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YAMO: YET ANOTHER METHODOLOGY FOR LARGE-SCALE FACETED ONTOLOGY CONSTRUCTION

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Abstract

Purpose-This article proposes a brand new ontology development methodology, called Yet Another Methodology for Ontology (YAMO) and demonstrates step by step the building of a formally defined large-scale faceted ontology for food.
Design/Methodology/Approach- YAMO is motivated by facet analysis and analytico-synthetic classification approach. The approach ensures the quality of the system, more precisely; it makes the system flexible, hospitable, extensible, sturdy, dense and complete. YAMO consists of two way approach: top-down and bottom-up. Based on YAMO, domain food, formally defined large scale ontology is designed. To design the ontology and to define the scope and boundary of the domain, a group of people were interviewed to get a practical overview, which provided more insight to the theoretical understanding of the domain.
Findings- The result obtained from evaluating the ontology is a very impressive one. Based on the study it was found that 94% of the user's queries were successfully met. This shows the efficiency and effectiveness of the YAMO methodology. An evaluator opined that the ontology is very deep and exhaustive.
Practical implications – The authors envision is that the current work will have great implications on the ontology developers and practitioners. YAMO will allow the ontologists to construct a very deep, high quality and large-scale ontology.
Originality- This paper illustrates a brand new ontology development methodology and demonstrates how the methodology can be applied to build large-scale high quality domain ontology.

Keywords Methodology; Food; Restaurant Ontology; Domain Ontology; Application Ontology; Formal Ontology.
Paper type Research Paper

1. Introduction

Food is any nutritional substance that people eat or drink to stay healthy. People are taking up several professions pertaining to this industry. Careers can vary from preparing meals to helping clients to controlling weights. Professionals like chefs, nutritionists, dieticians, restaurant managers, food scientists, food critics, food tasters, cookbook authors, culinary experts, food inspectors, food photographers, food policy makers etc. to name a few, are of great demand as people are giving more importance to food and other components associated with it to stay healthy. These diverse professions connect to each other by one idea called food.

Ontology, a formal, explicit specification of a shared conceptualization (Studer *et al.*, 1998), provides a platform for knowledge sharing (Saito *et al.*, 2007). It is the best means through which knowledge can be represented, shared and distributed. Noy and McGuinness (2001) defined it as a formal explicit description of concepts or classes in a domain of discourse, with properties (roles or slots) of each concept describing various features and attributes of the concepts. Besides the identification of various attributes and relationships amongst the terms in the domain, it can potentially bring out the conceptual knowledge by establishing richer semantic relationships. Further it can be stated that, ontology can be considered as an enriched Thesaurus (Velardi *et al.*, 2001).

The current work aims to provide an unprecedented ontology development methodology, called Yet Another Methodology for Ontology (YAMO). Although, there are several ontology building methodologies available, such as, DILIGENT (Vrandecic *et al.*, 2005), which focuses on ontology evolution rather than initial ontology designing, TOVE (Gruninger and Fox, 1995), which highlights mainly upon ontology evaluation and maintenance, ENTERPRISE (Uschold *et al.*, 1995) discusses the informal and formal phase of ontology construction but is unable to clearly state how an ontological concept can be identified. KBSI IDEF5 (1994) and METHONTOLOGY (Fernandez *et al.*, 1997) provide more emphasis on ontology maintenance. Although these are the various popular approaches (Gomez-Perez *et al.*, 2004; Jones *et al.*, 1998), but there exists no such methodology, which give the detailed description of the steps along with a set of principles that are to be undertaken to build ontology.

In order to fill up the lacuna, YAMO methodology is built, which has been motivated by Ranganathan's concept of facet analysis and analytico-synthetic classification (Ranganathan, 1967). The novelty of this work lies in the fact that by applying analytico-synthetic approach, the authors demonstrate step by step the building of a formally defined large-scale faceted ontology for food, with the aid of guiding principles. The ontology construction process is illustrated considering restaurant, a possible application area of the ontology. Hence, the current ontology can also be referred as restaurant ontology. However, as described in (Dutta *et al.*, 2013) the core part, i.e., domain food is still intact in it and can be shared by all the aforementioned professionals coming under the roof of domain food by extending it further to suit their needs. Here the core part refers to the core ontology (an ontology that consists of the key concepts and properties required to describe a domain).The advantage of developing a system using facet analysis leads to the system to be flexible, hospitable, extensible, and dense and complete (Dutta *et al.*, 2011).

The rest of the paper is organized as follows: section 2 gives some background explaining the idea of analytico-synthetic approach to ontology; section 3 briefly explains the YAMO methodology; section 4 illustrates the ontology building and development by deploying YAMO and evaluation process with great details; section 5 provides statistical data of the domain; section 6 discusses the related works; section 7 finally concludes the paper with opening up the possibilities of future work in this area.

2. Background

2.1. *Faceted Approach*

The current work contributes in the design of food ontology by applying Ranganathan's analytico-synthetic approach, one of the most popular and deep-rooted approaches used for constructing ontologies. As the name suggests this approach consists of two phases: *Analysis* and *Synthesis*. In *Analysis* phase the compound and complex concepts or popularly known as ideas are broken into their fundamental ideas. These concepts/ideas are then analysed by their characteristics and are grouped together based on their similar features. The analysis phase can be conducted following two way approaches, namely, *top-down approach* and *bottom-up approach*. In case of the *Synthesis* phase, relationship is established between concepts. This is the process that leads to *facet* discovery, where a facet is a "clearly defined, mutually exclusive, and collectively exhaustive aspects, properties, or characteristics of a class or specific subject" (Taylor, 1992). Alternatively, facet is a hierarchy of homogenous group of terms (nodes), where each term in the hierarchy denotes a primitive atomic concept (Giunchiglia and Dutta, 2011).

2.2. *Two Way Approaches*

In the following a two way approaches are discussed, such as top-down approach and bottom-up approach, popularly known as *first-link-downwards* approach and *last-link-upwards* approach respectively, in Library and Information Science (LIS) discipline.

Top-down Approach:
The top-down approach involves in looking at the "big- picture" of the ontology at an abstract level. This is accomplished by building the root concepts and then gradually narrowing down to more specific concepts at the lower level related to the domain. So the top down approach proceeds from abstract level and reaches to a concrete level.

Bottom-up Approach:
The bottom-up method involves in identifying and studying the characteristics of base concepts and assembling them depending upon their similar features. These concepts are again clubbed together to form a large concept. They are yet again linked and after many such iterative processes the root concept is reached. So the bottom up approach proceeds from concrete ground and reaches to abstract level.

However both the methods have their pros and cons. The main disadvantage of the top-down method is that it is difficult to convince domain experts to come to an agreement over a domain, as one cannot enforce people to look at a domain from only one direction (Xu and Zlantanova, 2007), unless there is a valid justification for the approach. Moreover it is also nearly an impossible task to reach up to the base concept if one starts from the root concept i.e. food. The integrity of the model is lost as there is every possibility to ignore and overlook concepts at the lower levels while moving from an abstract level to a concrete base. On the other hand the bottom-up approach leads to a high level of detailing. With the ever growing nature of the universe of knowledge, the practice of listing concepts is an impractical job as the list can never be completed. So, it is quite obvious that it will lead to a lot of disagreements while selecting concepts because every new emerging concept will lead to reorganizing the entire list of concepts again. Therefore, it can be said that the bottom-up approach will not be practicable unless the totality of the concepts are known, which is not feasible. To maximize the advantage of both the methods and minimize their disadvantages, a combined approach has been used to build the current food ontology.

3. YAMO Methodology

In the due process of building the current multifaceted food ontology, authors have developed an ontology construction methodology called Yet Another Methodology for Ontology development (YAMO) consisting of ten steps. Notice that although YAMO is used to build food ontology, it proposes very generic steps, which make it applicable to build any other domain ontologies, like, Music, Movie, Space, etc. Figure 1 shows the general framework of YAMO methodology. YAMO includes the following steps:

Step 0: Domain Identification - It is to recognize a domain (where a domain is a specific area of knowledge or field of study that are of interest, e.g., music, movie, space) surrounding which the ontology will be built.

Step 1: Domain Footprint - It is to define the purpose and intention of building the ontology. It outlines the more specific use case scenario and application of the ontology for the end-users.

Steps 2: Knowledge Acquisition - It involves in gathering information from different resources leading to broadening the spectrum of domain knowledge. It is a brainstorming technique which helps in building the ontology by gathering domain related ideas, terms, concepts and their features.

Step 3: Knowledge Formulation - It involves in analyzing the domain related compound and complex ideas and breaking them into their elemental ideas. Then each of the ideas are analyzed based on their characteristic and are grouped together depending on their commonness.

Step 4: Knowledge Production - It involves in synthesizing the domain knowledge, which leads to arranging the domain knowledge, consisting of multiple facets, by establishing relationships between the concepts.

Step 5: Term Standardization - It leads in standardizing the terms denoting the domain concepts. It is known each concept can be potentially expressed by different terms. When more than one candidate terms exist, a preferred term should be selected among the synonymous terms. The preferred term is decided following its use by the domain experts in their written and verbal communication. This approach is similar to the Princeton's WordNet approach, where terms are ranked in the synset and the first one is considered as the preferred term.

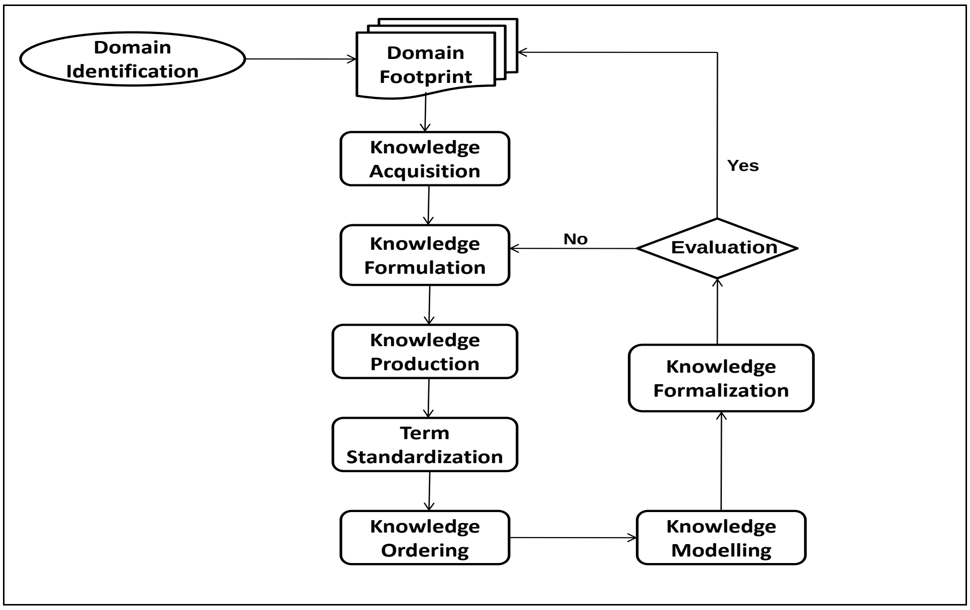

Figure 1. General Framework of YAMO

Step 6: Knowledge Ordering- It involves in ordering the terms within the array. There are many criteria one may follow. For instance, alphabetical order, increasing and decreasing intension, increasing and decreasing complexity, canonical order, etc. The knowledge ordering criteria is led by the purpose, scope and intention of the ontology as defined in Step 2.

Step 7: Knowledge Modelling- It involves in structuring and modelling the various facets of domain knowledge that are developed in the preceding steps. It depicts the entity, entity relationships and their properties unambiguously, and allows preservation of knowledge, which further ensures the aggregation, substitution, improvement, sharing and reapplication of the ontology.

Step 8: Knowledge Formalization- It is to formalize the domain knowledge for automatizing the process of knowledge extraction. It involves in expressing domain concepts unambiguously and formally following formal logic languages.

Step 9: Evaluation – This is the final step of YAMO. It involves in measuring the quality, standard and specification of the ontology, in order to verify how far the ontology had met the purpose for which it is built.

4. Food Ontology

This section illustrates in details the food ontology construction following YAMO. Besides YAMO, a set of principles of Ranganathan have been followed as described in (Ranganathan, 1967). These set of guiding principles ensures the quality of the ontology. The referred principles are cited in the whole process of ontology construction as discussed below.

4.1. *Domain Identification*

The Domain Identification is considered to be the most important step for the ontology building process as it acts as the foundation stone for the ontology that is being developed. This step involves in identifying a specific domain from the vast universe of knowledge. In general, the domain identification is guided by the user requirements, application needs and project goals.

4.2. *Domain Footprint*

The Domain Footprint accounts for the description of the purpose and application of the food domain in a specific scenario. In this case an attempt has been made to develop a framework in a restaurant specific environment, for those systems using ontology at their backend. These systems will act as a guide to its customers in selection of food, suggesting dishes, answering food and restaurant-related queries to its customer and also keeping a track of their likes and dislikes regarding food items. Thus an application ontology called restaurant ontology is engineered, that serves all the purposes mentioned above. Here a specific motivational scenario has been drawn that depicts a real life scenario for which the restaurant ontology is built.

4.2.1. A Motivational Use Scenario

Mr. X is an IT professional in his late twenties. He accompanied with his friends, visits a restaurant located near his office twice a month. He prefers halal meat. He has a taste for Afghani food. As he suffers from ulcer he does not consume very spicy food. In addition to that he is allergic to cumin seeds. He prefers to have sweet fresh lime soda, as a drink along with his appetizers and order chocolate ice cream for dessert. He does not consume any kind of alcoholic beverages. It is the time of Ramzan, so there are special delicacies available in the restaurant. As he is a regular visitor of the restaurant he possesses a membership card. The restaurant maintains a database for their dinners. They store not only the whereabouts and personal details of their clients but also their food preferences, choice of dishes or any other peculiar food habits, food restrictions etc.

To have an even better understanding regarding the usage and purpose of restaurant ontology, some frequent restaurant visitors have been involved, which includes Research

Scholars, Students and Professors from India and Italy. Simple competency questions and encouraging scenarios have been obtained from them. They were asked to list all those questions that they put forth to a restaurant manager or a waiter on their visit to an eating place. Table I enlists top ten frequently asked questions by the users. These questions not only provided a potential foundation to outline the multi-faceted approach of the ontology in the early stages of its development but had also provided sufficient inputs for developing the ontology.

Table I. List of top ten frequently asked questions

1. What is the special item available for the day? 2. How many pieces of chicken will be served in the plate? 3. How much time will it take to serve the dish? 4. Will the sauce be spicy/hot/mild/sweet? 5. Which is the most popular vegetarian item of the restaurant?	6. How will the dish be prepared (fried/roasted/sautéed)? 7. Does the restaurant serve halal meat? 8. What is available for starters? 9. What are the main ingredients present in the dish? 10. What are the desserts available for diabetic patient?

4.3. *Knowledge Acquisition*

Knowledge Acquisition is carried out to identify different terms relevant to the domain for which the ontology is built. A list of terms relevant to the domain is collected after interviewing more than fifteen people, frequent restaurant visitors, within the age group of 20-35. Moreover various other documents are referred in order to have an exhaustive list of terms pertinent to the food domain to build the restaurant ontology. One of the main documents that have provided a significant base for building the ontology is the document of food technology (Neelameghan and Sangameswaran, 1970). For this study Neelamegan's concept of 'Food Technology', proves to be a useful reference tool for suggesting ideas to be manually assimilated and has provided enough background knowledge to create the framework. The *Oxford Encyclopedia of Food and Drink in America* (2004) consists of 700 articles that cover significant information about preparation and consumption of food and drinks. Besides these domain specific resources, several lexical resources in this context are consulted which includes WordNet (http://wordnet.princeton.edu) and EuroWordNet (http://illc.uva.nl/EuroWordNet/) as they are helpful in resolving the ambiguity in the meaning of the language, providing both concept and consistency.

Besides the above mentioned references various knowledge resources are considered to gain a clear insight about the domain. To name a few of such sources are: *USDA National Nutrient Database for Standard Reference* provides information on over 8,000 foods. It is a database where food items can be searched and nutritional information is obtained (http://www.ars.usda.gov/ba/bhnrc/nd). *AGROVOC* is a multilingual controlled vocabulary constructed by the Food and Agriculture Organization of the United Nations. It has 32,000 concepts arranged in hierarchical order (http://aims.fao.org/agrovoc). *Schema.org* (http://schema.org/Recipe) offers a collection of terms, introduced by three search engines Bing, Google and Yahoo that provides a structured data markup schema.

From the finitely large set of collected domain related terms from several sources, a small list of the term are enlisted:

salad, chicken, eggplant, chicken kebab, ice cream, bacon, bean, avocado, whisky, tomato, butter, almond, spinach, protein shake, white wine, humus, oatmeal, coffee, wine, milk, lettuce, red wine, smoked salmon, tortilla, cucumber, apple milkshake, vodka, rice, drink.

4.4. *Knowledge Formulation*

Knowledge Formulation involves in analyzing the terms that are collected in the Knowledge Acquisition phase which is yet another important activity in the design of the ontology. It is the platform where ideas and imaginations assemble, based on the scope and coverage of the principle concepts surrounding a restaurant. There are certain basic principles followed during the analysis of the features of the terms and amalgamating them into clusters. They are *canon of relevance, principle of permanence, principle of exclusiveness, principle of exhaustiveness, principle of ascertainability, principle of consistency, principle of context* (Ranganathan, 1967).

Analysis is done based on the definition, characteristic and appropriateness of the identified terms pertaining to the restaurant specific environment. Keeping in view of the purpose of the domain by applying the Principle of Relevance, features are extracted from the term definitions and terms with similar characteristic features are grouped together. Terms like red wine (*wine having a red color derived from the skins of dark-colored grapes*), white wine (*pale yellowish wine made from white grapes with skins removed before fermentation*), pink wine (*pinkish table wine from red grapes whose skins are removed after fermentation began*), etc. have similarity in their features. Each of them according to their definitions is considered as different types of wine with unique color. So they are grouped together under Wine. WordNet defines Wine as *fermented juice*. Wikipedia defines Wine as *alcoholic beverage made from fermented grapes or other fruits.* This process is carried out to create a large number of groups from the enlisted terms by providing an abstraction technique (which is the process of formulating general concepts by hiding the detailed features of individual concepts) for assembling individual terms with similar properties in one group.

4.5. *Knowledge Production*

Identification of a large set of terms and their characteristics in this phase results in facet discovery and arrangement by applying *Principle of Helpful Sequence, Principle of Context,* and *Principle of Consistency*. The advantage of using the top down approach for developing restaurant ontology can be justified in this scenario. For instance two generic facets *edible food* and *drinkable food* are identified which clearly shows that the domain *food* is sub divided into two mutually exclusive groups. These facets are again classified into their sub-facets where edible food will be classified into sub facets: *food of plant origin, food of animal origin* and *food of mixed origin. Drinkable Food* is further subdivided into two facets i.e. *alcoholic drink* and *non-alcoholic drink*. Yet again the terms that are analyzed and grouped at the Knowledge Formulation phase can be mapped to more generic groups using bottom-up approach. So *red wine*, *white wine*, *pink wine* are grouped under *Wine*. *Wine* is mapped under *fermented beverage*, and *fermented beverage* is a sub class of *alcoholic drink.* In this way facets are created which is an iterative process (Prieto-Diaz, 2003) and at the end of categorization and organization of the facets, several facets and sub-facets are identified for the domain. Some of such facets discovered during this process are, *edible food, food of animal origin, food of mixed origin, drinkable food, alcoholic drink, non-alcoholic drink, taste, nutrient, cooking method, cuisine*, etc. Table II represents an excerpt of two such sub-facets of the food ontology.

Table II. An excerpt of two sub-facets of the food ontology

Edible Food
    Animal Origin Food
        Meat Product
            Bird Product
                Chicken Kebab
            Fish Product
                Smoked Salmon
	Drinkable Food
	    Alcoholic Drink
	        Fermented Beverage
	            Wine
	                Red Wine
	        Distilled Beverage
	            Whisky

4.6. *Term Standardization and Ordering*

Term standardization involves in standardizing the terms denoting the concepts within the ontology. It is known that each concept can be potentially expressed with any synonymous terms. When more than one candidate term exists, a preferred term is to be selected amongst the synonymous terms. For example, term *beverage* (any liquid suitable for drinking) has synonymous terms like *drink, drinkable, potable*. In case of the current food ontology, authors have selected beverage as a preferred term, while the others recorded as synonymous terms. Similarly, the term *chicken* (the flesh of a chicken used for food) has synonymous terms like *poulet, volaille*. For this ontology, chicken is selected as a preferred term whereas others are enlisted as synonymous terms. These synonymous terms are useful when concept mapping scenario comes into picture which is exemplified in section 4.9. This approach is similar to the Princeton's WordNet, where terms are ranked in the synset and the first one is the preferred term. The selection of preferred term is made following its use by the domain experts in their written and verbal communication.

Knowledge Ordering involves in ordering the terms within the array. There are many criteria one may follow. Some of the notable criteria as discussed in (Ranganathan, 1967) are increasing and decreasing intension of knowledge, increasing and decreasing complexity of knowledge, increasing and decreasing quantity, literary warrant, centre to periphery, periphery to centre, chronological order, canonical order, alphabetical order, later in evolution, etc. The knowledge ordering criteria should be led by the purpose, scope and intention of the ontology. In case of the current work, authors mostly opted for canonical order. Table III shows the final result after ordering.

Table III. Final result after ordering

Edible Food
  Animal Origin Food
    Meat Product
      Fish Product
        Smoked Salmon
      Bird Product
        Chicken Kebab
	Drinkable Food
	  Alcoholic Drink
	    Distilled Beverage
	      Whisky
	    Fermented Beverage
	      Wine
	        Red Wine

4.7. *Knowledge Modelling*

Knowledge Modelling involves in structuring and modelling the various facets of domain knowledge. The idea is to build the domain ontology showing its various components like entity, entity relationships and their properties. In the current work, to model the domain food, DERA framework (*where D stands for domain, E stands for Entity, R stands for Relation and A stands for Attribute* (Giunchiglia and Dutta, 2011) is used, a faceted knowledge organization framework for representing domain knowledge (where, a domain (D) is any area of knowledge or field of study that are of interest, e.g., Space, Food, Music). DERA which is extensible and scalable allows structuring the domain ontologies and their exploration for automatic reasoning via direct encoding into Description Logics (Giunchiglia *et al.*, 2014). Extendibility and scalability is gained by allowing the definition of any number of domains. As the framework allows addition of domains, facets and terms at any point of time, reflected in section 5, use of such a framework makes the restaurant ontology expansive and extendable. A DERA domain D consists of three main elements: Entity (E), Relation (R) and Attribute (A) and is expressed as a triple D = <E, R, A>, where,

(1) *E = Entity* – consists of a set of facets where each facets represent a group of related terms denoting the entity classes of the real world entities (instances) having perceptual correlates or only conceptual existence. For example, in case of domain *Food*, *Alcoholic drink* and *Non alcoholic drink* etc. are entity classes, while *black dog* and *milo* are instances. Term hierarchies within the facets are defined by *is-a* and *part-of* relations, and the entity instances are linked to their classes by *instance-of* relation.

(2) *R = Relation* – consists of a set of facets where each facets represent a group of related terms denoting the relations between entities. For example, in case of domain *Food*, the property of a food item, say, *chicken biryani* is *accompaniment*. The property *accompaniment* will link *chicken biryani* with the entities such *raita* and *pickle*. Terms hierarchies within the facets are defined by *is-a* relation.

(3) *A = Attribute* – consists of a set of facets where each facets represent a group of related terms denoting the *qualitative* and/or *quantitative* properties of entities. For example, in context of domain *Food*, *price* (of food), *color* (of wine), *serving temperature* (of a drink), *calorie content* (of food), *rating* (of food) are attributes. In DERA, attribute names and values are differentiated explicitly. Terms, denoting the attribute names, within the hierarchies are connected through *is-a* relation and

attribute name and their corresponding values are connected through the *value-of* relation.

In Figure 2, dashed arrow represents the relationship between an instance and its entity class. For instance, chicken kebab is an instance of entity class Chicken Kebab. Here, the instance chicken kebab refers to a real world entity, let's say, that is ready to eat. In this model, Chicken Kebab is a concept and any item that is cooked following the recipe and ingredient to prepare Chicken Kebab forms an instance of the concept Chicken Kebab. Here, the argument is each of the chicken kebabs prepared by various chefs, or even may be by the same chef prepared at different point of time, would be completely different in terms of their taste, color, etc. This can be due to the variance in their cooking style, ingredients used, and so forth. Hence, each of the cooked chicken kebabs are treated as the individual entities of the entity class Chicken Kebab. Note that, each of the cooked chicken kebabs share a set of common properties (e.g., main ingredient), which ensure their identity as Chicken Kebab. However, besides their common properties, each of the entities will have some further unique characteristics (e.g., flavour, other ingredient), which make them different from each other's. This argument is also valid for the entity class Black Dog and its instance, which is a bottle of scotch whiskey. In the Figure 2, black dog is an instance of the class Black Dog Scotch Whiskey.

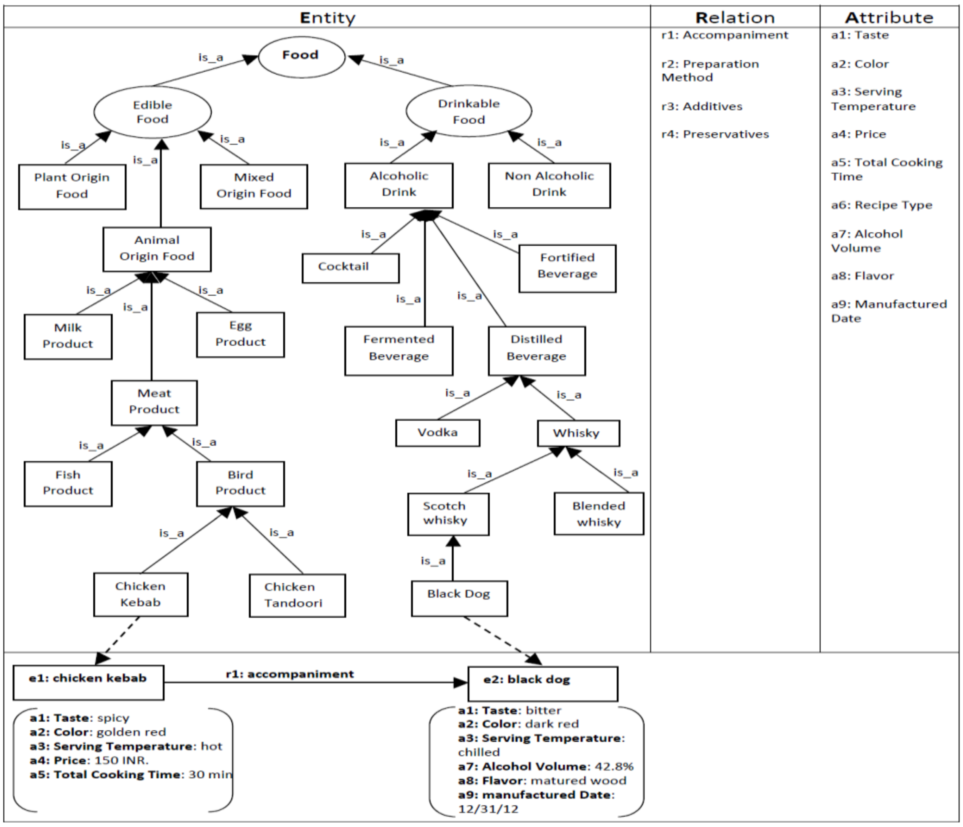

Figure 2. Shows a snapshot of the food ontology modelled following the DERA framework

4.8. *Knowledge Formalization*

As discussed in (Giunchiglia *et al.*, 2014), Description Logics (DL) formalization of any DERA domain is a direct encoding from the DERA facets into DL formulas. The DL formalization of DERA domain is done by modeling its components, such as, entity, relation, and attribute as DL concepts, roles, and individuals as shown in the DL formalization Table IV. In this Table IV, entity classes, representing a sets of entities, are formalized as DL concepts, entity instances are formalized as DL individuals, relations and attributes are formalized as DL roles. Here, E_i(i = 1,…, m) are concepts for entity classes, e_j(j = 1,…, n) are individuals for entities instances, R_k(k = 1,…, s) are roles for relations, A_x(x = 1,…, u) are roles for attributes. *Is-a* relation corresponds to subsumption relation (⊑) between concepts, and between roles, *part-of* and *associative* relations corresponds to DL roles, and *instance-of* relation corresponds to subsumption relation between entity classes and instances.

Table IV. Formalization of food ontology into DL

	Food domain elements	**DL formalization**	
$E_1,\ldots, E_m$	Entity classes	Concept	**Tbox**
$R_1,\ldots, R_s$	Relation between classes	Roles	
$A_1,\ldots, A_u$	Attributes	Roles	
is-a	Hierarchical relation	Subsumption (⊑)	
part-of	Hierarchical relations	Role	
any relations that are non-hierarchical type (e.g., ingredient, calorie content, diet)	Associative relations	Role	
value-of	Hierarchical relation	Role restriction	
$e_1,\ldots, e_n$	Entity instances	Individuals	**Abox**
$r_1,\ldots, r_t$	Relation between entities	Role assertions	
$a_1,\ldots, a_v$	Attributes of entities	Role assertions	
$v_1,\ldots,v_u$	Attribute values	Individuals	
instance-of	Hierarchical relations (between entity class and entity instances)	Concept assertions	

In order to define the formal semantics of domain food, an *Interpretation I* of domain Food consist of the Domain of Interpretation D (a non empty set) and an *Interpretation Function* I are considered. Therefore, a DL interpretation *I* = <D, I>, where, Domain of Interpretation D is a set of entity instances (e^I_n) which provide the extensions of concepts, relations and attributes E^I_i, R^I_k and A^i_x respectively. For instance, ChickenKebab^I ∈ E^I is a concept with name (i.e., a natural language label) Non-*Vegetable Dish*, while chicken_kebab^I ∈ E^I is an individual for concept *ChickenKebab*. Similarly, each relations (R_k) corresponds to DL roles and are interpreted as binary relations $R^{I}_{k} \subseteq D \times D$, each attributes ($A_x$) corresponds to DL roles and are interpreted as binary relations $A^{I}_{x} \subseteq D \times D$. In order to sum up, there exists:

$$E^{I}_{i} \subseteq D \qquad R^{I}_{k} \subseteq D \times D \qquad A^{I}_{x} \subseteq D \times D \qquad \ldots\ldots.(1)$$

$$e^{I}_{j} \in D \qquad r^{I}_{m} \in D \times D \qquad a^{I}_{n} \in D \times D \qquad \ldots\ldots\ldots..(2)$$

Here, the equation (1) corresponds to *intentional knowledge*, so called, TBox (Terminological Box) is a terminology module consists of conceptual definitions, or in other words, a set of concepts and a set of properties of these concepts (e.g., concept *ChickenKebab* and its properties like m*ain ingredient*, *preparationMethod*). And equation (2) corresponds to extensional knowledge, so called, ABox (Assertional Box) is an assertional module consists of the assertions about individuals and the value of their properties (e.g., individual *chicken_kebab* has main ingredients *chicken*, preparationMethod is *roasting*). Table V presents an excerpt of formalization in terms of TBox and ABox for the ontology in Figure 2.

Table V. TBox and ABox

TBox	ABox
Food ≡ EdibleFood ⊔ DrinkableFood EdibleFood ≡ AnimalOriginFood ⊔ PlantOriginFood ⊔ MixedOriginFood MeatProduct ⊑ AnimalOriginFood BirdProduct ⊑ MeatProduct ChickenKebab ≡ BirdProduct ⊓ ∃mainIngredient.Chicken ⊓ ∃preparationMethod.PreparationMethod mainIngredient ⊑ ingredient	ChickenKebab(chicken_kebab) mainIngredient(chicken_kebab, chicken) preparationMethod(chicken_kabab, roasting) taste(chicken_kebab, spicy) color(chicken_kebab, golden_red) recipeType(chicken_kebab, non-vegetarian)

4.9. *Evaluation*

The ontology evaluation is concerned with gauging the formal facets of the ontology and aims to rate the technical competence of the ontology and finally, its system implementation. Thus evaluation phase comes after the ontology has been formalized. The assessment undertaken in this study is more inclined with the idea of appraising the utility and usability of ontology as a practice for "judging the ontology content from the user's point of view" as described by Gomez-Perez *et al.* (2004). This approach, qualitative in nature and user-centered, aims at evaluating the adequacy and efficacy of the ontology for its projected tasks and how well it epitomizes the domain of interest.

Ontology evaluation and quality assessment by the human users/experts is a very popular and widely practiced phenomenon (Lozano-Tello and Gomez-Perez, 2004). The restaurant ontology model was validated and verified by conducting a task-based user study. The study took place in the workplace and ABC lab of DRTC, Indian Statistical Institute, Bangalore. The evaluation of the restaurant ontology was carried out by experts who were very frequent visitors of restaurant and had tried to analyze how well the ontology could meet their standards; specifications and criteria. The task encouraged the examination and annotation of concept maps, portrayed on a white board, during which participants were encouraged to share their thoughts out loud.

4.9.1. Experimental Setup

A huge white board was used to display the entire restaurant ontology model. Three different types of colored markers i.e. red, green and black had been used to build relationship between different foods related attributes and instances. To complete the task, the participants had to manually navigate through concept maps and show their searching and seeking process by drawing their search paths with colored marker pen and encircling/marking target concepts, once they found an answer to their query. Blue, pink and yellow colored sticky notes were used as a label on which name of different attributes of the ontology was imprinted.

4.9.2. Participants

Ontology evaluators' team consisted of 14 professionals which includes professors, research scholars and master students from Indian Statistical Institute, Bangalore and University of Trento, Italy. The sample was chosen keeping in mind that there will be no common individuals performing both evaluation and providing the competency question during the initial stage of modeling the domain. The participants were good critics. They had good knowledge on cuisine around the globe and therefore their feedback was very effective.

Interview took place during 6 week period with 14 individuals. Each session had lasted for 20-30 minutes. Those participants who were involved for evaluation belonged to the age group of 22-60 years. Majority of the participants were male. 80% of the participants were from the school of information science.

4.9.3. Procedure

The researchers explained the task with the following scenario: "Imagine that you have visited a restaurant and you would like to place your order, then in such a scenario what are the questions that you would like to ask the waiter regarding the food that you wish to order ?" For each session, the participants had to perform two tasks.

Task 1. Participants were instructed to enlist questions based on the above scenario. The purpose of this task was to gather as many user queries as possible in order to understand the appropriateness of the ontology model and observe the participants approach to enquiring for food related information. This would be helpful to develop user interface in future.

Task 2. Participants were asked to manually navigate and annotate the concept model displayed on the white board with colored marker pens. They were also encouraged to annotate the diagrams and write down any questions, concerns and suggestions they might have. This technique required participants to express their thoughts as they performed the task (Ericsson and Simon, 1993). The purpose of this task was to gain feedback on the perceived usefulness of the ontology.

Moreover, during the entire process of performing Task 1 and Task 2, several analysis were done and observations made that lead to numerous findings which are elaborately explained in the following steps.

Step 1: Task 1 yielded a set of questions from the participants keeping the particular scenario in mind.
Step 2: Key terms were extracted manually from the list of questions. Table VI represents a set of unique questions that have been put forth by the participants along with their extracted key terms.

Table VI. List of top questions and their corresponding key terms identified

Questions	Key Terms
What is the price of the Banana Sundae?	<price, banana sundae>
Is the meat halal or not?	<halal, meat>
Will mushroom pepper dry be spicy?	<mushroom pepper dry, spicy>
What is the time taken to serve the food?	<time, serve>
What is the amount of food served?	<amount, food>
Do you have Chinese food?	<chinese, food>

Step 2: Participants were instructed to use colored marker pen to navigate through the designed ontology to search for the answers to the queries.
Step 4: The set of questions have been categorized based on the user satisfaction level i.e. s*atisfactory*, p*artially satisfactory* and u*nsatisfactory*.

Satisfactory: If there exists an exact match between the participants query term and the ontology term then the scenario is considered as *Satisfactory*. Here the authors have not only considered the mapping of terms but also mapped the concepts. If a key term is matched with that of a concept in the ontology, then it is also considered to give a s*atisfactory* result.
e.g. Term Mapping
Question: *What are the ingredients present in the mushroom pepper dry?*
Key term: <ingredient, mushroom pepper dry>
Ontology term: <ingredient, mushroom pepper dry>
e.g. Concept Mapping
Question: *Do you provide complementary drinks with main course?*
Key term: <complementary, drink, main course>
Ontology term: < complementary, beverage, main course >

Partially Satisfactory: If the ontology can partially answer to the participants' questions then it is considered to be Partially Satisfactory.
e.g. Term Mapping
Question: *Do you allow takeaway food in paper bags?*
Key term: <takeaway food, paper bag>

In case of the above question, the system will only be able to answer whether takeaway food is available in the restaurant. Unfortunately the system cannot provide answer for the type of bags used to takeaway food. In such a case the result will be *Partially Satisfactory*.

Unsatisfactory: If the query provided by the participant is out of the scope of the enlisted concepts or the ontology terms then the result will be u*nsatisfactory.* There can be two such scenarios:

1. Questions those are not relevant for this ontology.
 e.g. *Do you charge for car parking?*
2. Concepts which are relevant to this ontology but developers were unaware.
 e.g. *Do you have some light food?*

In this case the system does not define anything called as *light food.*

It is to be noted that during the process of evaluation, if any of the evaluators' queries are not met (partially satisfactory and unsatisfactory cases) which is indicated as No in Figure 1, then the missing concepts or attributes or instances should be reformulated and the entire process should be started from Section 4.4. It is assumed that a time will come when the ontology will come to a saturation level where it will leave no evaluators unsatisfied, and then in that case one can say that the restaurant ontology model is complete and is marked as YES in Figure 1, where the cyclic process continues in developing other application ontology for any identified domain.

4.9.4. Results and Observation

The task was successfully performed by the participants and their feedback was collected for analysis and modification purpose. The data was analysed based on the three different level of criteria, i.e., *satisfactory*, *partially satisfactory* and *unsatisfactory*. The data was used to assess the quality of the ontology model. The results of the analysis have been briefly illustrated in the Table VII.

Table VII. Analysis of the questions enlisted by the ontology evaluators

Evaluators	**No of queries**	**Evaluation Parameter**		
		Satisfactory	**Partially satisfactory**	**Unsatisfactory**
Participant 1	11	10	0	1
Participant 2	10	8	0	2
Participant 3	6	4	2	0
Participant 4	13	11	1	1
Participant 5	10	8	0	2
Participant 6	9	9	0	0
Participant 7	8	7	0	1
Participant 8	18	17	0	1
Participant 9	8	7	0	1
Participant 10	8	6	0	2
Participant 11	6	6	0	0
Participant 12	10	9	0	1
Participant 13	15	15	0	0
Participant 14	14	14	0	0
Total	146	131	3	12

It has been found that out of 146 questions, the ontology could answer approximately 90% of the questions satisfactorily, while 2% of the questions provided partially satisfactory answers and 8% of the questions remained unanswered that were put forth by 14 participants. Out of 12 unsatisfactory questions it has been investigated that 7 questions are not relevant to the ontology. Some of such non relevant questions are enlisted below:

- Is there smoking zone available in the restaurant?
- Is there extra charge for A/C rooms?
- Does the owner have a license for this restaurant?

Thus after analyzing the evaluation result it can be concluded that out of 139 relevant questions only 4% of the questions remained unanswered whereas more than 94% of the questions are answered successfully.

The comment and feedback of the participants have enriched the ontology further in terms of the number of concepts and attributes. For example, properties like "temperature specification", "type of service" were not available in the ontology before the evaluation, but after the evaluation process these attributes have found a place in the ontology. One of the evaluators commented after his evaluation that "*The ontology is pretty exhaustive*".

5. Domain Statistics

Table VIII and Table XI provides the statistical details of the restaurant ontology, before and after evaluation. It gives the picture of the number of concepts, relations and attributes existing in the food ontology. It is taken under consideration that there exists a finitely large list of real world entities belonging to the restaurant ontology that cannot be accommodated within this scope. Also notice that the faceted approach used to build the current ontology allows addition of new entities, which may lead to increase in the number of entity classes, relations and attributes. Undoubtedly this ontology will grow with time.

Table VIII. Statistics of restaurant ontology before evaluation

Before Evaluation	Domain concepts	No of domain concepts	Terms
	Entity class	263	358
	Relations	59	73
	Attributes	18	32
	Entity	+ ∞	+ ∞

Table XI. Statistics of restaurant ontology after evaluation

	Domain Concepts	No of domain concepts	Terms
After Evaluation	Entity class	275	380
	Relations	62	76
	Attributes	23	44
	Entity	+ ∞	+ ∞

6. Related Work

Ontology is a strong tool to represent knowledge on the web. Domain experts are constructing ontologies in different fields and for various purposes, by making use of different methodologies. For the last few decades ontology related to food, nutritional health benefits, cooking etc., have gained immense popularity. FOODS (Snae and Bruckner, 2008) is an expert system for menu planning in a restaurant, clinic or home, choosing a combination of top-down and bottom-up approach to develop the ontology. Cantais *et al*. (2005) initiated food ontology to cater to nutritional and health care issues by bringing into play TOVE methodology. A fuzzy ontology is generated to recommend personal diabetic meal plan putting to use fuzzy logic system (Chang-Shing *et al.*, 2010). Automated food ontology is constructed for diabetic people (Li and Ko, 2007) by the help of hierarchical clustering algorithm. Ontology in the area of cooking, featuring few major concepts like food, kitchen, utensil, action and recipe are built (Ribeiro *et al*. and Batista *et al*., 2006) by applying Methontology methodology.

Noy and McGuinness (2001) contribute in the development of wine (main concept) and how wine can blend with different meals. A simple knowledge engineering methodology is provided to achieve the goal. Graca *et al.* (2005) reveals a specific wine ontology that deals with analysis of grape maturity, different processes of wine making and their characteristics and classifies wine based on its origin and production. The methodology used to design the wine ontology was inspired by Methontology and Enterprise Ontology. The ontology for beer is established based on the SHOE (Simple HTML Ontology Extension) framework (Heflin, 2007), which does not throw enough light upon the methodology undertaken to generate the ontology.

Food ontology is built to extract information about food recipe from any text (Villarias, 2004) by following Methontology. Ontology is established to reuse existing recipes available on the web to create a new recipe using CommonKADS methodology (Makino *et al.*, 2009). Palaniappan and Rao (2010) demonstrates a new system for ontology-based query answering (QA) bringing into play query outline for dining ontology as the main domain, although the method is not domain specific. Its main focus is on the RDF, Ontology Model and Web Ontology Language. Although architecture is provided for the dining ontology but it is not elaborately explained in their work. The pizza ontology contains all constructs required for the various forms of Pizza made around the globe (Drummond *et al.*, 2005). The ontology is built using Protégé Owl and does not provide any clue regarding the methodology undertaken to form the ontology. Semantic Diet is established wherein each food is grouped and information is extracted from the USDA's National Nutrient Database for Standard Reference.

A significant portion of the above works concentrated either on a small section of food domain, or ontology is built targeting a very specific application. This paper presents a novel approach to build multi-faceted large scale food ontology.

7. Conclusion and Future Work

This paper has demonstrated construction of food ontology based on YAMO, Yet Another Methodology for Ontology, which is motivated by Ranganathan's analytico-synthetic approach. This work is not the first attempt to build food ontology. Many such attempts have been made in the past as discussed in the paper. However, this ontology building methodology gives the detailed description of the steps along with the guiding principles that are to be undertaken to achieve the goal. Moreover, the methodology in general is explicitly presented as a non-domain specific approach. Thus it has far-reaching implications for the construction of new ontologies in several other domains like real estate, tourism, movie, music, disaster management, etc.

As future work, the authors aim to link the food ontology with other popular food and related ontologies, and with the top-level ontologies, like, SUMO, OpenCyc, DOLCE. Moreover they are looking forward to release the current food ontology both in English and Hindi in order to reach to a wider community.

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References

Batista, F. and Pardal, J.P., Vaz, P., Mamede, N., Ribeiro, R. (2006). *Ontology construction: cooking domain*, Technical Report, INESC-ID. Lisbon.

Cantais, J. and Dominguez, D., Gigante, V., Laera, L., Tamma, V. (2005). An example of food ontology for diabetes control. *International Semantic Web Conference, Workshop on Ontology Patterns for the Semantic Web.*

Chang-Shing, L. and Mei-Hui, W., Hagras, H. (2010). A Type-2 Fuzzy Ontology and its Application to Personal Diabetic-Diet Recommendation. In *IEEE Transactions on Fuzzy Systems*, 18(2):374-395.

Drummond, N. and Horridge, M., Stevens, R., Wroe, C., Sampaio, S.(2005). *Pizza Ontology*, The University of Manchester.

Dutta, B. and Chatterjee, U., Madalli, D.P. (2013). From Application Ontology to Core Ontology. In *Proceedings of International Conference on Knowledge Modelling and Knowledge Management*, Bangalore, India. ISBN: 978-93-5137-765-8.

Dutta, B., Giunchiglia, F. and Maltese, V. (2011), "A Facet-based methodology for Geo-spatial modelling", *in Proceedings of Fourth International Conference on GeoSpatial Semantics*, Brest.

Ericsson, K.A. and Simon, H.A. (1993). *Protocol analysis: Verbal reports as data* (rev. ed.), MIT Press.

Fernandez, M. and Gomez-Perez, A., Juristo, N. (1997). Methontology: from ontological art towards ontological engineering. In *Proceedings of the AAAI97 Spring Symposium Series on Ontological Engineering.*

Giunchiglia, F. and Dutta, B. (2011), *DERA: a Faceted Knowledge Organization Framework,* available at: http://eprints.biblio.unitn.it/archive/00002104/ (accessed 20 October 2013).

Giunchiglia, F. and Dutta, B., Maltese, V. (2014). From Knowledge Organization to Knowledge representation. *Knowledge Organization*,41(1): 44-56.

Gomez-Perez, A. and Fernandez-Lopez, M., Corcho, O. (2004). *Ontological engineering: With examples from the areas of knowledge management, e-commerce and semantic Web*, Springer Verlag, London.

Graca, J. and Mourao, M., Anunciacao, O., Monteiro, P., Pinto, H.S., Loureiro, V. (2005). Ontology building process: the wine domain. *Proceedings of the 5th Conference of EFIT*.

Gruninger, M. and Fox, M. (1995). Methodology for the design and evaluation of ontologies. *Workshop on Basic Ontological Issues in Knowledge Sharing*, Montreal, Canada.

Heflin, J. (2000, April). *Beer Ontology 1.0* (Draft). Available at http://www.cs.umd.edu/projects/plus/SHOE/onts/beer1.0.html (accessed 27 December 2012).

Jones, D. M. and Bench-Caponand,T. J. M.,Visser,P. R. S. (1998). Methodologies for Ontology Development.In *Proceedings of the IT and KNOWS Conference of the 15th FIP World Computer Congress*.

KBSI (1994). *The IDEF5 Ontology Description Capture Method Overview*. KBSI Report, Texas.

Li, H.C. and Ko, W.M. (2007). Automated food ontology construction mechanism for diabetes diet care. In *International Conference on Machine Learning and Cybernetics,* 5: 2953-2958.

Lozano-Tello, A. and Gomez-Perez, A. (2004). Ontometric: A method to choose the appropriate ontology. *Journal of Database Management*, 15(2):1–18.

Makino, R. and Kobayashi, I., Izumi, N., Hasida, K. (2009). An ontology approach to creating a new recipe by reusing parts of the existing recipes. *IEEE International Conference on Intelligent Computing and Intelligent Systems,* vol. 3.

Neelameghan, A. and Sangameswaran, S.V. (1970). *Food Technology: depth classification version of CC.* Sarada Ranganathan Endowment for Library Science, Bangalore.

Noy, N.F. and McGuinness, D.L. (2001). Ontology development 101: A guide to creating your first ontology, retrieved from Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880.

Palaniappan, L. and Rao, N.S. (2010). An ontology based question answering method with the use of Query Template. *International Journal of Computer Applications,* 9(9).

Prieto-Díaz, R. (2003). A Faceted Approach to Building Ontologies. In *IEEE International Conference on Information Reuse and Integration,* pp. 458-465.

Ranganathan, S.R. (1967). *Prolegomena to library classification.* Asia Publishing House, New York.

Ribeiro, R.D. and Batista, F.M., Nuno, J., Pardal, J.P., Pinto, H.S. (2006). Cooking an ontology. *12th International Conference on Artificial Intelligence: Methodology, Systems, Applications,* Berlin, pp. 213-221.

Saito, A., and Umemoto, K., Ikeda, M. (2007). A strategy-based ontology of knowledge management technologies. *In Journal of Knowledge Management,* 11(1): 97-114.

Smith, A.F. (Ed.) (2004). *The Oxford Encyclopaedia of food and drink in America*. Oxford University Press.

Snae, C. and Bruckner, M. (2008). FOODS: a food-oriented ontology-driven system. In *IEEE International Conference on Digital Ecosystems and Technologies,* pp. 168-176.

Studer, R. and Benjamins, V.R., Fensel, D. (1998). Knowledge engineering: Principles and methods. In *Data and Knowledge Engineering,* 25 (1-2): 161-197.

Taylor, A.G. (1992). Introduction *to Cataloguing and Classification* (8th ed.), Libraries Unlimited, Englewood, Colorado.

Uschold, M. and King, M., Moralee, S., Zorgios, Y. (1995). The Enterprise Ontology. In *The Knowledge Engineering Review,* Vol. 13.

Velardi, P. and Missikoff, M., Basili, R. (2001). Identification of relevant terms to support the construction of Domain. *Workshop on Human Language Technologies,* France.

Villarias, L.G. (2004). Ontology-based semantic querying of the web with respect to food recipes. Doctoral Dissertation, Technical University of Denmark, Denmark.

Vrandecic, D. and Pinto, S., Tempich, C., Sure, Y. (2005). The DELIGENT knowledge processes. In *Journal of Knowledge Management,* 9(5): 85-96.

Xu, W. and Zlatanova, S. (2007). Ontologies for disaster management response. *Geomatics Solutions for Disaster Management*, pp. 185-200.

Appendix A.

ENTITY TYPE	ATTRIBUTES	RELATION
✚ Food ▪ Edible Food ○ Plant Origin Food • Processed Vegetable – Cereal Product – Fruit Product – Legume Product – Vegetable Product – Mixed Vegetable Product • Raw Vegetable – Root Vegetable – Stem Vegetable – Edible Flower – Edible Fruit – Edible Seed ○ Animal Origin Food • Egg Product • Milk Product • Meat Product ○ Mixed Origin Food • Soup • Snack • Salad • Dessert ▪ Drinkable Food ○ Alcoholic Drink • Fermented Beverage • Distilled Beverage • Fortified Beverage • Cocktail ○ Non Alcoholic Drink • Drinking Water • Nourishing Drink • Refreshing Drink • Stimulating Drink	✚ Price ✚ Rating ✚ Regional Name ✚ Critics Review ✚ Serving Size ✚ Image ✚ Calorie Content ✚ Cooking Level ✚ Expiry Date ✚ Manufactured Date ✚ Serving Temperature ✚ Special Occasion ✚ Available Quantity ▪ Alcohol Volume	✚ Type Of Food ▪ Belief Based Food ▪ Weight Control Food ▪ Vegetarian Food ✚ Accompaniment ▪ Raita ▪ Dips ▪ Pickle ▪ Sauce ▪ Chatney ✚ Ingredient ▪ Animal Origin Ingredient ▪ Plant Origin Ingredient ✚ Recipe ▪ Recipe Category ▪ Recipe Type ▪ Recipe Instruction ✚ Cuisine ▪ Global Cuisine ▪ Regional Cuisine ✚ Cooking Method ▪ Dry Heat Cooking ▪ Moist Heat Cooking ▪ Frying ▪ Microwaving ✚ Course Description ▪ Appetizer ▪ Beverage ✚ Additive ▪ Acid ▪ Food Flavouring ▪ Food Colorant ✚ Preservative ▪ Drying ▪ Salting

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