

A Knowledge-based Framework for Development of Personalized Food Recommender System

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Abstract

The personalized food recommender system aims to assist the users in daily diet selections based on some nutrition guidelines. This paper describes a food ontology and recommender system development using a knowledge-based framework. The main components of the system are user personal profiles, food and nutrition database and knowledge base. The developed food and nutrition ontology is integrated with rule-based knowledge in providing food recommendations based on the user's nutrition requirements as well as food preference.

Keywords: Ontology Development, Food and Nutrition Ontology, Personalization

1 Introduction

Food is among the most basic human needs. Proper dietary habit can generally promote good health. However, each person's diet need is typically varied based on some individual factors including gender, age, physical differences or health status. In addition, each person usually differs in terms of food preference. Thus, a diet selection that balances between the individual need and preference is often challenging.

Some chronic illnesses are generally known to relate to dietary habits, such as obesity, diabetes, and heart diseases, etc. Thus, lifestyle modification, i.e. changing dietary habits, is increasingly promoted as an effective mechanism

in disease prevention and treatment. In addition, the information provided for patients should take into account each patient's distinctive life circumstances.

This paper focuses on development of a personalized food recommender system that can provide dietary recommendations, which are based on both individual diet needs and preference. The design of the system uses a knowledge-based framework. Specifically, the knowledge engineering approach is used in modeling the relevant user profile as well as food and nutrition knowledge in an ontology form. The ontology and some rule-based knowledge are used as the basis for constructing a knowledge base in providing the user recommendations. Both the ontology and system development processes are elaborated and exemplified.

2 Related Works

Cantais et al. [1] designed food ontology for diabetes control from a nutrition viewpoint to support health care of diabetes patients in 2005. The ontology was developed based on some referenced nutrition guides for diabetes patients. The food ontology consists of 177 classes 53 properties and 632 instances. The 13 major classes of food types were defined including beverages, fruits, grain products, meat, etc. Some defined properties included amount of nutrition, e.g. fat, fiber, carbohydrate, etc.

The Food-Oriented Ontology-Driven System (FOODS) [2] is a food search system designed

primarily for restaurant, clinic or home uses. The system applied food ontology in supporting the user to search for food menu. The food classes were defined from nine major aspects including ingredients, nutrition, cooking instruments, cooking processes, price, etc.

The intelligent ontological agent for diabetic food recommendation [3] applied ontology in developing a food recommender system for diabetes patients. Two main ontologies were developed: Taiwanese food ontology consists of food items divided into six major groups: rice and grains, vegetables, fruits, milk, fats, meat and protein. The personalized food ontology consists of three main groups of the user profiles: personal profile, diet goals and favorite foods. The system can recommend some food choices for the user's dinner menu using a fuzzy inference mechanism.

Our work adopted some food ontology design schemes from [1-3]. However, comparing to [1,2], our work differs in focusing more on personalization of recommendation results. We extended the personalized food ontology defined in [3] by adding the information related to user's health status that may affect the user's nutrition need. In addition, our recommendations results were based on the recommendations from a clinical practice guideline document, which were transformed into rule-based knowledge. The clinical practice guideline provided reliable knowledge that was agreeable in terms of expert opinions.

3 Knowledge Framework

This section describes a knowledge-based framework used in the food recommender system development (see figure 1). This section focuses on acquisition and access of the knowledge related to food and nutrition as well as user health status. It consists of two main components: knowledge base and recommender engine.

Knowledge Base. The construction of the knowledge base basically relied on some domain experts, nutrition guides and clinical practice guidelines. It consists of two forms of knowledge: ontology and rules. The ontology-based knowledge represents knowledge structure of food and their relations. In addition, it also represents knowledge structure of

user and user's health-related status. The rule-based knowledge represents decision model used in generating recommendation results.

Recommender Engine. The recommender engine processes the ontology data in OWL format from the knowledge base. It also performs database to ontology mapping process using the RDF model in order to manipulate the database records according to the ontology structure. The rule-based knowledge is subsequently applied to the data in producing the recommendation results. The Jena API is mainly used in manipulating the knowledge base data.

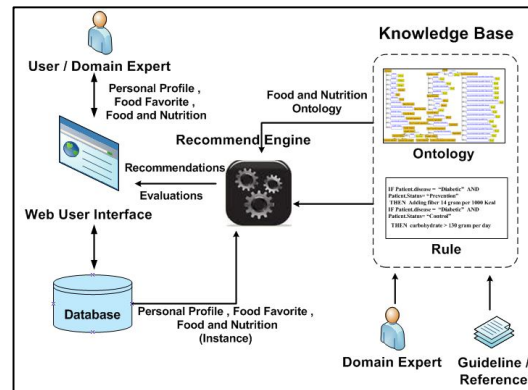


Figure 1. Knowledge-based framework for the food recommender system

4 Design and Implementation

4.1 Ontology Development

The personalized food ontology was developed using the Hozo ontology editor (see figure 2). The development process was based on the methodology. It involved defining classes, class hierarchies, properties, and property constraints. The personalized food ontology consists of 710 classes 94 properties. The ontology was modeled based on two main concepts: Person and Food Menu concepts.

Person Concept. The "Person" class represents an abstract concept of personal profile which involves both person's health-related status and food-related preference.

- "Person" is a major class which contains user profile and preference. Its attributes include personal data such as age, BMI, etc.

Table 1. Some examples of usage scenarios consisting of the user scenarios and the recommendation rules that applied.

Scenarios	Recommendation Rules
Mr. A prefers no- meat diet. His BMI (Body Mass Index) value is 24.	IF Person.BMI \geq 24 AND Person.unFavoriteIngredient = Meat THEN Person.RecommendedFood_ingredientType = (Low_Calorie AND Vegetable)
Ms. B wants to have diet that promotes diabetes prevention. She likes having fish. Her BMI is 27.	IF Person.BMI \geq 24 AND Person.healthStatus = PreventDiabetic AND Person.favoriteIngredient = Fish THEN Person.RecommendedFood_ingredientType = (Fish AND Low_Calorie AND High_Fiber) AND Person.recommendedFood_processType = Steaming
Mr. C is a diabetes patient who wants strictly controlled diet. He doesn't eat vegetables.	IF Person.healthStatus = ControlAndPreventComplication AND Person.unFavoriteIngredient = Vegetable THEN Person.recommendedFood_ingredientType = (Low_Sodium AND Low_Calorie AND High_Fiber AND Meat) OR Person.recommendedFood_ingredientType = (Low_Sodium AND Low_Calorie AND High_Fiber AND Cereals)

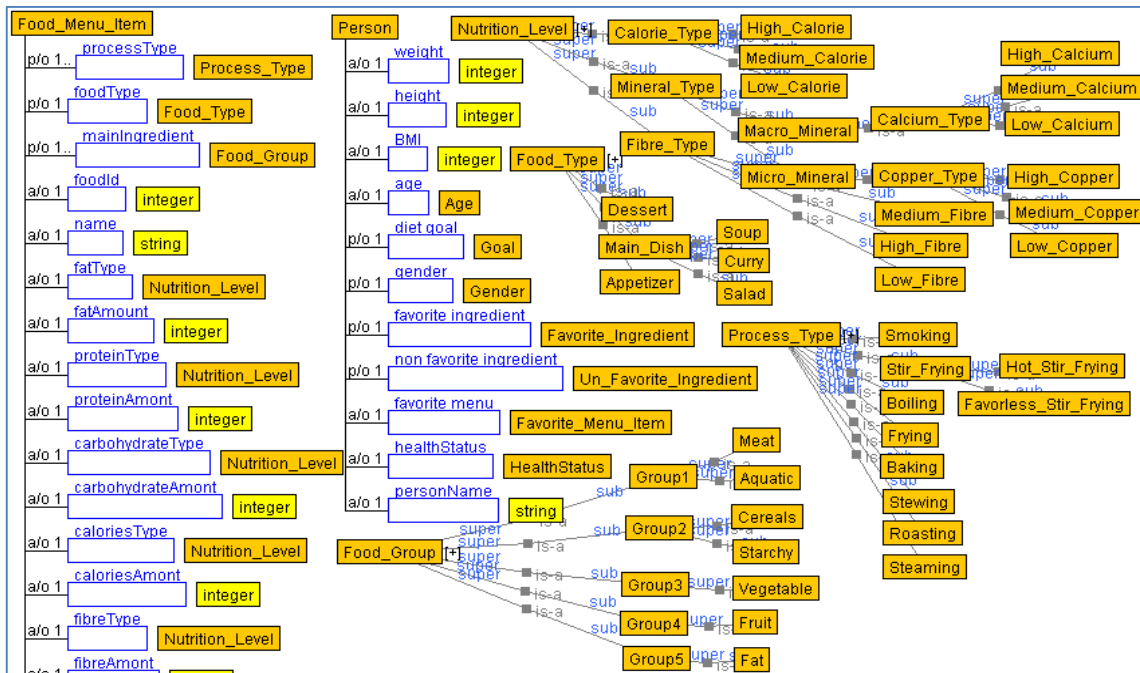


Figure 2. The personalized food ontology

- “Health status” represents current health status of person. Different degrees of preventive status, which can affect the food recommendation.
- “Goal” represents person’s daily diet goals.
- “Favorite Menu” represents person’s preference for some food dishes.
- “Favorite Ingredient” represents person’s preference for some ingredients containing in a food dish.
- “Un-favorite Ingredient” represents person’s dislike for some ingredients containing in a food dish.

- “Meal Record” represents the information related to person’s daily meals (i.e., list of food dishes for each meal)

Food Concept. The “Food” class represents an abstract concept of food item which involves food types, cooking methods, food group and nutrition level.

- “Food Menu Item” is a major class of food concept which is related to food types, cooking methods, food groups, and nutrition level.

- “Food Type” represents type of food item which divided into three groups: appetizer, dessert, main dish.

- “Process Type” represents cooking method of food item (i.e., Stir frying, Frying, Steaming, Boiling, Baking, etc.)
- “Food Group” represents group of food ingredients which divided into five groups follow on Thai foods.
- “Nutrition Level” represents level of nutrition which are groups based on nutrition value (i.e., Fiber Type consists of High Fiber, Medium Fiber and Low Fiber, etc.)

4.2 Defining Rules

The rule-based knowledge was defined based on some recommendations from a clinical practice guideline document, i.e. the clinical guideline for diabetes care issued by Thailand’s Ministry of Public Health [4]. The recommendations were subsequently transformed into rule-based knowledge using a rule editor. Rule conditions can be defined based on the terms defined in the ontology. Recommendation results must also be defined in generating inference results.

Table 1 exemplifies some user’s health conditions and preferences and recommendations rules that can be applied. The more restrictions the user has, the less number of recommended food items will appear in his or her recommendation results.

4.3 Food Search and Recommender System

User Profile

Name : Nisa Tongdee

Age : 26

Height : 161 cm.

Weight : 55 kg.

BMI : 21.48

Health Status : Control Diabetic

Evaluation Results

You have normal BMI but you have diabetes.

Food Recommendations

<input type="checkbox"/>	Food Name	Dish Type	Process Type	Energy	Ingredient
<input type="checkbox"/>	แกงจืดผักกวาง	Main Dish	Boiling	150.00	Chinese white cabbage, Paakwaan
<input type="checkbox"/>	ซุปผักฤดูร้อน	Main Dish	Boiling	189.25	Garden peas young pods, potato, Carrot, Yard long Beans Green
<input type="checkbox"/>	ผัดเนยข้าวโพด	Main Dish	Stir Frying	136.80	Cucumber, Corn whole kernel baby, Tomato, Cabbage, Pineapple

Figure 3. Show an example of a user interface for food recommendation results

A food search and recommender system was developed to process the ontology data in OWL format from the knowledge base. It also performed database to ontology mapping

process using the RDF model in order to manipulate the instance data according to the ontology structure. Subsequently, the rule-based knowledge was applied in producing the recommendation results.

The user can view the food items that were recommended (see Figure 3). In searching for food, food conditions for the user is transformed into SPARQL query in retrieving food items from the knowledge base. The food conditions were defined based on the defined concepts and properties in the ontology.

5 Conclusion

This paper describes development of a personalized food recommender system using the knowledge-based framework. The knowledge base construction focuses on ontology and rule-based knowledge development. The knowledge-based food recommender system can be extended to support some healthcare application development, e.g., meal suggestion system for hospital patients or to support preventive healthcare, etc.

Our future works include evaluation of the developed food ontology by nutrition experts and evaluation of the recommender system based on user questionnaire similar to [5].

References

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