Ontology Modelling of Malaysian Food Exchange List

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Abstract: Designing dietary menu planning is a complex problem-solving task. It involves several constraints and extensive common sense. Case-based reasoning (CBR) solves the complexity by storing an expert common sense in the case base. Case adaptation (CA) is important for design task using CBR since old cases are partially similar as a current one. An automatic CA mainly focused on the processing level rather than at the data level. On the other hand, semantic technology (ST) inserts the intelligence features by shifting the focus on the application code to the data. This can leverage the burden on the logical processing of adaptation engine. Ontology is a prerequisite in ST. Thus, this research proposes a computational model of design CA using an ontological approach. This paper discusses the experience we gained during the process of ontology modelling based on the OD101 method. The Malaysian food ontology was successfully developed to make the domain assumptions explicit in supporting the reasoning process of case adaptation for dietary menu planning recommendation.

1 INTRODUCTION

Designing a dietary menu planning is a complex process. A dietitian needs to incorporate several constraints, including numeric nutrition constraints, personal food preferences and aesthetic criteria. All of these constraints have to simultaneously satisfy. Marling et al., (1999) stated at least three factors that make designing dietary menu planning difficult i.e. interrelated and unconstructive constraints and extensive of common sense. Common sense is vital in order to generate the sensible menu for a patient. Although few applications (Noah et al., 2004; Saludin et al., 2010; Chien-Yeh et al., 2011) have been developed to assist in dietary menu planning, they are still lack the common sense elements. It is difficult to design dietary menu planning from scratch due to the great amount of the common sense. Marling (1996) proposed Case-Based Reasoning (CBR) as the solution to this problem. By using CBR, the menu generated will never go implausible because the expert's common sense were embedded in the case base.

Design is one of the synthesis tasks in CBR. It involves the redesign process to generate a new design solution. This process is essential because existing design is rare to exactly match the demands of a new requirement. In CBR, redesign is performed by case adaptation. Case adaptation is the most difficult of CBR's cycle to be implemented specifically when involving constraints. Extensive application code programming is required for their heuristics process in automatic adaptation. In other words, efforts in automating the case adaptation algorithm have been mainly focused at the processing level rather than at the data level. Any changes in the adaptation algorithm require extensive changes to the developed programming code.

The emergence of semantic technology (ST) can leverage the burden on the processing level of adaptation strategy since the intelligence aspect is encoded in the data rather than embedded in the application code. The reasoning process of adaptation strategy executed by means of ontology which is the main component in ST. Thus, this research aims to propose a computational model using an ontological approach for design case adaptation.

In this paper, we discuss how to model and

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develop the ontology which supports the constraint-based case adaptation of a domain. The domain in concern is the dietary menu planning for diabetic patients where various constraints must be met before a suitable menu can be generated. To this aim, the paper is structured as follows. The domain of dietary menu planning for diabetic is concisely described in section 2. Section 3 explains the motivating scenarios of the application. Section 4 discussed the tasks executed according to the ontology development methodology to build the ontology. The experience gained from the ontology development is discussed in section 5. And finally, section 6 concludes the implementation of the ontology.

2 DIETARY MENU PLANNING – THE DOMAIN

Dietary menu planning focus on a patient where therapeutic diet is one of the treatments that can improve their health conditions. Diabetes is one of the diseases where healthy eating is the key feature in its treatment plan. Healthy eating can be achieved through balanced intake of macronutrients i.e. carbohydrate, protein and fat. A dietitian works out with a diabetic to design a healthy personalized dietary menu plan. This menu plan not only sounds nourish but, it has to consider the personal food preferences of a diabetic.

Foods are groups into eight main groups, including starch, vegetables, fruits, milk and yogurt, seafood, meat, plant-based proteins and fats. Each food contains nutritional values i.e. energy, macronutrients, vitamins and minerals such as sodium and potassium. Foods are measured according to its serving size. The unit of serving size is refer using a household measures such as cup, slice, tablespoon and teaspoon. The food groups, the nutrient values and the serving size are referred as general information of foods and also known as nutrient data. In Malaysia, these nutrient data are published in the food composition database namely nutrient composition of Malaysian foods (Tee et al., 1997). Another reputable source that provides nutrient data is the Unites States Department of Agriculture (USDA) nutrient database.

Other information that can be tagged on a food such as does the food contains any one of eight allergy foods i.e. milk, egg, peanut, tree nuts, fish, shellfish, wheat, and soy, the suitable time to take this food, is it during breakfast, lunch or dinner, is this food has been allowed in a religion, which cultural this food is belong, is this food a superfood for a diabetic. This information is referred as the auxiliary information to the food.

The nutrient data is used for numerical nutrition constraints in dietary menu planning system. This data is required to calculate the total of energy, macronutrients, cholesterol, vitamins and minerals. At this point, serving size plays very important role to ensure the dietary menu planning do not exceed the proportion of macronutrients that has been allocated to a diabetic according to their calorie needs. Nevertheless, serving size calculation is a challenging task, and it has become one of the reasons the urge of dietary menu planning automation (Kovacic, 1995).

Warshaw (2010) stressed the importance of personalization in healthy eating plan for a diabetic. Personalization is related with food preferences, including like and dislike foods, foods that cannot be eaten due to the health matter or also known as allergy foods, cultural and religious food habits. Thus, food preferences become one of the constraints needs to be fulfilled when designing a dietary menu planning. The auxiliary knowledge of foods is utilized to solve the personal food preferences constraints.

3 MOTIVATING SCENARIOS

A scenario was outlined to show how significant the ontology in solving the problems by providing possible solutions. We designed a possible scenario where ontology is used to support the reasoning process of adaptation engine in dietary menu planning application.

The main actor in our scenario is Miss Anna, who is the registered dietitian. She is specializes in diabetes medical nutrition therapy (MNT). Miss Anna wants to make a personalized dietary menu planning recommendation of her patient, John who had type-2 diabetes. At first, she calculates John's calories level which is 1800 kcal. By using this data, she is able to design the mealtime exchange table (MET) as shown in Table 1. This table is used as guideline to ensure the dietary menu planning is balanced accordingly to the eight food groups for each of the meal time. Then, she starts using the dietary menu planning system to make the recommendation based on the nutrition and personal preference constraints of her patient.

Table 1: Meal exchange table of 1800 kcal.

Food group	Exc	BF	MS	L	AS	D
Starch	9	3	-	3	-	3
Vegetable	4	-	-	2	-	2
Fruit	3	-	1	1	1	-
Milk	2	-	1	-	1	-
Fish	4	-	-	4	-	-
Meat	3	-	-	-	-	3
Plant based	1	1	-	-	-	-
Fat	8	2	-	3	1	2

Exchange (Exc), Breakfast (BF), Morning snack (MS), Lunch (L), Afternoon snack (AS), Dinner (D).

She input the patient details such as calorie level, body mass index (BMI) classification, religion and race where these data are used as indexed features, personal preferences i.e. like and dislike food, allergy and prohibit food and MET. The system retrieves the best case based on the similarity of the indexed features of new case with the old case. The best case will be adapted if it does not comply with the constraints. The first constraint is MET. The adaptation process checks whether each of the food group in MET has been fulfilled by the best case. If there is any food group in MET does not exist in the best case, adaptation engine will make a suitable recommendation of the food belong to the food group. The next constraints are the forbidden foods. The adaptation process checks does the best case consist of any forbidden food. If the best case has this kind of food, adaptation engine will substitute it with an eligible food. Adaptation process also checks the food accompaniment between foods that has been suggested by the adaptation engine so that the menu planning is sensible. Finally, it checks the serving size of food items to ensure the meal planning is within the calorie range. If the serving size is less than the required value, adaptation engine will make a recommendation of a new food to fulfil the serving size. The output from system is the recommendation of personalized dietary meal planning for the patient.

The adaptation engine use ontology to perform the semantic reasoning. A reasoner in the ontology can compute the superclass-subclass relationship or also known as *class subsumption* automatically. This feature can be used in the adaptation engine to make a recommendation of new food for MET and serving size constraints. While forbidden food and food accompaniment constraints exploit the reasoning through the *object property* that assigned to each of the food instances.

4 BUILDING THE MALAYSIAN FOOD EXCHANGE LIST ONTOLOGY

We applied the Ontology Development 101 (OD101) method proposed by Noy and Mcguinness (2001) as the guideline to build our first ontology of Malaysian foods exchange list (MyFELO).

4.1 Specification: Determine the Domain, Purpose and Scope of the Ontology

The first step in OD101 is specification where its domain, purpose and scope were defined. The representation of MyFELO is the domain of the ontology. Two main purposes of building MyFELO are to represent the general knowledge using in hierarchical form and to reason the general knowledge in supporting the constraint-based case adaptation. By identifying the scope, ontology is limits to contain the most relevant concepts that regards to the application only. Scope helps to minimize the complexity of ontology as the cost of inference is higher for complex ontology. A competency questions is a tool in determining the scope. It is a basic and simple list of questions in natural language form that need to be answered by ontology.

4.2 Specification: Reusing Existing Ontologies

Reusability is one of the facilities offered by ontology to share the domain knowledge. It can prevent an ontologist from reinventing the wheel, hence faster development progress. Hebeler et al., (2009) delineate other benefits of reuse such as simplify the domain concepts, better solution, shorter development timeline, and focus only on ontology modelling for a specific problem-solving methods of the application.

In this research, relevant existing ontologies i.e. nutritional food and cooking was considered. The nutritional food is related to the study since our domain is dietary menu planning, while cooking ontology is related with a prepared food. Eight existing ontologies that relate with the domain were analysed from its content to determine its suitability. Three most relevant ontologies were selected. There are fuzzy food ontology (FFO) (Lee et al., 2010) and type-2 fuzzy food ontology (T2FFO) (Lee et al., 2010). FFO shows how to model the raw ingredients of food, while T2FFO focus on the cooked food modelling. However, these ontologies were not available for used by others. Thus, they merely become our references for building the ontology. The food ontology by Cantais et al., (2005) was imported to MyFELO as was available for others to use.

4.3 Conceptualization: Enumerate Important Terms

The first task in conceptualization phase is to list all the related important terms of the domain to be included in the ontology. The aim of this activity is to create a comprehensive list of important terms for the key concepts. For example, important food-related terms are nutrients data for food – `energy`, `carbohydrate`, `protein`, `fat`, `fibre`, `sodium`, `cholesterol` and `serving size`; `mealtime` that is suitable for food, `food allergy`, `cultural` and `religious` that is associate with a food, food groups i.e. `starch`, `vegetables`, `fruits`, `milk and yogurt`, `meat and meat substitutes` and `fats`; different types of food, such as `raw`, `processed and cooked food`, and so on.

Intermediate representations (IRs) is the tool proposed by METHONTOLOGY (Gómez-Pérez et al., 2004) to model the conceptualize knowledge. The set of IRs represent the conceptual model in tabular or graph notations. We adapt the IRs idea in building MyFELO conceptual model.

4.4 Conceptualization: Define Class and Class Hierarchy

This phase starts with defining the class. From the list that obtained from the previous task, the terms that represent a class was selected. One of the way to identity the term as a class by looking at the term that describe object, having independent existence rather than terms that describe these objects (Noy and Mcguinness, 2001).

Next, the classes were arranged into a superclass-subclass hierarchy, or known as taxonomy. Uschold and Gruninger (1996) proposed three approaches in defining class hierarchy i.e. top-down, bottom-up and middle-out. The selection of which approach to apply is mainly depend on how an ontologist views the domain. Since we think of foods by differentiating the most general concept first, thus, we opted to top-down approach. Herein class and concept are used interchangeably.

The taxonomic relations in OD101 are referring to the Frame ontology and the OKBC ontology (Gómez-Pérez et al., 2004). Both of these ontologies are knowledge representation ontologies. Among the taxonomic relations discussed in OD101 are: *subclass-of, superclass-of, disjoint-decomposition* and *instance-of.* The subclass-of is based on “is-a” relation. A class B is a subclass of A if and only if every instance of B is also instance of A. For example, cereal is a subclass of starch; since every cereal grains is under starch food group. Superclass-of relation is the inverse of subclass-of relation. Thus, starch is the superclass for cereal. Disjoint-decomposition relation is refers to disjoint classes, where there is no common instances between them. Cereal, rice and wheat was set as disjoint classes, thus, any instance in one class cannot be an instance of another class. OD101 also explains regarding on the *multiple inheritance*, another subclass-of taxonomic relation. This relation allows a class to be subclass of several classes.

4.5 Conceptualization: Define Properties of Classes

Properties are relation between two things also known as binary relations. From the list of terms created at step 4.3, the remaining of important terms are probably the properties of the classes. The examples of remaining terms are food’s `energy`, `carbohydrate`, `protein`, `fat`, `fiber`, `sodium`, `serving size` and `allergy` of a food.

In OD101, for each property in the list, we need to associate which classes it belongs. Subclass inherits the properties of their superclass. Thus, property should relate to the most general class that belongs to it. However, this technique is no longer available for Protégé. Protégé is the ontology tool that support OD101. Thus, for this step, we refer to the tutorial of building OWL ontologies using Protégé 4 (Horridge, 2011) *Object property* and *data property* are two main types of property in OWL. The first link an individual to an individual namely relationships between individual, while the latter link an individual to data literal which they describe relationships between an individual and data values.

From the remaining important terms list, we identified the two main types of property. Object property link between an individual with an individual, while data property link between an individual with data literal. For example, food’s energy, carbohydrate, protein, fat and fiber are data property, where the data literal is float. Allergy, companion, served with and serving size are object property because it links between individual food and individual from different classes.

The naming convention for property name is prefix with the word 'has' or the word 'is' for the inverse property. It should start with a lower case letter, no spaces and the second words start with capital case letter. This naming convention helps the property become clearer to human.

4.6 Conceptualization: Create Instances

The final step in conceptualization phase is to create instances of classes. Defining an instance involve the activities of choosing a class, creating an instance of that class and assign the object or data properties value.

4.7 Implementation

During this phase, the conceptual model is transform into formal model using an ontology language. The ontology language chosen for this study is Web Ontology Language (OWL). OWL is one of the ontology markup languages based on eXtensible Markup Language (XML). OWL consists of OWL Lite, OWL DL (Description Logic) and OWL Full. OWL DL was chosen in this research as it contains the complete OWL vocabulary. Protégé 4.3 has been chosen as the ontology development tool.

5 DISCUSSION

OD101 gives a good starting point to a new ontology designer to build the ontology. It encourages a novice to make the design decision based on their own understanding and point of view towards the domain. This not rigid approach gives freedom in designing the ontology as long as the ontology capable to fulfill the requirement of an application. It proposes the iterative design process which allows the beginner to start small at the ontology. Then, the ontology is revised by assess it in the application. The refinement is made and this evolving ontology is continuing until it is complete. For instance, we started the MyFELO from the class of raw and processed food, and created the properties and instances for the breakfast's menu data, then the ontology was evaluate by using the application. After the refinement, the ontology was proceed with the second mealtime i.e. morning snack and these process are continue until the development is finish.

OD101 emphasizes more on the conceptualization activity due to the two most important tasks in ontology development contained in it. Defining the class hierarchy and the properties are explained in detail so that a beginner has thorough guidelines to follow.

One good tip that can be addressed in this method is to be consistent when using singular or plural for naming convention of concept names. Personally, we think singular for class name is better because it keep simple.

The main drawback of OD101 is the missing of management and support activities as in METHONTOLOGY. It also lack of the IRs to model the informal knowledge.

6 CONCLUSION

The purpose of this study was to develop the MyFELO according to the OD101 method. This paper has described each of the process in the method i.e. specification, conceptualization and implementation. OD101 proposes the iterative approach for the ontology development. The complexity of ontology is simplified by building an initial version and develops it gradually along the life cycle.

MyFELO consists of the nutritional and personalization aspect such as race and religion. It also includes a companion among the foods. It covers from raw to prepared foods. This ontology is used to make the domain assumptions explicit so that it can leverage the burden on the processing level of adaptation strategy in designing dietary menu planning.

This research is still in progress. We are at the stage of evaluation. The ontology development already finished and the adaptation methods are completed. To the best of our knowledge, the reasoning process of MyFELO has successfully adapt the menu of the most similar case to satisfy any constraints that demand in the current problem of dietary menu planning.

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