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An Ontology of Blood Pressure: A Case Study Using Protégé OWL

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Abstract

Although there are vast amounts of information accessible through Web technology, retrieving specifically related information through the Internet can still be difficult. In order to cope with this problem, the World Wide Web Consortium has developed an extension of the current Web called The Semantic Web. The Semantic Web is a standardized mechanism for obtaining meaningful definitions and a fundamental philosophic logic that relates entitites by means of integral relations (the basis for granularity) using conceptual ontology. In this article, the authors describe the essential features of OWL, an Ontology Web Language, and the Semantic Web, and outline their respective representations in Protégé. The authors then utilize OWL to formulate an ontology of blood pressure by extending Kumar and Smith's original blood pressure case study to a domain composed of medical entities. We have a software package that comes with this paper to demonstrate the Ontology for Blood Pressure to a domain composed of medical entities.

Introduction

There are vast amounts of biomedical information available on the Internet today, such as research articles, images, clinical guidelines, cancer research reports, etc. Like other available internet data, biomedical information is very difficult to identify by means of data arising from different resources (Golbeck, 2003). To make the matter worse, the exponential growth of terms used in bioinformatics makes accessing data even more confusing. There is an urgent need for a more structured way to develop biomedical information databases.

Fortunately, researchers in biomedical informatics have realized the importance of developing a universally accessible platform to share data for both humans and machines, and, accordingly, many biomedical ontologies have been developed. For example, the National Cancer Institute has been developing a thesaurus project to provide a well-defined conceptual model so that cancer-related resources can be structured according to the Semantic Web guidelines.

The purpose of this paper is three fold. Firstly, we draw on the seminal work, "Weaving the Biomedical Semantic Web with the Protégé OWL Plugin," by Knublauch, Damerob and Musen, to give an overview of Protégé and its OWL support. Secondly, we implement, in OWL, an ontology of blood pressure. Thirdly, we extend Kumar and Smith's original contribution via reference to a domain expert in medicine, Dr. Allan March (March, 2004), specifically in relation to blood pressure. We examine the granularity and relations between concepts of ontology, and we regroup and zoom them as necessary.

Ontology and the Semantic Web

The word ontology was first introduced by Christian Wolff in her book "Philosophia prima sive Ontologia (1729)." It is a Greek word meaning "…science of being. Such general notions are the notions of essence, existence, attributes, modes, necessity, contingency, place, time, perfection, order, simplicity, composition, etc." (Wolff, 1728). Despite this rigorous and essential philosophical definition however, over the years the notion of a foundation or "essence of being" for ontology has been delimited even in philosophy (Haynes, 2004). When computer science, or more particularly, artificial intelligence, first borrowed the term ontology from philosophy, of necessity the term became appropriately minimalised to a study of ontology being the study of entities and their relationships (Haynes, 2004). In Information Systems, we note the definition "*Specification of a conceptualization*" from Gruber (1993), who introduces ontology in the context of knowledge sharing.

As we note above, the concept of ontology has been borrowed to enable knowledge sharing and logical articulation of entities in artificial intelligence. Thus, in information systems, ontology is defined as "a set of definitions of a formal vocabulary" in the context of knowledge sharing. Importantly, such a definition reveals some "properties" of ontology in the area of knowledge sharing and of AI, thus forming the basis for the community to agree to use the same vocabulary specified by the ontology language (Gruber, 1993).

Ontologies in the context of artificial intelligent are usually presented in a logic-base language, so that they express sound and meaningful relationships for class, functions, properties and relations as they would ideally in the real world. Such ontologies include machine readable definitions of concepts and the relationships among them to automate searching across different resources; they also are human friendly for easy understanding and editing.

The web can only reach its full potential where all data becomes shared through an automatic tool both by machine and humans. Open specifications of the infrastructure components have to be developed for large scale deployment that will be necessary to scale in the Web in the future. For the past five years, the World Wide Web Consortium has been trying to extend the current web to The semantic Web largely through research efforts (Miller, 2004).

The Semantic Web is defined as "a common framework that allows data to be shared and reused across applications, enterprises, and community boundaries." (Brickley et al, 2004) In February 2004, the World Wide Web Consortium approved two key Semantic Web technologies, the revised Resource Description Framework (RDF) and the Web Ontology Language (OWL). It has marked the starting of a broad commercial platform for data on the web after over five years of research. It is an important signal for a mass market for tools that enable complex association for structured data on the web (Brickley et al, 2004).

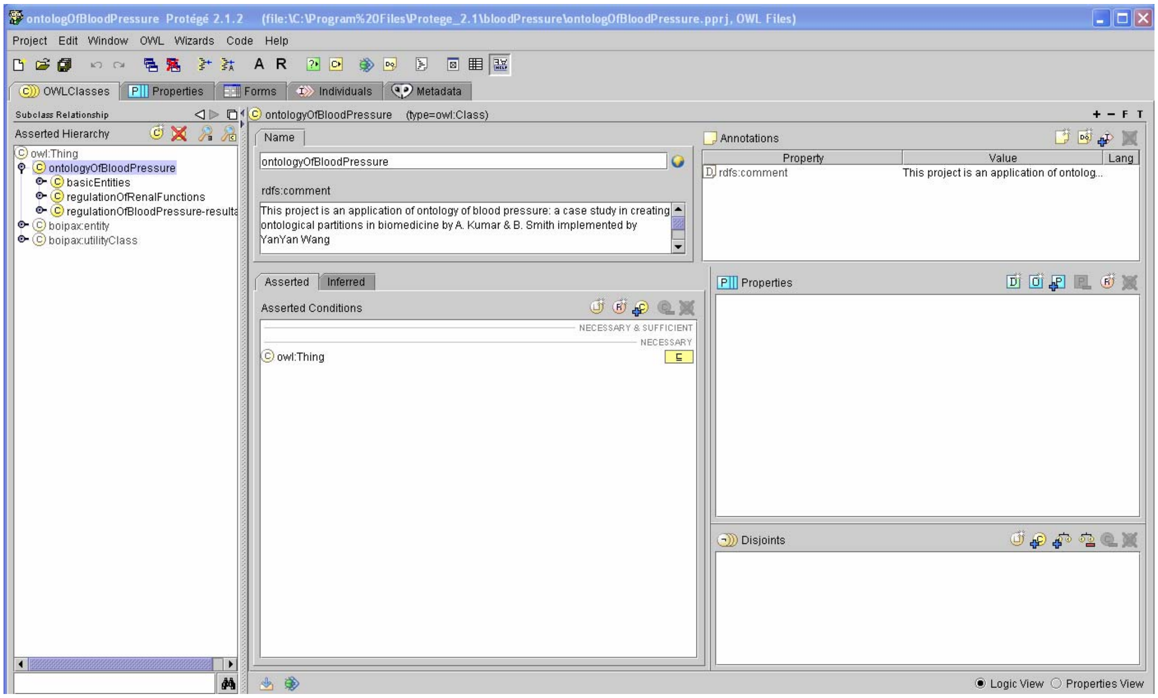
OWL, a Web Ontology Language, unlike earlier web ontology languages such as DAML + OIL have been used for specific user communities (particularly in the sciences and in company-specific e-commerce applications). It is designed for the architecture of World Wide Web, especially for The Semantic Web. OWL builds on RDF and RDF Schema and adds more vocabulary to describe properties and classes: among others, relations between classes, equality, richer typing of properties and characteristics of properties, and enumerated classes (Miller, 2004). This richer typing of properties by OWL enables a more meaningful granularity (or at the very least a sense of granularity) and as such brings OWL, an example of an ontology, closer to the earlier philosophical definition of ontology (Haynes, 2004). Accordingly, many philosophers have contributed to OWL (Smith, Kumar, and Gruber to name a few).

Protégé and OWL

Promoted by the World Wide Web Consortium, OWL is now a widely utilized ontology language for information sharing for Semantic Web contents. Many ontology development tools have been enabled to create the OWL ontology, among them, Protégé, which is an open source development environment with a large community of active users maintained by the Department of Informatics at Stanford University. Ever since the beginning of the 1990, Protégé has been used to build large-scale biomedical applications. With the recent creation of the OWL Plugin, Protégé has become one of the leading OWL development environments.

Protégé provides capabilities for editing classes, properties, and instances (individuals) of the classes (see figure 1). One of its strengths is that it can automate a user interface from class definitions of source code, thus speeding up the knowledge acquisition process and making the user interface customization easy. The OWL Plugin can be used to edit OWL files in various ways, to edit OWL ontologies class definitions, and to link external resources to one's own ontologies, etc. Its user friendly interface makes this editing less confusing, time sufficient, and energy saving (Knublauch et al, 2004).

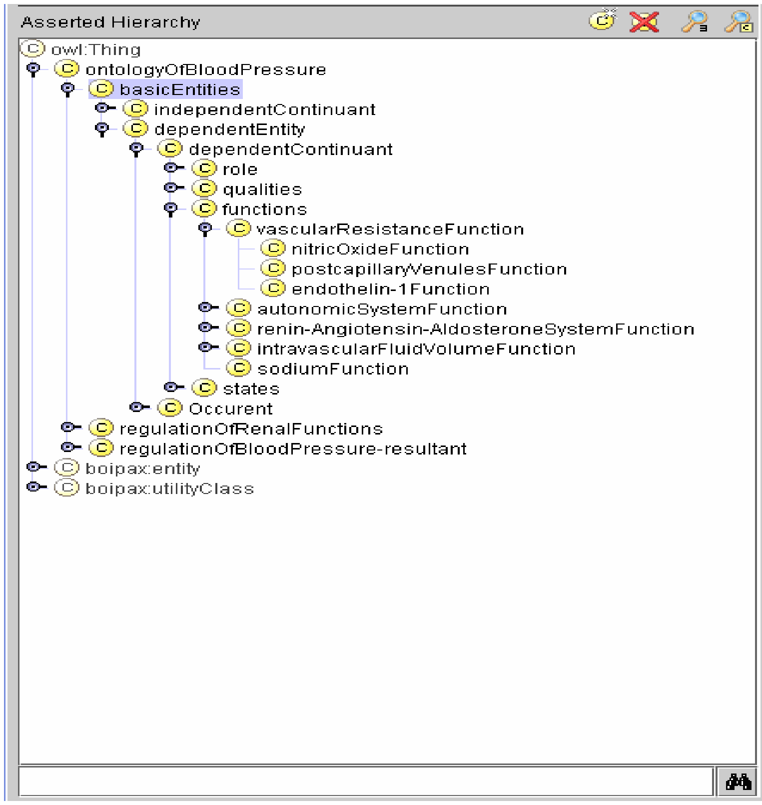
Figure 1: protégé class editor



An OWL ontology is a complex network of entities and their relationships. These networks such as blood pressure are, in essence, the art of partitioning. There are many ways to group these entities, and there is no single best approach. Different partitions are possible to represent different levels of granularity (Kumar et al, 2003) and ontology grouping. For each given partition, there are usually many groups and each of them consists of layers of classes, subclasses, and instances. For example, in the domain of blood pressure, we will have sodium Function, Function, dependent Continuant, basis entity, then ontology of blood pressure, etc. Each class and instance are then related through their properties and restriction. For example, renin is related to Angiotensin I because creation of renin in kidney will produce angiotensin I.

Classes define groups of individuals that share some characteristics or properties. Classes can be nested in multiple layers, and a class can be a subclass of multiple super-classes. Therefore, one can infer that if an individual is a sodium Function, then it is also a basic entity (see figure 2). Properties state relationships among individuals or from individuals to data values. Examples of properties include hasName, hasNumber, hasFunction, and isPartOf. The first two are related to two different datatypes, the third one is a related one of an individual to another, the last one is a state one individual and has intersection to another individual (McGuinness, 2004).

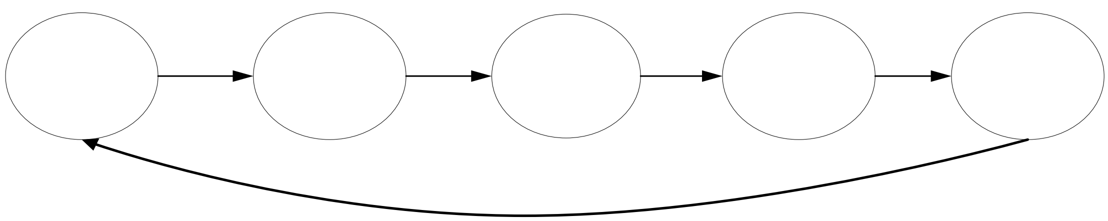
Figure 2: Class hierarchy



Building an ontology of blood pressure with Protégé

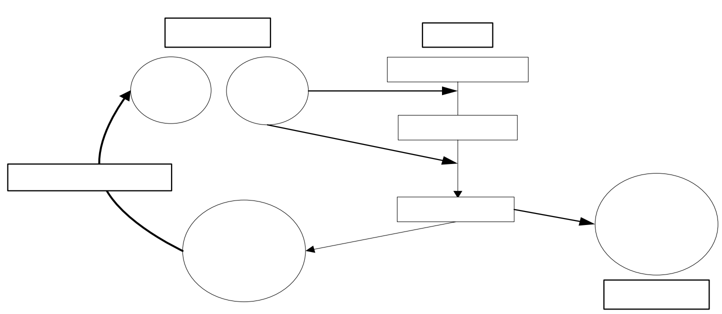
One of the most important aspects of OWL is in terms of its isomorphism characteristic. Recall the goal of the Semantic Web is to create a universal medium for the exchange of information. OWL was designed as the tool to achieve this purpose. Consider that an ontology has to strive to be flexible as possible, for the more general the data sets are, the more isomorphism they get, and the easier access between the resources relevant to the domain in question, the more it will reveal elements of reality represented by a maximally comprehensive philosophical ontology of that domain (Simon et al, 2004). "Blood pressure is the pressure exerted on the arterial walls by the flow of blood." (Kumar et al, 2003). The definition reveals that "blood pressure" includes both function to exert pressure, and also some states. Just like all other aspects of the body system, blood pressure is subdivided into many functions and at a variety of levels. All functions, sub-functions, involve "massive causal interaction with each other and with their surrounding environments." (Smith et al, 2004.) An ontology of blood pressure has to be able to reveal the complex association of body functions and the relationship between the entities by which blood pressure is regulated, as well as the anatomical structure and physiological process (Kumar et al, 2003).

Figure 3: Regulation of blood pressure by blood pressure (March, 2004)



For example, as we change position from laying down to suddenly standing up, our blood pressure is decreased. Then the baro-receptor will sense the change, and baro-receptor reflex is stimulated by the decrease in blood pressure. This change will affect the autonomic nervous system. The cardiac output function (manifested by an increased heart rate) is likely to be affected by the change in the autonomic nervous system; therefore, there will be an increase in blood pressure. This sequence of related occurrences thereby restores the blood pressure to its normal level (March, 2004).

Figure 4: Regulation of blood pressure (March, 2004)



The regulation of blood pressure is much more complicated than we have demonstrated above. Each function is nested in functions, and each of them is related in a web of networks. An ontology of blood pressure needs to be able to reveal the relationship for all of the entities, functions, processes, states – involved in the above and more. Based on partition in the Kumar article, we divide the ontology in two subclasses, basic entities and 'Regulation of'.

Discussion and Conclusion

OWL has the capacity of thousands of classes and each of them can have many properties as well. For the purpose of this paper, we start with a less ambitious implementation ontology of blood pressure. The potential usage for this project could be teaching, decision support for clinical practice, sharing of neuro-imaging data, or semantic assistance for data processing tools.

In this brief version of a much larger paper, we have presented an ontology in relation to biomedical data through implementing an ontology of blood pressure using the Protégé OWL Plugin. Although many have studied the use of an ontology in the development of large clinical terminologies, much more work needs to be done, in particular in association with biomedical domain experts to use the rich semantics of OWL.

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