

KNOWLEDGE REPRESENTATION IN ENVIRONMENTAL IMPACT ASSESSMENT

A Case of Study with High Level Requirements in Validation

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Abstract: An ontology which allows to represent knowledge of environmental impact assessment (EIA) and its involved processes is presented. This knowledge representation is designed to be used in two contexts. The first one is a repository of the elements and concepts used in EIA by environmental experts as a structured knowledge source. The second one is a formal definition of the concepts to be used in an intelligent system for EIA. The first usage requires obtaining a high level of consensus about what elements have to be defined.

1 INTRODUCTION

Environmental impact assessment (EIA) ensures that environmental consequences of projects are identified, assessed and taken into account before the decisions are made. A lot of methodologies and tools for EIA have been built although most of them were designed for a specific human activity. In fact, software based on word computing and methodologies for mining, civil construction and landfills have been developed by our group (Delgado et al., 2006).

These experiences have encouraged us to develop a generic tool for EIA which is able to assess any industrial activity. This ambitious project requires more sophisticated approaches due to the complexity. Consequently, processes and elements involved in EIA have to be gathered and organized using knowledge representation by mean of ontologies.

The final software will be based on this knowledge representation and the ontology is expected to be used by environmental experts as a knowledge source so that a consensus in its contents must be reached. Approaches for validation already exist although they are focused on metrics to design a formal model for evaluation (Gangemi et al., 2006; Brank et al., 2005) whereas this ontology needs a higher effort in evaluating their contents.

The first section describes the methodology followed to build the ontology. Next section shows the most significant design decisions and the general structure. Section 4 explains a developed web appli-

cation to manage the ontology evaluation to reach a consensual knowledge. And finally further work and references are included.

2 METHODOLOGY

Nowadays, there is no standard defined for building ontologies so that each developer tends to follow his own design criteria and principles depending on the ontology usage.

However, some authors suggest guidelines and methodologies such as the Uschol and King's method (Uschold and Grüninger, 1996), the method used in the KACTUS project (Schreiber et al., 1995), the Sensus project (Swartout et al., 1997) or the Methontology method (Fernández et al., 1999).

In (Gómez and Benjamins, 1999) it is explained that most of methods do not put enough attention in development phases like management, merging, learning, integration, tracing and evaluation whereas they focus its effort on conceptualization and ontology implementation.

Combining the previous methodologies explained above, we have established a set of steps to build the proposal of EIA ontology.

1. *The aim and scope identification.*
2. *The ontology construction process.*
 - (a) *Getting knowledge: Top-down.*
 - (b) *Encoding phase.*

- (c) *Integration with other ontologies.*
- (d) *Inference.*

3. *Evaluation.*
4. *Documentation.*
5. *Maintenance.*

In the following paragraphs, the most significant points of the ontology-building steps are briefly commented below.

The aim and the scope consist of building an ontology which establishes a conceptual framework for EIA with two main objectives. On the one hand, it must provide a structured knowledge which can be used by environmental experts as a reference guide. Moreover, it can be a helpful tool during the new methodologies development for EIA. On the other hand, the ontology cannot be only used as a glossary for environmental experts. It includes formal semantic definitions for processing and reasoning tasks.

The ontology has been designed with a top-down strategy because new knowledge can be aggregated in the future. This new knowledge will correspond with concepts belonging to the EIA of activities not still considered.

A strict and complex getting knowledge phase must be accomplished due to the ontology will be used by environmental experts. Hence they must participate in the evaluation phase too.

Protégè¹ has been chosen for building the ontology due to its characteristics. Firstly, it permits ontologies creation in OWL², avoiding the direct treatment of OWL syntaxes and following the W3C (World Wide Web Consortium) recommendations. Secondly, it is an open-source platform, so it can be customized to create knowledge models and data inputs, e.g. adding vagueness or uncertainty to the concepts, or using plugins. Furthermore, it works with external dig reasoners like Pellet³ or Racer⁴.

A lot of ontologies related to the environmental sciences have been found, although none of them related to EIA. Most of these ontologies were rejected because of an unsuitable granularity or content, so that only a few existing concepts have been included.

The evaluation process has been accomplished during the whole development in a cyclic way. Experts of environmental technologies area have evaluated prototypes with different granularity levels and they have provided a general review and new knowledge.

¹Developed by Stanford Medical Informatics.

²OWL (Ontology Web Language) is a semantic markup language for publishing and sharing ontologies.

³<http://pellet.owldl.com/>

⁴<http://www.racer-systems.com/>

Documenting the main design decisions only is the normal way to follow. By contrast, the first ontology objective obeys to write a large documentation where almost every concept or groups of concepts has been justified.

3 ONTOLOGY DESIGN

The main concepts of the ontology are extracted and justified from its own definition.

From a technical viewpoint, EIA is an analysis process to identify cause-effect relationships and to quantify, assess and prevent the environmental impact of a project or an activity (Gómez, 2003).

As it is explained above, this structure will help to environmental staff to understand the ontology organization in order to accomplish the first objective, using the ontology like reference knowledge. Hence, the concepts should be grouped in a logic way.

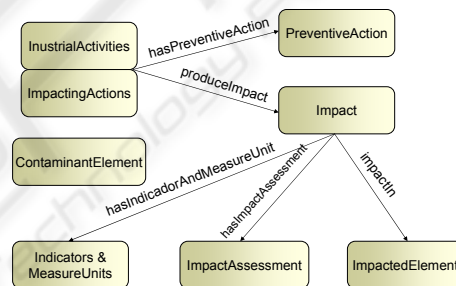


Figure 1: Main concepts and relationships.

These important concepts are:

- Environmental impact which is any adverse or advantageous change in the environment produced by the activities, products or services of an organization.
- Environmental elements which may suffer impacts.
- Human actions which may produce impacts and affect to the environment. These are the cause of the impacts.
- Industrial activities, which are strongly related to the human actions, although they have their own troubles and a different abstraction level.
- Substances or contaminant elements. Although these are not the cause or effect of an impact, many times they are the way the impact is produced.
- Preventive actions, which are actions used to prevent or hinder environmental damages.

- Environmental indicators or measure units for impacts.
- Impact assessment, which are qualities linked to the impacts.

These aforementioned concepts belong to the first hierarchical level although there are others concepts and other levels below it.

The source used to extract the knowledge is not so important for knowledge based systems although it has more importance in the context of environmental experts. These sources are books (Gómez, 2003; Garmendia et al., 2005; Smith, 2002; Block, 2000; Baretino et al., 2005); technical reports (Carter and Sadler,); other ontologies (GCMD,); standards like UNE 150008 and UNE 14001; PhD Thesis (Colomer, 2007; Garrido, 2008); Spanish legislation like 1131/1988 and 11/2005; and international legislation such as the European directives 2000/60/CE, 96/61/CE, 92/43/CEE, 79/409/CEE, 2455/2001/CE and 85/337/CEE. In addition, a large range of bibliography has been used but not referenced here.

3.1 Relationships and Concepts

A schematic diagram describing the most relevant concepts and relationships among them is showed in figure 1. These relationships are extracted instinctively from the EIA definition as well as the concepts. These are:

- **hasPreventiveAction:** An impact has a preventive action.
- **produceImpact:** An industrial activity or an impacting action produces an impact.
- **hasIndicatorAndMeasureUnit:** The indicator of an impact or its measure unit.
- **hasImpactAssesment:** An impact has a specific impact assessment.
- **impactIn:** An impact is produced over an environmental factor.

The relationships allow the ontology improvement adding knowledge and specifying formal definitions of concepts.

These formal definitions are the base of any reasoning task and thus using the ontology to generate new knowledge is possible. For example, the ontology could be queried for the environmental indicators of a series of impacts which are being evaluated.

The ontology is allocated for free access in the web site <http://arai.ugr.es/eiadifusa> so that the whole hierarchy can be explored.

4 WEB APPLICATION FOR CONSULTING AND CONTRIBUTIONS

An ontology with these characteristics needs to make a strong effort in the evaluation phase. It has to include the concepts which really have interest in the EIA process. This is the only way they could use it like a knowledge base to give an assist with the methodologies development by hand. Furthermore, this is necessary to carry out the next step, to obtain machine-driven development of EIA methodologies.

To sum up, the evaluation and the knowledge homogenization are the objectives of the web application and this task should be done with the assistance of environmental experts. However, they do not know about OWL and requiring them to install applications like Protègè tends to be problematic, because this is a tool too much powerful for people who only have to explore and check the ontology.

Moreover, a mechanism to collect the suggestions should be made automatically to organize the information properly and deal with a wide range of referrees.

A web application⁵ has been developed to collect criticisms or suggestions and solve both problems. The web interface is organized in two frames. The first one contains the concepts hierarchy and it allows browsing it. The second one shows the concept information when it is selected.

Two different kinds of contributions can be chosen, related to a specific concept or with a general character. Both fill a simply form which contains information contact if it is necessary to establish communication to clarify the criticism.

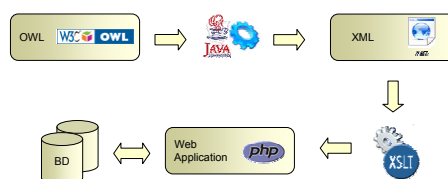


Figure 2: Generation process of the web application.

The web application has been built according to figure 2 and using the own experience in the development of a Final Application Generator based on model-driven software development (Garrido et al., 2007).

First of all, the generation process begins pre-processing the ontology in OWL. Then, an intermediate representation is produced in XML. And finally,

⁵<http://arai.ugr.es/eiadifusa>

all the files required by the php application are generated from the intermediate representation by a XSLT transformation.

The routine work required to create a working application is automated, thus avoiding the common mistakes in a manual process; it would entail and improve the overall application quality. Consequently, if any change in the ontology or in the source files of the web application is needed, it will be accomplished and after that the web application will be generated again.

5 FURTHER WORK

An ontology for EIA is built in order to provide experts with a reference for their methodologies development. This use requires that it contains standard and consensual knowledge so that a web application is development to allow the evaluation of their contents. Hence, Environmental experts are called for contributions and suggestions, which will be later analyzed, contacting directly with them or during conferences related to EIA.

An application will be developed to give assistance in the development process of methodologies. The user will obtain the concepts related to the EIA of a specific activity by querying the ontology.

Finally, as it mentioned before, the ontology will be used to manage the knowledge of an EIA expert which will provide information access, reasoning capabilities and a mechanism to assess the environmental impact of an industrial activity.

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