary pattern to do a proper food recommendation. The ontology can provide an abstract view of an application domain. Lee et al. presented many applications of specific domains. For example, the fuzzy ontology for a news summarization [2] and an episode-based ontology construction mechanism to extract the domain ontology from unstructured text documents [3]. In the field of healthcare, they also presented an ontology-based intelligent healthcare agent for the respiratory waveform recognition [4], and an ontological fuzzy agent for electrocardiogram application [5]. In addition, Yan et al. [6] developed a multi-layer perceptron-based medical decision support system to support the diagnosis of heart diseases. Moreover, an agent is a physical or virtual entity that is capable of acting in an environment and communicating directly with other agents [7]. Hamdi developed a multi-agent information customization system that adopts the machine-learning paradigm to advise students by mining the Web [8]. Lee et al. proposed an ontology-based intelligent decision support agent for Capability Maturity Model Integration (CMMI) project monitoring and control [9].

There are 20.8 million children and adults in the United States, or 7% of the population, who have diabetes according to American Diabetes Association [14]. While in Taiwan, the prevalence of diabetes continues to grow according to the Department of Health, Executive Yuan [15]. With so many people affected by diabetes, there has been considerable research on diabetes. A fuzzy-based controller for glucose regulation in Type-1 diabetic patients was proposed by Campos-Delgado et al. to control an intensive insulin treatment [10]. In addition, a new model for the diabetic neuropath is proposed by Lascio et al. to diagnose the diabetic neuropathy [11]. Besides, lifestyle factors, such as diet, physical activity and obesity, have a major influence on the development and progression of the conditions that precede the onset of Type-2 diabetes and subsequent complications [12].

This paper combines the domain knowledge of the ontology, diabetes, and nutrition to propose an intelligent ontological agent for diabetic food recommendation, including the Taiwanese food ontology, a personal food ontology repository, and a personal food recommendation agent. First, the personal food recommendation agent retrieves the meal records and the predefined Taiwan food ontology to carry out the ontology creating mechanism and the personal ontology filter to acquire the personal food ontology. Then, the food fuzzy number creating mechanism is responsible for constructing fuzzy numbers for all kinds of food and each person's diet goal. Next, the fuzzy inference mechanism combines fuzzy operators with the personal food ontology to get the remaining calories for dinner intake. Finally, the real-time food recommendation mechanism follows the personal food guide pyramid predefined by domain experts to do a personal food recommendation for dinner. The experimental results show that the proposed method can work effectively. The remainder of the paper is organized as follows. Section II describes the system structure for diabetic food recommendation. The proposed intelligent ontological agent for diabetic food recommendation is introduced in Section III. The experimental results are shown in Section IV. Finally, conclusions are drawn in Section V.

This work was supported by the National Science Council of Taiwan under the grant NSC95-2221-E-024-009-MY2, and by the III Innovative and Prospective Technologies Project of Institute for Information Industry and sponsored by MOEA, Taiwan, ROC.

Chang-Shing Lee and Mei-Hui Wang are with the Department of Computer Science and Information Engineering, National University of Tainan, Taiwan. (*Corresponding Author: phone: 886-6-2606123 ext. 7709; fax: 886-6-2606125; e-mail: leecs@mail.nutn.edu.tw).

Huan-Chung Li is with the Innovative Digitech-Enabled Applications & Services Institute, Institute for Information Industry, Taipei, Taiwan.

Wen-Hui Chen is with the Department of Nutrition & Dietetics, Changhua Christian Hospital, Changhua, Taiwan.

978-1-4244-1819-0/08/$25.00©2008 IEEE

II. System Structure for Diabetic Food Recommendation

The paper presents an intelligent ontological agent for diabetic food recommendation. The system structure and the ontology model are briefly described in this section.

A. System Structure

Figure 1 shows the system structure for diabetic food recommendation.

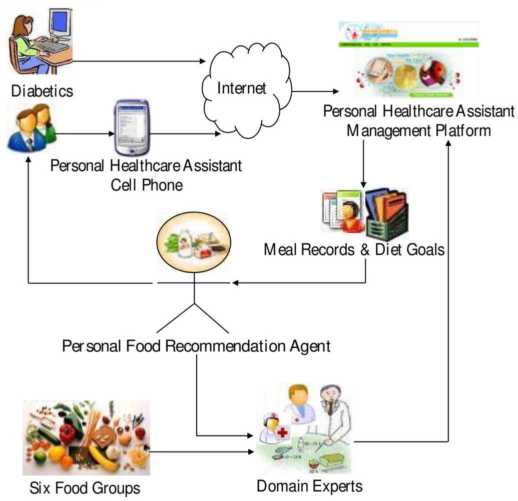


Fig. 1. System structure for diabetic food recommendation.

First, the nutrition facts for some popular food eaten in Taiwan are defined by domain experts and then stored in the personal healthcare assistant management platform. The information about each food's nutrition facts contains the amount of various nutrients, calorie, portion size, and servings of six food groups, In addition, the domain experts also estimate the unique daily calorie goal for each person's meals a day. Diabetics then login the constructed platform, a personal healthcare assistant management platform or a personal healthcare assistant cell phone, to keep a daily food record. Through the Internet, the collected information about diabetics' eating habits, including the amount of food, type of food, and the date and time having meals, is stored on the personal healthcare assistant management platform. Next, the personal food recommendation agent retrieves the collected meal records and the pre-estimated diet goals to build the Taiwanese food ontology and a set of personal food ontology. Afterwards, the agent performs fuzzy operations to recommend a personal menu for dinner according to the personal food ontology. Finally, the domain experts evaluate if the recommended menus meet a balanced and healthy diet.

B. Ontology Model

There are two types of ontology applied to this paper: the Taiwanese food ontology and the personal food ontology. The food pyramid divides food items into six major groups, including grains & starches group, vegetables group, fruits group, milk group, meats & proteins group, and fats group. In Fig. 2, we provide an illustrative example of the Taiwanese food ontology. The definition of the ontology can be referred in Ref. [2][3][4][5]. The domain layer represents the domain name of the ontology, "Six Food Groups." The categories in the category layer include "Grains & Starches," "Vegetables," "Fruits," "Milk," "Meats & Proteins," and "Fats." Each concept in the instance layer contains a concept name with several attributes, such as food's portion size, nutrition facts per 100g or 100cc, and servings of six food groups per portion.

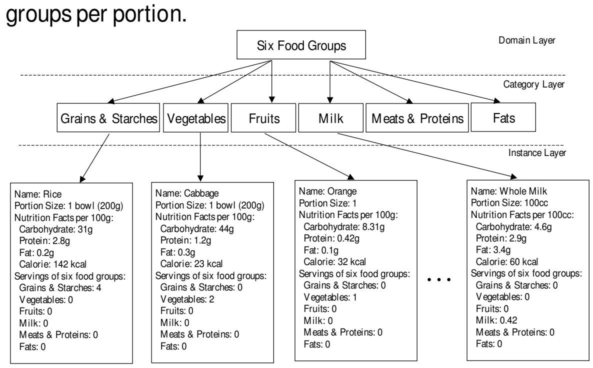


Fig. 2. Illustrative example of Taiwanese food ontology.

Next, we introduce the personal food ontology for the proposed agent. People's eating habits vary by the individual, and may be influenced by original nationality, personal preference, social status, economic position, and region. Therefore, the domain experts such as a medical expert or a health expert would plan the unique diet goal for each person to meet a balanced diet. The Harris-Benedict Equation [13], listed in Table I, is commonly used to figure out the energy requirements based on each person's sex, height, weight, and age. So, first the domain experts plan how many calories each patient needs per day according to the Harris-Benedict Equation. Then, the domain experts multiply by a factor of 1.2~1.5 to account for extra calories according to the patient's physical activity. Table II lists the recommended percent of the daily intake for carbohydrate, protein, and fat. Table III shows the well-balanced diet for an adult Taiwanese. Finally, the domain experts set how many servings of each food group should be needed for each meal per person according to the Table II and Table III.

TABLE I
Harris-Benedict Equation

Sex	Basal Metabolic Rate (BMR)
Male	$66 + (13.7 \times \text{Weight}) + (5 \times \text{Height}) - (6.8 \times \text{Age})$
Female	$655 + (9.6 \times \text{Weight}) + (1.8 \times \text{Height}) - (4.7 \times \text{Age})$

TABLE II
Recommended Percent of the Daily Intake for Carbohydrate, Protein, and Fat

Nutrient	Percentage of total daily calories (%)
Carbohydrate	55~65
Protein	10~20
Fat	25~35

By taking into account all the considerations described above, the construction of the personal food ontology has been designed, shown in Fig. 3. In the domain layer, the domain name is "Personal Food Ontology." The category layer is composed of "Profile," "Diet Goals," "Favorite

Food." Some parts of the adopted instances are represented in the instance layer.

TABLE III
WELL-BALANCED DIET FOR AN ADULT TAIWANESE

Six Food Groups	Serving Size	Servings a day
Grains & Starches	1 serving =1/4 bowl of cooked rice (50g) =1/4 steamed bread (30g) =1/2 bowls of rice porridge =1/2 bowls of noodle =1 slice of toast =3 pieces of soda biscuit	3~6
Vegetables	1 serving =100g raw vegetables =1 1/2 bowl of cooked vegetables	3
Fruits	1 serving =1 medium orange =1 guava =13 pills of grapes	2
Milk	1 serving =1 cup (240cc) milk =1 piece of cheese =3 tablespoons of low fat milk powder	1~2
Meats & Proteins	1 serving = 30g meat, poultry, or fish =1 piece (100g) of tofu =1 cup (240cc) of soybean milk =1 egg	4~5
Fats	1 serving =2 tablespoons of vegetable oil =2 tablespoons of peanut butter	2~3

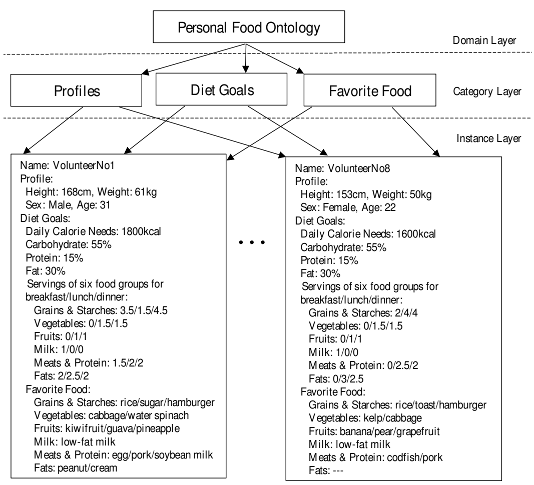


Fig. 3. Structure of the personal food ontology.

III. PERSONAL FOOD RECOMMENDATION AGENT

Figure 4 shows the detailed system structure for the personal food recommendation agent, including an ontology creating mechanism, a personal ontology filter, a food fuzzy number creating mechanism, a fuzzy inference mechanism, and a real-time food recommendation mechanism. Now, we briefly describe them as follows.

A. Ontology Creating Mechanism

The personal food recommendation agent retrieves the collected meal records from the personal healthcare assistant management platform. Then, based on the predefined nutrition facts for food, the ontology creating mechanism performs the construction of the food ontology, including the Taiwanese food ontology and the personal food ontology.

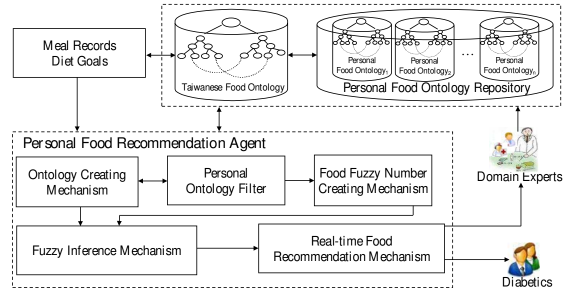


Fig. 4. System structure for a personal food recommendation agent.

B. Personal Ontology Filter & Food Fuzzy Number Creating Mechanism

The personal ontology filter carries out the individualization to build the personal food ontology and then to store the individual food ontology to the personal ontology food repository. Next, the food fuzzy number creating mechanism constructs the fuzzy numbers for each food item and the individual daily calorie requirement. In this paper, the membership function is determined using the following four fuzzy numbers, where a, b, c, and d denote the begin support, begin core, end core, and end support, respectively. Equation (1) denotes the trapezoidal membership, represented as [a, b, c, d]. Figure 5 shows the membership function for the fuzzy variable "orange(柳丁)."

$$\mathrm{trapezoid}(x:a,b,c,d)=\begin{cases}0, x<a\\(x-a)/(b-a), a\le x<b\\1, b\le x<c\\(d-x)/(d-c), c\le x<d\\0, x\ge d\end{cases} \quad (1)$$

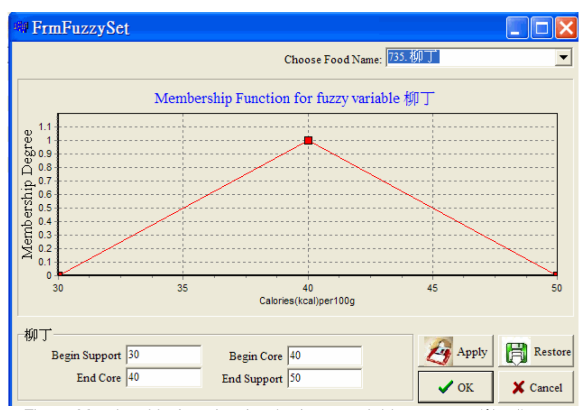


Fig. 5. Membership function for the fuzzy variable "organge(柳丁)."

C. Fuzzy Inference Mechanism

Based on the Taiwanese food ontology and the personal food ontology, the fuzzy inference mechanism performs the fuzzy operators, $f_{owa}(\tilde{m}_{A_i}, \tilde{m}_{B_i}, \tilde{m}_{C_i}, \tilde{m}_{D_i}, \tilde{m}_{E_i}, \tilde{m}_{F_i})$, to calculate the remaining calorie allowance for dinner intake. But first, we briefly introduce the basic concept of ordered weighted averaging (OWA) operator [16]. An OWA operator of dimension n is a mapping $f: R^n \rightarrow R$, that has an associated vector $W = [w_1\ w_2 \cdots w_n]^T$, such that

(1) $w_i \in [0,1]$,

(2) $\sum_{i=1}^{n} w_i = 1$.

Furthermore, $f(x_1, x_2, ..., x_n) = \sum_{j=1}^{n} w_j y_j$, where y_j is the jth largest value of the sequence of x_i, for i = 1, 2, …, n. The fundamental aspect of OWA operator is the re-ordering step. Yager pointed out that the three important special cases of OWA aggregation [16] are given below:

(1) $F^*(x_1, x_2, ..., x_n) = Max(x_1, x_2, ..., x_n)$,

$\quad$ where $W = W^* = [1\,0 \cdots 0]^T$.

(2) $F_*(x_1, x_2, ..., x_n) = Min(x_1, x_2, ..., x_n)$,

$\quad$ where $W = W_* = [0\,0 \cdots 1]^T$.

(3) $F_{Ave}(x_1, x_2, ..., x_n) = \frac{1}{n}\sum_{i=1}^{n} x_i$,

$\quad$ where $W = W_{Ave} = [\frac{1}{n}\,\frac{1}{n} \cdots \frac{1}{n}]^T$.

Hence, for any OWA operation f:

$F_*(x_1, x_2, ..., x_n) \le f(x_1, x_2, ..., x_n) \le F^*(x_1, x_2, ..., x_n)$

The OWA operator is applied to the fuzzy inference mechanism to infer the servings of each food group according to the personal food ontology. The fuzzy inference rule i is described as follows:

Rule i:

IF ($\tilde{A}_i$ is $\tilde{m}_{A_i}$) and ($\tilde{B}_i$ is $\tilde{m}_{B_i}$) and ($\tilde{C}_i$ is $\tilde{m}_{C_i}$) and ($\tilde{D}_i$ is $\tilde{m}_{D_i}$) and ($\tilde{E}_i$ is $\tilde{m}_{E_i}$) and ($\tilde{F}_i$ is $\tilde{m}_{F_i}$)

THEN

$$y_i = f_{owa}(\tilde{m}_{A_i}, \tilde{m}_{B_i}, \tilde{m}_{C_i}, \tilde{m}_{D_i}, \tilde{m}_{E_i}, \tilde{m}_{F_i})$$
$$= \frac{\tilde{m}_{A_i} \otimes \tilde{A}_i \oplus \tilde{m}_{B_i} \otimes \tilde{B}_i \oplus \tilde{m}_{C_i} \otimes \tilde{C}_i \oplus \tilde{m}_{D_i} \otimes \tilde{D}_i \oplus \tilde{m}_{E_i} \otimes \tilde{E}_i \oplus \tilde{m}_{F_i} \otimes \tilde{F}_i}{\tilde{m}_{A_i} + \tilde{m}_{B_i} + \tilde{m}_{C_i} + \tilde{m}_{D_i} + \tilde{m}_{E_i} + \tilde{m}_{F_i}}$$

The $\tilde{A}_i$, $\tilde{B}_i$, $\tilde{C}_i$, $\tilde{D}_i$, $\tilde{E}_i$, and $\tilde{F}_i$ represent the "Six Food Groups" shown in Fig. 2, including "Grains & Starches," "Vegetables," "Fruits," "Milk," "Meats & Proteins," and "Fats," respectively. In addition, the $\tilde{m}_{A_i}$, $\tilde{m}_{B_i}$, $\tilde{m}_{C_i}$, $\tilde{m}_{D_i}$, $\tilde{m}_{E_i}$, and $\tilde{m}_{F_i}$ denote the membership degree of the ith specific food belonged to $\tilde{A}_i$, $\tilde{B}_i$, $\tilde{C}_i$, $\tilde{D}_i$, $\tilde{E}_i$, and $\tilde{F}_i$, respectively.

D. Real-Time Food Recommendation Mechanism

According to the individual eating habit stored in the personal food ontology, the real-time food recommendation mechanism generates some dinner menus recommended for diabetics. Meantime, the recommended menus are also given to domain experts to confirm if they are met a balanced and healthy diet. Next, we show the detailed algorithm of the proposed personal food recommendation agent.

Personal Food Recommendation Agent Algorithm

Input:

1. All nutrition facts for all food items (FI_1, …, FI_m) predefined by domain experts.
2. Meal records for volunteers with diabetes (DM_1, …, DM_n).
3. Diet goal for all volunteers.

Output:

1. Dinner allowance for all volunteers.
2. Recommended dinner menu for all volunteers.

Method:

Step 1: For all food items (FI_1, …, FI_m)

Step 1.1: Retrieve the portion size and name.

Step 1.2: Retrieve the nutrition facts, including the amount of carbohydrate, protein, fat, and calorie per 100g or 100cc.

Step 1.3: Retrieve the servings of six food groups and the amount per portion.

Step 1.4: Construct the trapezoidal membership function for fuzzy number Calorieper100g/cc (C_{FI_i}), where $1 \le i \le m$, and denote as $[BS_{C_{FI_i}}, BC_{C_{FI_i}}, EC_{C_{FI_i}}, ES_{C_{FI_i}}]$

Step 2: According to the nutrition facts, construct the Taiwanese food ontology.

Step 3: For all volunteers with diabetes (DM_1, …, DM_n)

Step 3.1: Retrieve personal profile, including height, weight, sex, and age.

Step 3.2: Retrieve diet goal, including daily calorie needs, the recommended percentage of daily intake for carbohydrate&protein&fat, and servings of six food groups for breakfast&lunch&dinner.

Step 3.3: Retrieve the favorite food.

Step 3.4: Construct the trapezoidal membership function for fuzzy number DailyCalorieNeeds (DCN_{DM_i}), where $1 \le i \le n$, and denote as $[BS_{DCN_{DM_i}}, BC_{DCN_{DM_i}}, EC_{DCN_{DM_i}}, ES_{DCN_{DM_i}}]$

Step 4: According to the personal profile, diet goal, and favorite food, construct the personal food ontology.

Step 5: For all volunteers with diabetes (DM_1, …, DM_n)

Step 5.1: Retrieve meal records for the duration of the research project.

Step 5.2: Perform the fuzzy operations to compute the calorie used at breakfast, denoted as $[BS_{CBreakfast_{DM_i}}, BC_{CBreakfast_{DM_i}}, EC_{CBreakfast_{DM_i}}, ES_{CBreakfast_{DM_i}}]$

Step 5.2: Perform the fuzzy operations to compute the calorie used at lunch, denoted as $[BS_{CLunch_{DM_i}}, BC_{CLunch_{DM_i}}, EC_{CLunch_{DM_i}}, ES_{CLunch_{DM_i}}]$

Step 5.3: Perform the fuzzy operations to get the calories remaining at dinner, denoted as $[BS_{CDinner_{DM_i}}, BC_{CDinner_{DM_i}}, EC_{CDinner_{DM_i}}, ES_{CDinner_{DM_i}}]$

Step 5.4: According to the personal food ontology and a well-balanced diet, compute the servings of six food groups for dinner intake.

Step 5.5: Based on the servings of six food groups for dinner intake and personal food ontology, the agent recommends some dinner menus.

Step 6. End.

IV. Experimental Results

The ontological intelligent agent for diabetic food recommendation was implemented with the Borland C++ Builder programming language. The experimental environment was constructed by National University of Tainan, Institute for Information Industry, and Changhua Christian Hospital to test the performance of the proposed method. The experiment involved 8 volunteers with diabetics. The volunteers' profiles are given in Table IV. The meal records were collected by the personal healthcare assistant management platform and the personal healthcare assistant cell phone for five months. Figure 6 shows the screen shot of the proposed agent, which lists the detailed information of each food item. Figure 7 shows the second volunteer's diet goal from September 12th, 2007 to November 1st, 2007. Figure 8 shows the screen shot of daily meal records for the second volunteer.

TABLE IV
VOLUNTEERS' PROFILES

Volunteer No	Sex	Age	Height (cm)	Weight (kg)
1	Male	31	168	61
2	Male	39	169	87
3	Male	30	170	66
4	Female	27	163	65
5	Male	60	169	79
6	Male	60	167	80
7	Female	24	158	65
8	Female	22	153	50

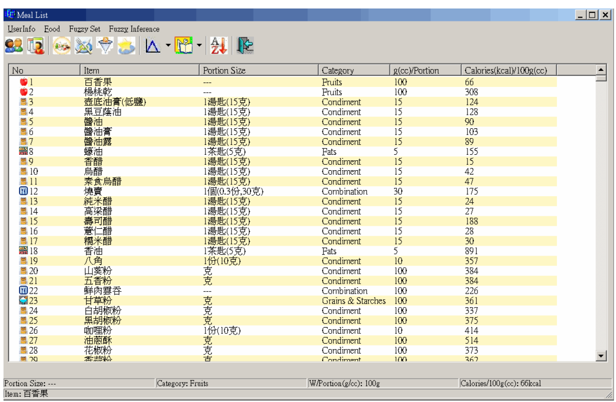


Fig. 6. Screen shot of the food items.

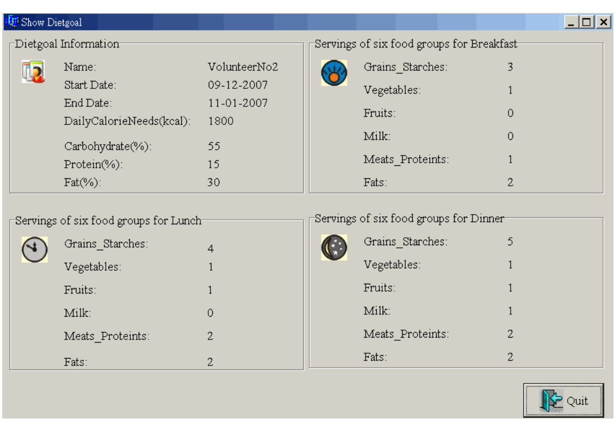


Fig. 7. Screen shot of the diet goal for the second volunteer.

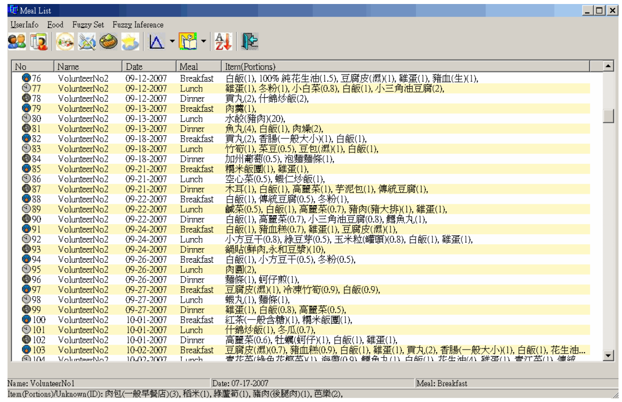


Fig. 8. Screen shot of meal records for the second volunteer.

Consider volunteer 2 as an example. Figures 9 and 10 show the breakfast and lunch intake for the second volunteer on September 24th, 2007, respectively. Figure 9 shows that the second volunteer ate "1 bowl of rice (白飯)," "0.7 portion of pigs blood cake (豬血糕)," "1 egg (雞蛋)," and "1 tofu cover (豆腐皮)," at breakfast which the total used calories were about 480kcal. Figure 10 shows that lunch intake by the second volunteer was "0.8 tablespoon of corn (玉米粒)," "1 bowl of rice (白飯)," "1 bowl of green sprouts (綠豆芽)," "0.8 portion of dried tofu (豆干)," and "1 egg (雞蛋)," which the total energy of food eaten was 470kcal.

Figure 11 shows the favorite food of each food group for the second volunteer. Then, according to the second volunteer's diet goal, shown in Fig. 7, the daily calorie needs on September 24th, 2007, are 1800 kcal, and the dinner servings of six food groups for grains & starches, vegetables, fruits, milk, meats & proteins, and fats are 5 servings, 1 serving, 1 serving, 1 serving , 2 servings, and 2 servings, respectively. Figure 12 shows the servings and many different food choices of each food group after performing the fuzzy inference mechanism. For example, in the grains & starches group, the second volunteer can choose 1.3 bowls of rice(白飯), 2.5 bowls of noodles(麵條), 2.5 bowls of bean thread noodles(冬粉), or 2.4 portions of instant noodles(泡麵) to get the calories about 5 servings of grains & starches, 350 kcal. In the fruits group, the second volunteer can choose 1 apple(青蘋果), 23 small tomatoes(聖女番茄), 1 pear(世紀梨), or 13 pills of grapes(葡萄) as the dinner intake. Figure 13 shows the four recommended dinner menus for the second volunteer on September 24th, 2007. The second volunteer can choose one of them to be as his today's dinner menu.

Besides, based on the personal food ontology, we also measure if the volunteer ate too much or too little for the volunteer's breakfast and lunch on a specific day. In Figure 14, the red, yellow, and green lights mean "eating too much," "eating too little," and "eating just right," respectively. Figure 14 shows the evaluation results of the calories intake for the first volunteer. It indicates the first volunteer ate just right on July 20th, 2007.

V. Conclusion

This paper proposes an intelligent ontological agent for diabetic food recommendation, including an ontology creating mechanism, a personal ontology filter, a food fuzzy number creating mechanism, a fuzzy inference mechanism, and a real-time food recommendation mechanism. The needed domain knowledge is stored in the Taiwanese food ontology and the personal food ontology. The experimental results show that the proposed agent is capable of recommending an individual dinner menu according to the pre-constructed domain ontology. In the future, the Type-2 fuzzy set would be introduced to create the membership functions of the Taiwanese food ontology and personal food ontology. Besides, the semantic inference and the adaptive learning capabilities will be added to the proposed agent to enhance the performance and the ability of the intelligent ontological agent.

Acknowledgment

The authors would like to thank the experts of diabetes education center, Changhua Christian Hospital, Changhua, Taiwan, for their constructive and useful comments.

References

[1] American Diabetes Association, "Standards of medical care in diabetes-2007," Diabetes Care, vol. 30, no. 1, pp. S4-S41, Jan. 2007.

[2] C. S. Lee, Z. W. Jian, and L. K. Huang, "A fuzzy ontology and its application to news summarization," IEEE Trans on Systems, Man, and Cybernetics, Part B, vol. 35, no. 5, pp. 859-880, Oct. 2005.

[3] C. S. Lee, Y. F. Kao, Y. H. Kuo, and M. H. Wang, "Automated ontology construction for unstructured text documents," Data & Knowledge Engineering, vol. 60, no. 3, pp. 547-566, 2007.

[4] C. S. Lee and M. H. Wang, "Ontology-based intelligent healthcare agent and its application to respiratory waveform recognition," Expert Systems with Applications, vol. 33, no. 3, pp. 606-619, 2007.

[5] C. S. Lee and M. H. Wang, "Ontological fuzzy agent for electrocardiogram application," Expert Systems with Applications, vol. 37, no. 3, 2007. Digital Object Identifier: 10.1016/j.eswa.2007.08.025.

[6] H. Yan, Y. Jiang, J. Zheng, C. Peng, and Q. Li, "A multiplayer perceptron-based medical decision support system for heart disease diagnosis, Expert Systems with Applications, vol. 30, no. 3, pp. 272-281, 2006.

[7] J. Ferber, "Multi-Agent Systems," Addison-Wesley: New York, 1999.

[8] M. S. Hamdi, "MASACAD: A multiagent based approach to information customization," IEEE Intelligent System, vol. 21, no. 1, pp. 60-67, 2006.

[9] C. S. Lee, M. H. Wang, and J. J. Chen, "Ontology-based intelligent decision support agent for CMMI project monitoring and control," International Journal of Approximate Reasoning, 2007. Digital Object Identifier: 10.1016/j.ijar.2007.06.007.

[10] D. U. Campos-Delgado, M. Hernandez-Ordonez, R. Femat, and A. Gordillo-Moscoso, "Fuzzy-based controller for glucose regulation in type-1 diabetic patients by subcutaneous route," IEEE Trans. on Biodmedical Engineering, vol. 53, no. 11, pp. 2201-2210, Nov. 2006.

[11] L. D. Lascio, A. Gisolfi, A. Albunia, G. Galardi, and F. Meschi, "A fuzzy-based methodology for the analysis of diabetic neuropathy," Fuzzy Sets and Systems, vol. 129, no. 2, pp. 203-228, 2002.

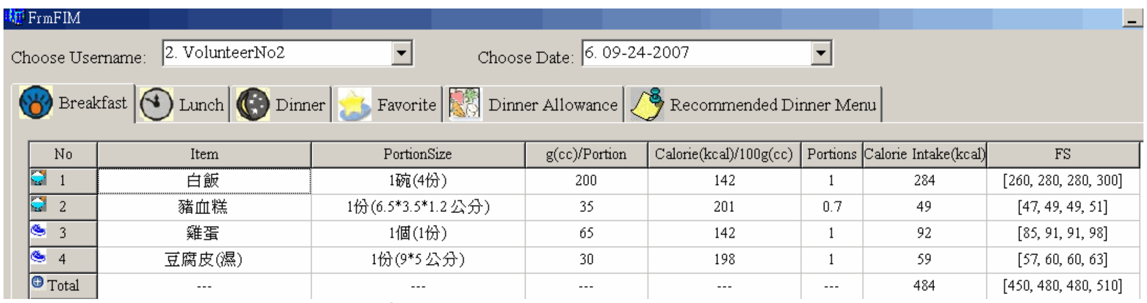
[12] G. Hu and J. Tuomilehto, "Lifestyle and outcome among patients with type 2 diabetes," International Congress Series, vol. 1303, pp. 160-171, 2007.

[13] D. C. Frankenfield, E. R. Muth, W. A. Rowe, "The harris-benedict studies of human basal metabolism: history and limitations," Journal of the American Dietetic Association, vol. 98, no. 4, pp. 439-445, 1998.

[14] American Diabetes Association, http://www.diabetes.org/home.jsp.

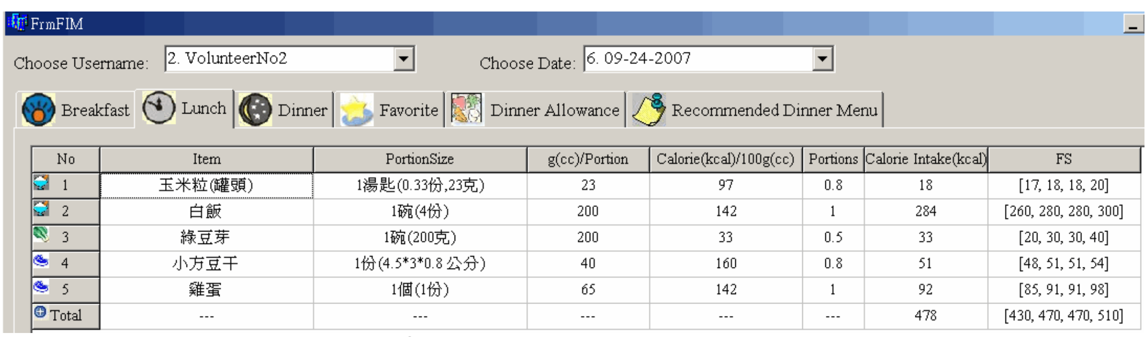
[15] Department of Health, http://www.doh.gov.tw/CHT2006/index_populace.aspx

[16] R. R. Yager, "On ordered weighted averaging aggregation operators in multicriteria decisionmaking," IEEE Trans on Systems, Man, and Cybernetics, vol. 18, no. 1, pp. 183-190, 1988.



No	Item	PortionSize	g(cc)/Portion	Calorie(kcal)/100g(cc)	Portions	Calorie Intake(kcal)	FS
1	白飯	1碗(4份)	200	142	1	284	[260, 280, 280, 300]
2	豬血糕	1份(6.5*3.5*1.2 公分)	35	201	0.7	49	[47, 49, 49, 51]
3	雞蛋	1個(1份)	65	142	1	92	[85, 91, 91, 98]
4	豆腐皮(濕)	1份(9*5 公分)	30	198	1	59	[57, 60, 60, 63]
Total	---	---	---	---	---	484	[450, 480, 480, 510]

Fig. 9. Screen shot of breakfast intake for the second volunteer.



No	Item	PortionSize	g(cc)/Portion	Calorie(kcal)/100g(cc)	Portions	Calorie Intake(kcal)	FS
1	玉米粒(罐頭)	1湯匙(0.33份,23克)	23	97	0.8	18	[17, 18, 18, 20]
2	白飯	1碗(4份)	200	142	1	284	[260, 280, 280, 300]
3	綠豆芽	1碗(200克)	200	33	0.5	33	[20, 30, 30, 40]
4	小方豆干	1份(4.5*3*0.8 公分)	40	160	0.8	51	[48, 51, 51, 54]
5	雞蛋	1個(1份)	65	142	1	92	[85, 91, 91, 98]
Total	---	---	---	---	---	478	[430, 470, 470, 510]

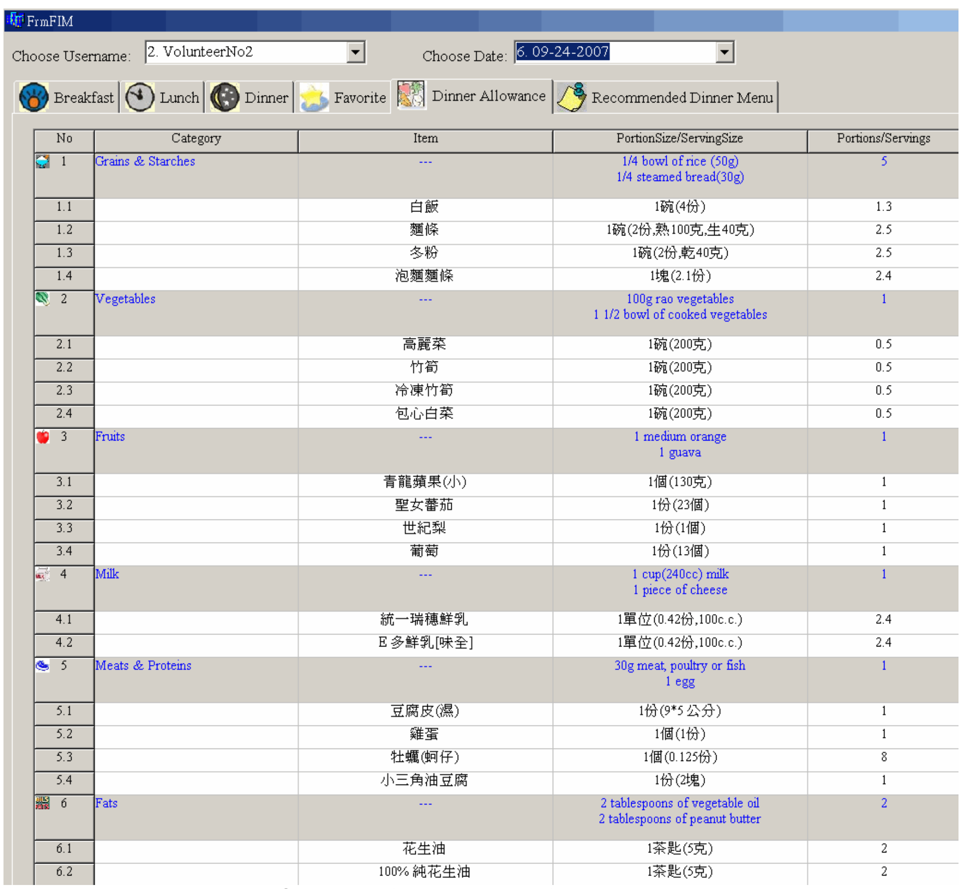
Fig. 10. Screen shot of lunch intake for the second volunteer.


FrmFIM
Choose Username: 2. VolunteerNo2
Choose Date: 6. 09-24-2007
Breakfast | Lunch | Dinner | Favorite | Dinner Allowance | Recommended Dinner Menu

No	Item	PortionSize	g(cc)/Portion	Calorie(kcal)/100g(cc)	Portions	Calorie Intake(kcal)	FS
1.1	白飯	1碗(4份)	200	142	1	284	[260, 280, 280, 300]
1.2	麵條	1碗(2份,熟100克,生40克)	40	357	1	143	[140, 144, 144, 148]
1.3	冬粉	1碗(2份,乾40克)	40	349	1	140	[136, 140, 140, 144]
1.4	泡麵麵條	1塊(2.1份)	60	472	1	283	[276, 282, 282, 288]
2.1	高麗菜	1碗(200克)	200	23	1	46	[20, 40, 40, 60]
2.2	竹筍	1碗(200克)	200	22	1	44	[20, 40, 40, 60]
2.3	冷凍竹筍	1碗(200克)	200	17	1	34	[20, 40, 40, 60]
2.4	包心白菜	1碗(200克)	200	12	1	24	[0, 20, 20, 40]
3.1	青龍蘋果(小)	1個(130克)	130	46	1	60	[52, 65, 65, 78]
3.2	聖女蕃茄	1份(23個)	175	35	1	61	[53, 70, 70, 88]
3.3	世紀梨	1份(1個)	200	30	1	60	[40, 60, 60, 80]
3.4	葡萄	1份(13個)	130	46	1	60	[52, 65, 65, 78]
4.1	統一瑞穗鮮乳	1單位(0.42份,100c.c.)	100	65	1	65	[60, 70, 70, 80]
4.2	E 多鮮乳[味全]	1單位(0.42份,100c.c.)	100	40	1	40	[30, 40, 40, 50]
5.1	豆腐皮(濕)	1份(9*5 公分)	30	198	1	59	[57, 60, 60, 63]
5.2	雞蛋	1個(1份)	65	142	1	92	[85, 91, 91, 98]
5.3	牡蠣(蚵仔)	1個(0.125份)	8	77	1	6	[6, 6, 6, 7]
5.4	小三角油豆腐	1份(2塊)	55	138	1	76	[72, 77, 77, 83]
6.1	花生油	1茶匙(5克)	5	883	1	44	[44, 44, 44, 45]
6.2	100% 純花生油	1茶匙(5克)	5	883	1	44	[44, 44, 44, 45]
8.1	紅茶(一般含糖)	1單位(0.57份,100c.c.)	100	34	1	34	[20, 30, 30, 40]
9.1	素食高湯(香菇雞)	---	100	17	1	17	[10, 20, 20, 30]
10.1	魚丸	1顆(0.15份,11克)	11	140	1	15	[14, 15, 15, 17]
10.2	蝦丸	1顆(0.19份,20克)	20	113	1	23	[20, 22, 22, 24]
10.3	香腸(鮪魚,一般大小)	1條(1份)	40	335	1	134	[132, 136, 136, 140]
10.4	溫州餛飩	1個(0.6份,35克)	35	141	1	49	[46, 49, 49, 53]

Inference | Quit

Fig. 11. Screen shot of favorite food for the second volunteer.


FrmFIM
Choose Username: 2. VolunteerNo2
Choose Date: 6. 09-24-2007
Breakfast | Lunch | Dinner | Favorite | Dinner Allowance | Recommended Dinner Menu

No	Category	Item	PortionSize/ServingSize	Portions/Servings
1	Grains & Starches	---	1/4 bowl of rice (50g) 1/4 steamed bread(30g)	5
1.1		白飯	1碗(4份)	1.3
1.2		麵條	1碗(2份,熟100克,生40克)	2.5
1.3		冬粉	1碗(2份,乾40克)	2.5
1.4		泡麵麵條	1塊(2.1份)	2.4
2	Vegetables	---	100g rao vegetables 1 1/2 bowl of cooked vegetables	1
2.1		高麗菜	1碗(200克)	0.5
2.2		竹筍	1碗(200克)	0.5
2.3		冷凍竹筍	1碗(200克)	0.5
2.4		包心白菜	1碗(200克)	0.5
3	Fruits	---	1 medium orange 1 guava	1
3.1		青龍蘋果(小)	1個(130克)	1
3.2		聖女蕃茄	1份(23個)	1
3.3		世紀梨	1份(1個)	1
3.4		葡萄	1份(13個)	1
4	Milk	---	1 cup(240cc) milk 1 piece of cheese	1
4.1		統一瑞穗鮮乳	1單位(0.42份,100c.c.)	2.4
4.2		E 多鮮乳[味全]	1單位(0.42份,100c.c.)	2.4
5	Meats & Proteins	---	30g meat, poultry or fish 1 egg	1
5.1		豆腐皮(濕)	1份(9*5 公分)	1
5.2		雞蛋	1個(1份)	1
5.3		牡蠣(蚵仔)	1個(0.125份)	8
5.4		小三角油豆腐	1份(2塊)	1
6	Fats	---	2 tablespoons of vegetable oil 2 tablespoons of peanut butter	2
6.1		花生油	1茶匙(5克)	2
6.2		100% 純花生油	1茶匙(5克)	2

Fig. 12. Screen shot of dinner allowance for the second volunteer.

FrmFIM

Choose Username: 2. VolunteerNo2 Choose Date: 6. 09-24-2007

Breakfast | Lunch | Dinner | Favorite | Dinner Allowance | Recommended Dinner Menu

No	Item	PortionSize	Portions
1	Menu 1:	---	---
	白飯	1碗(4份)	1.3
	高麗菜	1碗(200克)	0.5
	青龍蘋果(小)	1個(130克)	1
	統一瑞穗鮮乳	1單位(0.42份,100c.c.)	2.4
	豆腐皮(濕)	1份(9*5 公分)	1
	花生油	1茶匙(5克)	2
2	Menu 2:	---	---
	麵條	1碗(2份,熟100克,生40克)	2.5
	竹筍	1碗(200克)	0.5
	聖女蕃茄	1份(23個)	1
	E 多鮮乳[味全]	1單位(0.42份,100c.c.)	2.4
	雞蛋	1個(1份)	1
	100% 純花生油	1茶匙(5克)	2
3	Menu 3:	---	---
	冬粉	1碗(2份,乾40克)	2.5
	冷凍竹筍	1碗(200克)	0.5
	世紀梨	1份(1個)	1
	E 多鮮乳[味全]	1單位(0.42份,100c.c.)	2.4
	雞蛋	1個(1份)	1
	100% 純花生油	1茶匙(5克)	2
4	Menu 4:	---	---
	泡麵麵條	1塊(2.1份)	2.4
	包心白菜	1碗(200克)	0.5
	葡萄	1份(13個)	1
	E 多鮮乳[味全]	1單位(0.42份,100c.c.)	2.4
	雞蛋	1個(1份)	1
	100% 純花生油	1茶匙(5克)	2

Fig. 13. Screen shot of dinner menu for the second volunteer.

Diet Alarm

No	Name	Date	Dietgoal	Breakfast	Lunch	RemainingDinner
1	VolunteerNo1	07-17-2007	1800	1080	180	450
2	VolunteerNo1	07-18-2007	1800	750	670	290
3	VolunteerNo1	07-19-2007	1800	180	120	1410
4	VolunteerNo1	07-20-2007	1800	300	700	710
5	VolunteerNo1	07-21-2007	1800	1400	960	-650
6	VolunteerNo1	07-23-2007	1800	60	1030	620
7	VolunteerNo1	07-27-2007	1800	890	1630	-810
8	VolunteerNo1	07-28-2007	1800	720	500	490
9	VolunteerNo1	07-30-2007	1800	480	1510	-280
10	VolunteerNo1	07-31-2007	1800	920	550	240
11	VolunteerNo1	08-01-2007	1800	480	560	670
12	VolunteerNo1	08-02-2007	1800	330	660	720
13	VolunteerNo1	08-05-2007	1800	70	640	1000
14	VolunteerNo1	08-08-2007	1800	1090	700	-80
15	VolunteerNo1	08-09-2007	1800	440	590	680
16	VolunteerNo1	08-10-2007	1800	470	280	960
17	VolunteerNo1	08-11-2007	1800	940	180	590
18	VolunteerNo1	08-13-2007	1800	1000	410	300
19	VolunteerNo1	08-14-2007	1800	370	620	720
20	VolunteerNo1	08-15-2007	1800	370	640	700
21	VolunteerNo1	08-16-2007	1800	210	780	720
22	VolunteerNo1	08-17-2007	1800	440	1040	230
23	VolunteerNo1	08-18-2007	1800	750	640	320
24	VolunteerNo1	08-19-2007	1800	60	450	1200
25	VolunteerNo1	09-07-2007	1800	480	560	670

Fig. 14. Evaluation result of the calories intake for the first volunteer.