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A knowledge base with modularized ontologies for eco-labeling: Application for laundry detergents

Da Xu, Mohamed Hedi Karray*, Bernard Archimède

Laboratoire Génie de Production, LGP, Université de Toulouse, INP-ENIT, Tarbes, France

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ABSTRACT

Along with the rising concern of environmental performance, eco-labeling is becoming more and more popular. However, the complex process of eco-labeling is demotivating manufacturers and service providers to be certificated. The knowledge contained in eco-labeling criteria documents is not semantically exploitable to computers. Traditional knowledge base in relational data model is not interoperable, lacks inference support and is difficult to be reused. In our research, we propose a comprehensive knowledge base composed of interconnected OWL (Ontology Web Language) ontologies. This ontology based knowledge base allows reasoning and semantic query. In this paper, a modularization scheme about ontology development is introduced and it has been applied to EU Eco-label (European Union Eco-label) laundry detergent product criteria. This scheme separates entity knowledge and rule knowledge so that the ontology modules can be reused easily in other domains. Reasoning and inference based on SWRL (Semantic Web Rule Language) rules in favor of eco-labeling process is also presented.

1. Introduction

Since the late 1980s, there has been a growing demand for products that do less harm to the environment. The public willingness to use buying power as a tool to protect the environment provides manufacturers with an opportunity to develop new products [1]. From a global point of view, promote of environment-friendly consumption and production will contribute not only to the life quality but also the economy itself. But how does a consumer judge and make good choices to reduce environmental impacts? How should we assess the validity of a statement about a product or service's environmental impacts? The need of evaluating a product's environmental performance has led to the establishment of eco-labels. Nowadays, most of the knowledge and criteria about eco-labeled products are published in official journals, web pages, and all kinds of documentation. Usually, this knowledge is presented in such complex regulation and specification documents that it is difficult to be understood even by humans. The integration of this knowledge into software requires that it must be exploitable to machines. However, until now, there is still a lack of computable format of that. Besides, traditional knowledge base in relational data model is not interoperable, lacks inference support and is difficult to be reused. In order to better understand these criteria and rules, stakeholders need a common and machine accessible presentation of the knowledge. To address such problems, in our research, we propose an ontological knowledge base composed of modularized ontologies. This scheme has been applied to the creation of the ontology knowledge base of EU Eco-label's laundry detergent products.

Due to the fact that EU Eco-label is a large and complex labeling system covering dozens of products and service groups, it is difficult and unrealistic to cover all its products and services in the research stage. Thus, we decide to choose laundry detergent products group which has a middle size knowledge volume to be our study case. The rest of the paper will follow this Outline: The first section presents a state of the art of eco-labeling and modularized ontology; in Section 3, an overview of the criteria document and requirement analysis is presented; The third section talks about how the terminology of ontology is retrieved; Section 5 presents detailed design and construction of the ontology. In particular, an entity-rule separation pattern is introduced. Basic idea of this separation is to put descriptive entity knowledge and subjective rule knowledge into different modules. This pattern is proven to be in favor of modularity and extendability, especially for the rule module. It can also be applied to the other product groups' ontology building and even other similar criteria-like document's knowledge extraction; the fifth section is about how to utilize

* Corresponding author.
E-mail addresses: da.xu@enit.fr (D. Xu), mkarray@enit.fr (M.H. Karray), bernard.archimede@enit.fr (B. Archimède).

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reasoner to do the reasoning upon the ontology knowledge base and the argumentation, which is very important to eco-labeling decision support process; in Section 7, we have a brief evaluation and analysis for the ontology; Section 8 is about some discussion of experience feedback, and learned lessons. Finally, in the last section, we have conclusion, discussion and future work.

2. State of art

2.1. Eco-label and EU Eco-label

According to Global Eco-labelling Network[1] (GEN), “eco-labelling” is a voluntary method of environmental performance certification and labelling that is practiced around the world. An “eco-label” is a label that identifies overall proven environmental preference of a product or service within a specific product/service category. They usually concern the whole life cycle of the product and are issued by a third party [2]. Eco-labeling has a number of benefits from various points of view. First, eco-labeling is a good way to inform consumers of the environmental impacts of selected products. In the practice of some existent eco-labeling, the fitness of use and human health aspects are also included. All this information will help a consumer make decision out of different willingness. Then, eco-labeling is generally cheaper than regulatory controls in terms of global economics. By empowering customers and manufacturers to make environmentally supportive decisions, the need for regulation is kept to a minimum. This is beneficial to both government and industry [3]. Eco-labeling will also stimulate market development and encourage continuous improvement on products and services.

EU Eco-label is a successful example among all the eco-labels. Created in 1992, EU Eco-label is the only official European ecological label authorized for use in every member country of the European Union [4]. Until 2011, there are over 1300 enterprises that have been issued EU Eco-label licenses. By September of 2014, there are already over 43,000 products or services being labelled [5]. France is always an important contributor to EU Eco-labeling. By March of 2016, 486 enterprises in France have obtained EU Eco-label licenses in various product groups and that makes France the first place as for the enterprises' possession of EU Eco-label licenses. As illustrated in Fig. 1, the removal of certain product group (e.g. IPV:Indoor paints and varnishes, SSC: Soaps, shampoos, and hair conditioners, and OPV: Outdoor paints and varnishes.) which happened in 2016 indicates that the alteration of EU Eco-label criteria is continuous. It also implies that the change of knowledge and rules. Although the size of LD (Laundry detergents) group is not the largest, it keeps increasing in the recent 4 years.

EUEB (European Union Eco-labeling Board) is responsible to develop and regularly review eco-label criteria. EUEB will set up an advisory body including representatives on behalf of different stakeholders. Feasibility study will be carried out to draft the environmental criteria. At last, representatives from every member state will be summoned to vote to approve the criteria or the guideline [6]. The guideline developed by the advisory body, together with the possible amendment or annex will be the baselines for the knowledge base that we developed in this work.

2.2. Ontology and modularized ontology

Derived from philosophy, in computer science, we refer to an ontology as a special kind of information object or computational artifact [7]. Studer et al. [8] gave definition stating that: “An ontology is a formal, explicit specification of a shared conceptualization”. Today, so many ontologies and knowledge repositories have been developed and adapted into applications, especially in biomedical domains [9]. Successful examples and platforms are BioPortal,[2] UniProt,[3] LEO,[4] etc.

Despite quite amount of ontologies of different domains are developed, a lot of problems are encountered when knowledge engineers as well as general users want to understand and reuse the ontologies into their own development. As for the application of ontology, there is definite need to gather knowledge from multiple remote ontological sources. It is known that, when knowledge is distributed, the idea to collect all knowledge and put them into a single repository (i.e. the integration approach) is very difficult to implement, because of semantic heterogeneity calling for human processing [10]. Another very important reason is the low reusable design of these ontologies. Good ontology design pattern has drawn the attention of many researchers. In [11] and [12], a method to describe ontology design pattern is presented. A Semantic Web portal called *OntologyDesignPatterns.org*[5] is also available. However, most of the submitted patterns are cataloged in Content Ontology Design Patterns which means that the patterns themselves may contain certain semantics and domain knowledge, which may still set obstacles to ontology reuse. Also, most of these patterns' structure is hard to be modularized and very few of them care about modularity in a specific way. Thus, better engineering principle and philosophy about ontology modularity is needed.

Generally speaking, there are two important aspects of ontology modularization: independently developing modules that can be integrated coherently and uniformly (ontology composition) or extracting such modules from an integrated ontology for supporting a particular use cases (ontology decomposition) [9]. Most of our research focus on the first aspect and we emphasize more on reusing, inference and change management of ontology knowledge base.

To achieve ontology modularity in a distributed scenario, different methods and schemes have been proposed. For example, E-Connection is proposed as a set of “connected” ontologies. An E-Connected ontology contains not only information about classes, properties and their individuals, but also a new kind of properties, called Link Properties, which establish the connection between the ontologies [13]. Another interesting approach is Distributed Description Logics (DDL) framework [14] and the distributed reasoner DRAGO (Distributed Reasoning Architecture for a Galaxy of Ontologies) [15] as formal and practical tools for composing modular ontologies. Also, there is Package-Based Description Logics as another formalism that supports contextual reuse of knowledge from multiple ontology modules [16]. While, these methods and formalism have more or less logic compatibility problems when we try to use them together. For example, the underlying logic formalism of E-Connection is OWL-DL (i.e. SHOIN); logic formalism for DDL is SHIQ; when it comes to Package-Based Description, it turns into SHOIQ. Very few of these methods have full compatibility and equal logic expressiveness as OWL standard. This could limit large scale reasoning and modification between heterogeneous and distributed modular ontologies. From practical perspective, these methods have not been applied in such a considerable scale. Most of the methods focus on low-level modularization of syntax and semantic level, a higher level consideration which

[1] http://www.globalecolabelling.net/.

[2] http://bioportal.bioontology.org/.

[3] http://www.uniprot.org/.

[4] http://leo.informea.org/.

[5] http://ontologydesignpatterns.org/wiki/Main_Page.