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Short Communication

ONTOLOGY CONSTRUCTION AND REASONING USING OWL: A CASE STUDY FROM SEAFOOD DOMAIN

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ABSTRACT

Ensuring the quality of any type of food, particularly seafood has increasingly become an important issue nowadays. The environment is polluted in many ways, such that the consumption of seafood by compromising the quality may cause diseases due to infection or intoxication. So the adoption of proper quality control systems is mandatory in any organization that deals with food processing and distribution. In this regard, we have proposed an ontology based system in seafood companies to ensure the quality of seafood. Ontology is a formal specification of the concepts within a domain and their interrelationships. It describes the logical structure of a domain, its concepts and the relations between them. The aim of ontology is to capture knowledge in related fields, provide a shared under standing of conceptual knowledge, define a common vocabulary in this field, and give clear definition to the mutual relationship between these words from different levels of formal models. This paper presents the initial phase of our research viz, design and construction of seafood ontology in Web Ontology Language [OWL]. It is an extension of our work which is published earlier. Protégé is used to implement the ontology.

Keywords: Ontology, seafood, taxonomy, protégé.

INTRODUCTION

Seafood has traditionally been a popular part of the diet in many parts of the world and in some countries constituted the main supply of animal protein (Vinu *et al*., 2012a). The global consumption of fish and seafood has doubled since 1973 and is expected to increase by 25% by 2015 (EIA, 2012). However, ensuring seafood quality has increasingly become an important issue nowadays and is the first step to get attention to countries seafood products. Consumption of seafood may cause diseases due to infection or intoxication (Vinu *et al*., 2012a). The environmental risks of seafood include water pollution, metal pollution and other bacterial pollution (Vinu *et al*., 2012a). The main hazards associated with seafood are bacteria such as E. coli, Salmonella, Vibrio Cholera etc., virus, bio-toxins such as PSP, DSP, NSP etc., histamine poisoning, parasites, chemicals such as cadmium, lead, mercury etc. Food regulations, such as Hazard Analysis Critical Control Point (HACCP), Good Manufacturing Practice (GMP), or Good Hygiene Practice (GHP), aim to guarantee a certain level of quality. To ensure the quality of seafood, we have proposed an ontology based systemin seafood companies and in this paper, we present the initial phase of our research viz, development of seafood ontology. It is an extension of our work published earlier (Vinu *et al*., 2012b).

The Semantic Web is simply a web of data described and linked in ways to establish context or semantics that adhere to defined grammar and language constructs (Hebler *et al*., 2009). The idea of Semantic Web is to make web resources more accessible to automated processes. WWW is formatted for human consumption rather than programs. So by incorporating semantics, if web pages are clearly understood by the machines, then they will be able to integrate information from different sources, automate the processes and reuse the information across various other applications in an automated way. The basis of the Semantic Web is semantic relationships. The relationships include definitions, associations, aggregations, and restrictions (Hebler *et al*., 2009). Semantic Web does not rely on text-based manipulation, but rather on machine processeble metadata. Metadata is data about data and it is able to capture the meaning of the data. Meta data consists of (attribute, value) pairs that helps to categorize web pages. Ontologies play an important role here, by providing a domain vocabulary for metadata using which the semantic description is built. They are well known for many years in the Artificial Intelligence and Knowledge representation communities (Akerkar, 2009). Ontology is a formal specificationof the concepts within a domain and their interrelationships

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(Sherimon *et al*., 2013a). Ontology defines the basic terms and relations comprising the vocabulary of a domain as well as the rules for combining terms and relations to define extensions to the vocabulary (Neches *et al*., 1991). They define vocabularies and their meanings, with explicit, expressive, and well-defined semantics, that can be easily interpreted by machines. Ontology contains both the asserted knowledge and the inferred knowledge (Sherimon *et al*., 2013c). Asserted Knowledge is the knowledge that is explicitly defined by the ontology developers. When ontologies are reasoned by machines, valid deductions and inferences are generated which iscalled inferred knowledge (Sherimon *et al*., 2013c).

To create ontology, W3C has proposed a number of languages. The first semantic web language as part of metadata standardization from World Wide Web consortium [W3C] is RDF (Hebler *et al*., 2009). The core format for representation of data in semantic web is RDF (Resource Description Framework) which is based on triples subject (resource)-predicate (property)-object (property-value). The fundamental concepts of RDF are resources, properties and statements. A resource can be anything in the world; for example a website, or a real object like 'apple'. Resources are identified using Uniform Resource Identifiers (URI), Uniform Resource Locator (URL) or a global, unique code based on W3C standards. Properties are a special kind of resources. They describe the relations between the resources. It is linked with other resources via URI which uniquely identifies documents. But using RDF, it is not possible to describe neither the relationship between the relationships themselves, nor the relationships between resources and properties. So W3C extended RDF to RDFS (RDF Schema) (Thottupuram *et al*., 2011). Using RDF Schema vocabulary terms and the relations between those terms can be defined. RDFS has still weaknesses; so on top of RDFS, W3C has built OWL. OWL ontologies are web documents referred to by URIs (Arroyo *et al*., 2004). OWL is a stronger language as compared to RDF and has much machine interpretability (Gupta *et al*., 2010).

MATERIALS AND METHODS

Ontology Design and Construction

To design ontology, many design decisions have to be made to ensure that it will suit the stated purpose. There is no single method to design ontology. We cannot say this is the right way or this is the wrong way, but still some of the designs provide clarity in the functionalities than others. The ontologies are derived from the real world conceptualization shared by humans as a knowledge base and implemented in digital through machine readable languages such as OWL, XML (Gupta *et al*., 2010). The first step consists of determining the domain and the scope of the ontology. It will be the first step to answer questions like for what purpose the ontology is being developed. It identifies the range of the users and the type of questions which the ontology should answer. Next is to decide whether to use already existing ontologies, and if so, how to use them. Then all the terms that are needed in the development of ontology is listed. Next, define the hierarchical structure (taxonomy) to organize the domain knowledge. The concepts in the domain are described by the main component of the ontology, which is class. Classes are defined using owl:Class. <owl:Thing> is the base class under which, the fundamental ontology constructs provided by OWL such as other classes, properties and instances are created. Classes may contain subclasses that inherit their characteristics and they also contain instances. Instances may have properties which connect them to values or other instances. Then the properties, facets and instances are defined. OWL supports two types of properties – data type and object. Object Properties relate objects to objects, whereas Data type properties relate objects to data type values.

Implementation of Seafood Ontology

Ontology Tools

Protégé, developed by Stanford University is currently the best known ontology editor. It is a free, open-source platform that provides a growing user community with a suite of tools to construct domain models and knowledge-based applications with ontology (Sherimon *et al*., 2013c). Further, Protégé can be extended by way of a plug-in Architecture and a Java based Application Programming Interface for building knowledge-based tools and applications (Sherimon *et al*., 2011). Protégé supports a number of plug-ins. OWL plug in produces ontologies in OWL language. OWLViz is the plugin used to visually represent the class hierarchies in the ontology. OntoGraf tool is used to represent the relationships in the ontology. SWRL [Semantic Web Rule Language] plugin supports the use of rules.

Classes and Subclasses

The ontology requires the representation of each concept in Seafood domain and its attributes. The Seafood ontology has been defined in OWL, and Protégé is used to model the ontology. Figure 1 represents the implementation of seafood ontology in Protégé. The main domain concepts which are disjoint are *Product, Fish, Test, Test-Specification, and Country*. *owl:Thing* is the most general class, which contains all the above concepts. The class *Product* is further categorized into disjoint subclasses *Chilled_Product, Frozen_Productand Raw_Material*. *Test Specification* is another main class which is further categorized into disjoint subclasses, *External-test* and *Internal-Test*. This is to describe the tests done in the factory (Internal-Test) and in outside governmental agencies (External-test). Each of these subclasses are again subdivided into two subclasses each for representing the test specifications of Seafood and non-food items like Water, Ice, Salt etc. Each of these

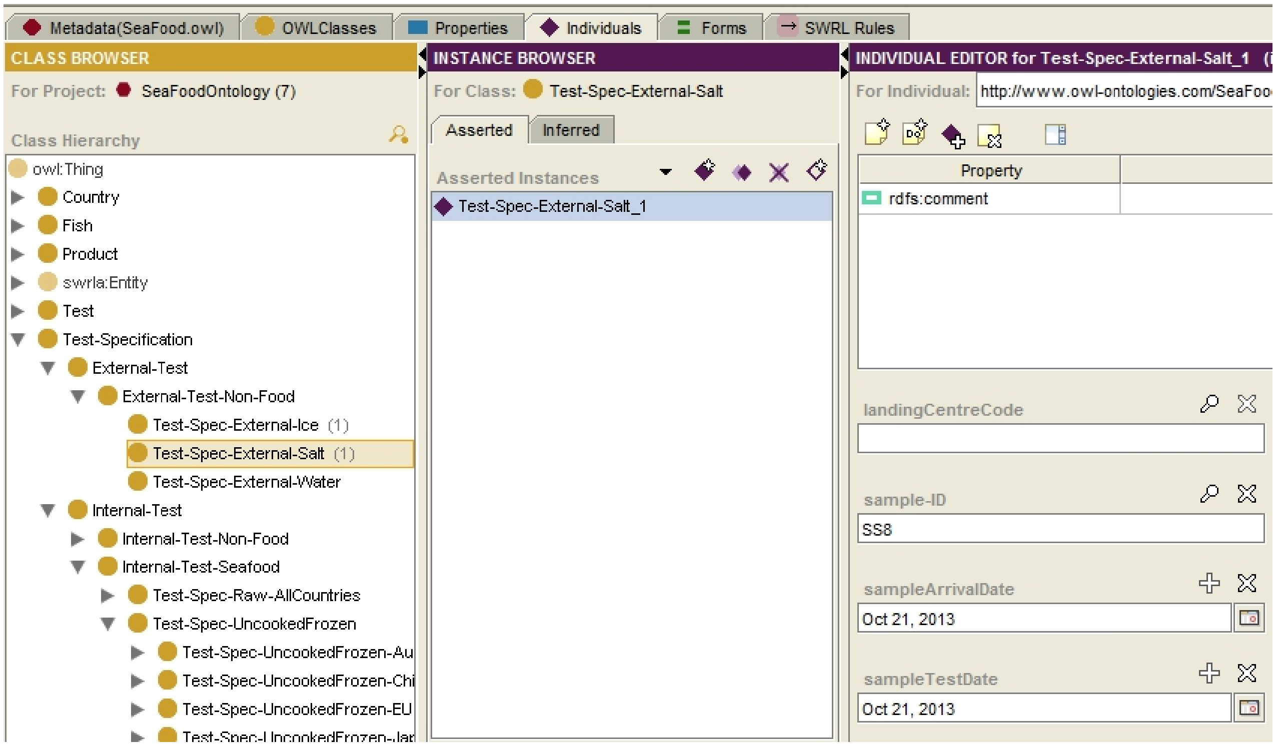

Fig. 1. Seafood Ontology.

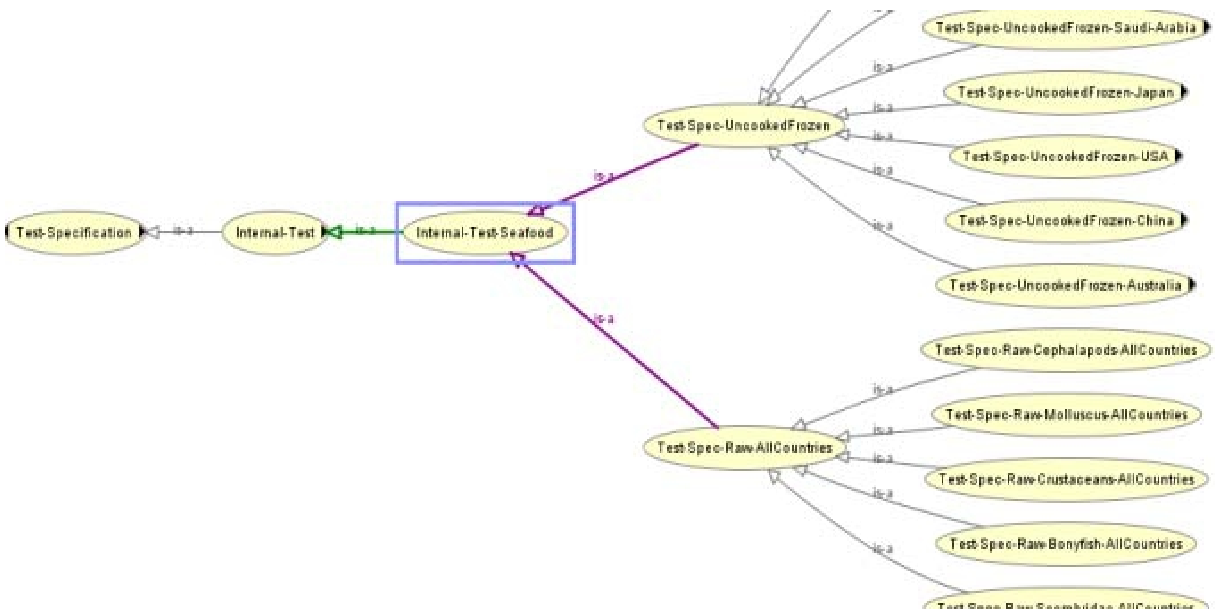

Fig. 2. Taxonomy Representation in OWLViz.

subclasses is further subdivided into many more subclasses which represents specific test item based on country, item type etc. To represent a product sample, an ID, the arrival date of the sample in lab, the date in which the sample is tested, and the country to which it is intended to export needs to be defined by building object and data properties such as *exportTo*, *sampleId*, *sampleArrivalDate*, *sampleTestDate* etc.

The plugin OWLViz enables class hierarchies in ontology to be viewed and incrementally navigated. Figure 2 represents a part of the taxonomy of Seafood ontology.

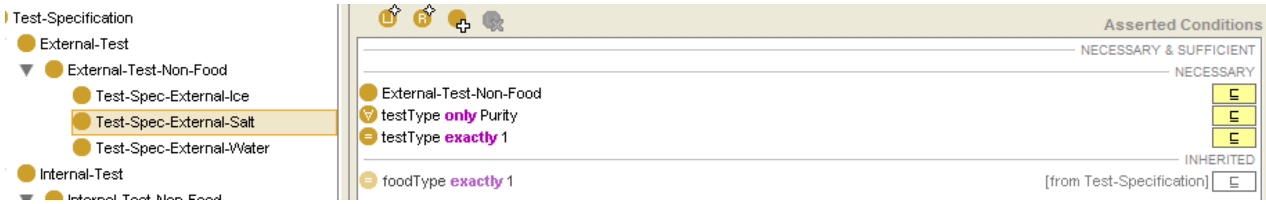

Fig. 3. Property Restrictions (Necessary Conditions) of Test-Spec-External-Salt class.

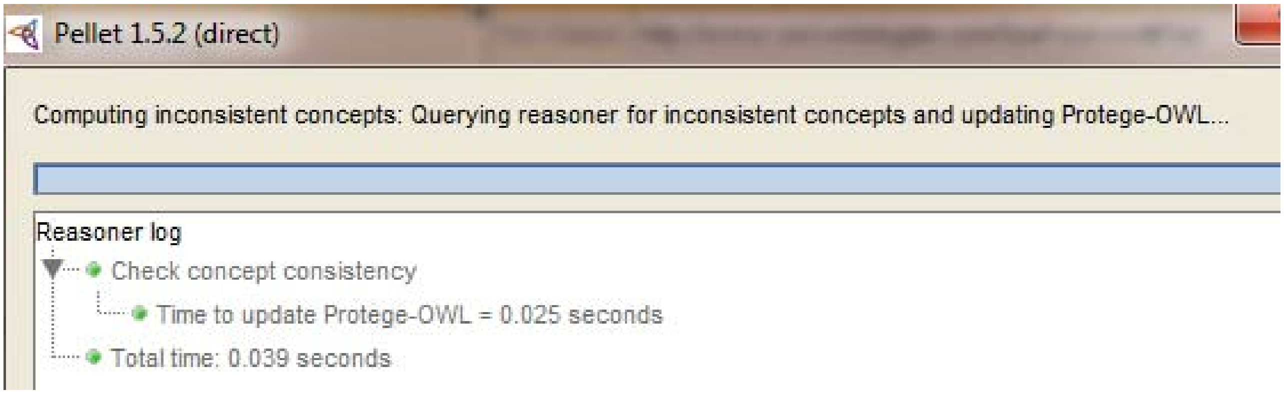

Fig. 4. Checking the Consistency of Ontological Concepts.

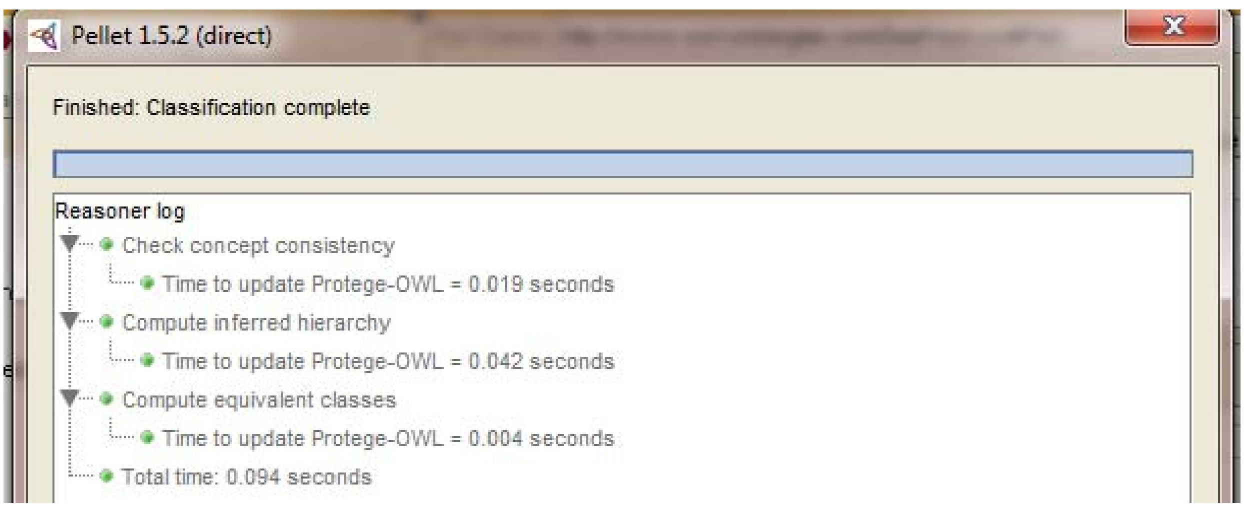

Fig. 5. Taxonomy Classification.

Apart from object and data properties, property restrictions are also specified in the ontology. A property restriction describes the class of individuals that meet the specified property-based conditions. Here necessary conditions are asserted to different classes and some are inherited from the parent class through cardinality restriction and value restriction. For instance, Property Restrictions defined in Test-Spec-External-Salt class are given below:

Test-Spec-External-Salt $\subseteq$ $\forall$ testType only Purity (1)
Test-Spec-External-Salt $\subseteq$ = testType exactly 1 (2)
Test-Spec-External-Salt $\subseteq$ = foodType exactly 1 (3)

The equation (1) represents a value restriction to specify the condition that all instances of External Test Specification of salt contains only purity test. The equation (2) is a cardinality restriction and it specifies that the instances of this class will have exactly one *testType*. This condition is implemented by the universal restriction *allValuesFrom* (only) and the cardinality exactly on the property *testType*. Both the above conditions are necessary conditions. This property specifies that all instances in this class must have values only from the

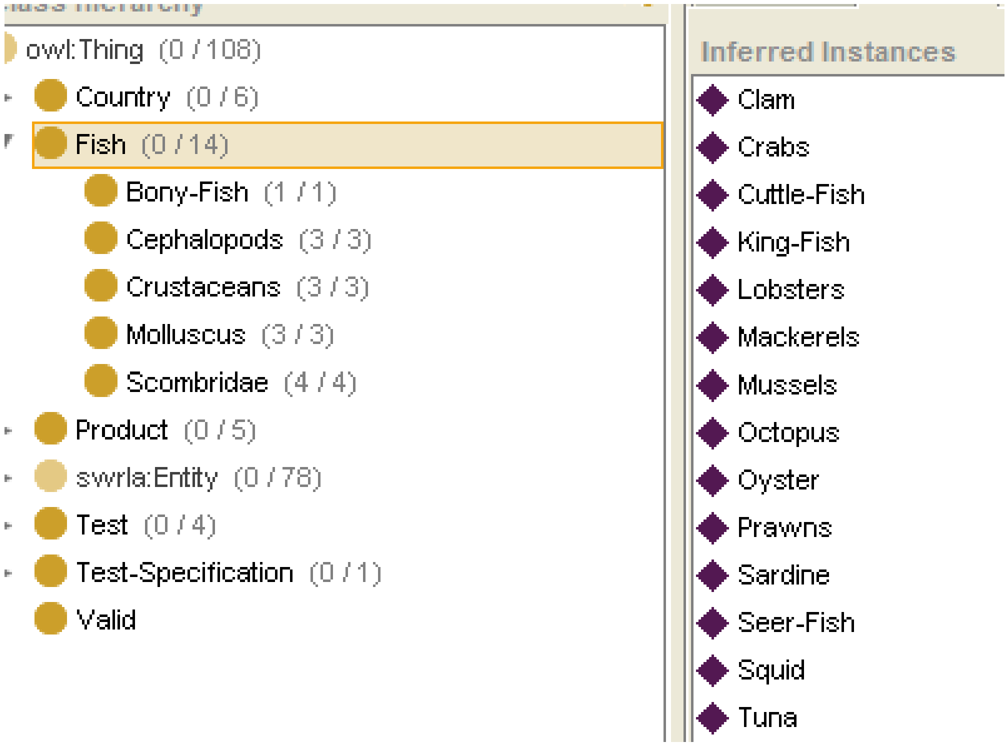

Fig. 6. Inferred Instances.

specified range for the specified property. Also the *Test-Spec-External-Salt* class inherits a value restriction from the parent class Test-Specification (See Fig. 3). Figure 2 represents the property restrictions of Test-Spec-External-Salt class.

RESULTS AND DISCUSSION

Ontology Reasoners are used to check the consistency of the ontology and to automatically compute the ontology class hierarchy (Sherimon *et al*., 2013b). The reasoner helps to check the consistency, classification, realization, and concept satisfiability. Reasoner checks whether there is any inconsistency in the class hierarchy. The reasonerwill find out any hidden relationship in the ontology (Sherimon *et al*., 2013d). If a class does not contain any individuals, it would be an inconsistent class. Also based upon the class description, reasoner will find out if there exist any subclasses of a given class. Thus class hierarchy will be inferred by the reasoner. Also all inferred axioms are generated by the reasoner. Ontology based reasoning makes a way to discover new knowledge, which can lead to new directions in research (Sherimon *et al*., 2014). Protégé does not include a reasoner. So we have to use external reasoners. By default, Protégé doesn't include any reasoning ability. But it supports many third party reasoners such as Fact++, HermiT and Pellet. Here, Pellet Reasoner, a popular open-source reasoner developed by University of Mary Land is used to reason the ontology.

In Seafood Ontology, reasoning is done using Pellet 1.5.2. The consistency is checked, taxonomy is classified and the inferred instances are computed. Figure 4 represents the result obtained when consistency checking is done. It was found that there are no inconsistent classes in the ontology. Figure 5 represents the result of taxonomy classification. Here inferred hierarchy and equivalent classes are computed and the total time to complete the task is generated. Figue 6 represents the inferred instances of the class 'Fish'. Thus the seafood ontology was tested and validated to verify the correctness of data.

CONCLUSION

The OWL based ontology for the Seafood, was constructed with Protégé according to the standard ontology development process. We have extended the seafood ontology that was developed earlier by us, by adding more concepts, properties and property restrictions. Consistency checking of ontology and classification of classes has been done with the support of Pellet reasoner. When ontologies are reasoned by machines, valid deductions and inferences are generated. Ontology provides a shared and common understanding of a domain that can be communicated across people and application systems. Ontologies are able to define relationships, semantics, enhanced clarity, all of which collectively enable information retrieval in a meaningful way. The future scope of this paper is to add rules to the ontology using SWRL [Semantic Web Rule Language] and to implement the ontology based seafood quality assurance system.

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