Waste Management Information System
An Expert System Using Ontologies

Erdogan Dogdu, Bahadir Katipoglu and Umutcan Guney
Department of Computer Engineering, TOBB University of Economics and Technology, Ankara, Turkey

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Abstract: Legal documents that include rules and regulations are hard to interpret most of the time. We present the requirements and the design of an ontology-based expert system framework that we are developing for easy translation of legal concepts, rules and constraints to an ontology. Ontology engineers and domain experts on specific legal documents work collaboratively on this system to generate generic and customized ontologies via an ontology generation workbench called WOBE (Ontology-based Expert System Workbench) and the expert system built using the workbench allows end users to follow the rules and regulations without consulting the complex legal documents. We compare WOBE framework with related tools at the end.

1 INTRODUCTION

Rules and regulations are difficult to follow using written legal documents. Therefore, domain experts and consultants are needed in many fields to help with compliance with the law and regulations. Waste management and related environmental laws are one of those areas that require strict compliance because the fines and penalties have been significantly increased in recent years all over the world in the case environmental violation of law. We have looked at the regulations that are overseen by the Waste Management Division of The Ministry of Environment and Urban Planning of Turkey. It consists of 16 separate documents with over 100.000 words. They are very detailed and difficult to search and follow. The regulations are very complex and therefore the Ministry publishes flow-charts to explain the rules for involved parties. There are over 700 environmental consulting companies and more than 11 thousand experts registered by the Ministry to help companies and institutions with the regulations.

We are developing a research project with funding from the Ministry of Science, Industry and Technology of Turkey to develop an expert system that will help companies, institutions, and individuals to comply with complex rules and regulations. The system will enable domain experts to define the rules for any application domain, and end-users to follow their compliance with the rules. For this purpose an ontology-based information system will be built with a dynamic graphical user interface for easy creation of rules with graphical components in a Web interface. The system will utilize reasoning capabilities of ontologies to deduce new information and additional rules, and automatically detect compliance or non-compliance situations for the users and alert them appropriately.

As a case study, we will convert all rules in 16 documents by the Waste Management Division into the system with the help of TAYTEK Waste Management Inc. (Ankara), an environmental consulting company located in Ankara with domain experts and is a partner and sponsor in our project. We will measure the effectiveness of the system with test cases in the field.

In section 2 we present the motivation for the project. Then, we present the related work in section 3. We present initial prototype design of the system in section 4. In the same section we also present WOBE (Ontology-based Expert System Workbench) that can be utilized in similar domains as an ontology-editor and presentation tool; the design and user interface of the WOBE prototype. We present the future evaluation plans and a comparison of WOBE to similar tools in section 5. We conclude in section 6.

2 MOTIVATION

We conducted a survey with 58 environmental engineers and environmental consultants from different regions of Turkey who gathered at a national work-

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shop in 2013 in order to discuss the alterations in the Turkish Environmental Legislation. This survey included questions like “Are you making any mistakes during the determination process of the articles that will be included in the regulation?”. According to the results of this survey, 69% of the participants answered “rarely” and 16% answered as “often”. Consequently, 85% of the participants accepted that they make mistakes in the process at some point. On the other hand, 72% of the participants agreed that “laws and regulations are not written in an understandable language (clearly)”. Among the participants of this survey, 87% of them were “not aware of expert systems”, 81% of them were “not aware of decision trees”, 83% of them were “not aware of ontologies”, and 91% of them were “not aware of semantic web”.

The results of this survey have shown that regulations are not clear and not easy to follow. And, there is a need for an expert information system for waste management that is easy to use, makes rules clear, and eliminates mistakes. This is also true for many such regulated domains.

We aim to develop a software system and related methodologies that can be used to transfer concepts, relations, and rules in written legal documents to a knowledgebase. An ontology engineer will use this system to design an initial generic ontology for a specific domain, and a domain expert will customize the ontology for the specific decision making processes in the related field of their expertise.

Since any such expert system will need a similar data and information management infrastructure, we decided to develop a generic workbench that can be used to develop similar expert systems. The workbench we are developing is called WOBE (Ontology Based Expert System Workbench) that serves as a framework and an infrastructure for developing expert systems.

3 RELATED WORK

There are many works in the literature on expert systems, ontology-based expert systems, and methods used in ontology-based expert systems. Here we mention some of the noteworthy work in the area. Ontologies are now being used in information systems more frequently than before. We also see more publications in this area in the literature. Ontology-based information systems are used in the domains of law, healthcare, education, science, business, manufacturing and so on.

There are also many works in the literature on the design and use of ontologies in legal information systems. Kayed presents an early attempt for an e-law ontology capturing legal concepts and relationships (Kayed, 2005). Gangemi proposes using Content Ontology Design Patterns which help ontology designers to develop legal ontologies easily (Gangemi, 2007). Khadraoui et al present guidelines for the development of an eGovernment Information System ontology towards an eGovernment Information System (Khadraoui et al., 2005). (Breuker et al., 2004), (Cheng et al., 2008), (Lame, 2005), (Wyner and Hoekstra, 2012), (Wyner, 2008), (van Heijst, 1995)

In JUMAS[1] (Judicial Management by Digital Libraries Semantics) project, which is a European Union supported research project between 2008 and 2011, tools and methods are developed for semantic enrichment of legal documents (via annotation) for easy discovery and presentation of legal document and multimedia libraries (audio and video). They developed a query expansion method and prototype implementation based on ontologies (Sartori and Palmonari, 2010).

To the best of our knowledge there is no work in the literature that fully converts a set of legal documents into a knowledgebase system for testing. In our project we aim to convert 16 legal documents in waste management area into a comprehensive ontology and also develop an expert system that will use these ontologies to guide end-users for compliance with those laws.

Question answering systems are getting popular with the advances in semantics-based knowledgebase systems. We also see relevance that in future expert systems and decision support systems this kind of semantic question answering will be used more robustly to guide users towards intelligentdecision making using automated reasoning and some sort of natural language processing. Hakimov et al developed and tested methods to answer natural language questions using linked data and relational patterns discovered in the Web (Hakimov et al., 2013). Angele et al developed an earlier question answering system that uses semantic Web concepts and ontologies based on chemical laws in the context of Digital Aristotle project (Angele et al., 2003).

In the system we are developing we also deal with visual presentation and manipulation of ontologies. In ontology visualization area, Katifori et al surveyed ontology visualization methods (Katifori et al., 2007). They present the existing methods, evaluate their characteristics and point to future directions in ontology visualization. They especially focus on 2D vs 3D visualization methods and their respective ben-

[1] JUMAS project, http://www.jumasproject.eu

efits and disadvantages (Katifori et al., 2007). Bosca et al developed a reusable component for 3D visialization of semantic Web (Bosca et al., 2007). We also decided to experiment with 3D visualization as a result of evaluating these work since 3D offer a richer view and better design approach in ontology visualization and construction.

4 ONTOLOGY-BASED EXPERT SYSTEM

We are designing an ontology-based expert system for waste management that will allow ontology engineers, domain experts, and end users to work together. The backbone of the system is an extended and extensible ontology that will define the meta-data and rules in written documents.

Expert system setup process consists of two main steps: ontology development and ontology usage phases as depicted in Figure 1. In the ontology development phase, ontology engineer creates a “generic ontology” by translating the artifacts (concepts, relationships, rules) in the legal document to ontology terms. While creating this ontology, engineer may use any suitable tool, such as Protégé[2], that is compatible with OWL2 standards. The ontology created at this phase is a “generic” one because it represents all of the general concepts and rules in the written legal document.

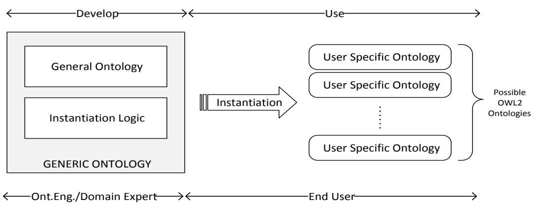

Figure 1: Ontology design and use phases.

In the ontology usage phase the domain experts and end users customize this generic ontology for their own needs in user specific ontologies (Figure 1). To this end they instantiate the ontological concepts and relationships by entering domain and/or user specific information. In the ontology design phage, ontolgy engineer also marks the decision points on the ontology and therefore decision trees are automatically generated for the domain expert's use. A sample decision point, the edge marked S between n_1 and n_2 nodes, is shown in Figure 2.

Even though separating the works of ontology engineer and domain expert is not completely possible,

[2]protege.stanford.edu

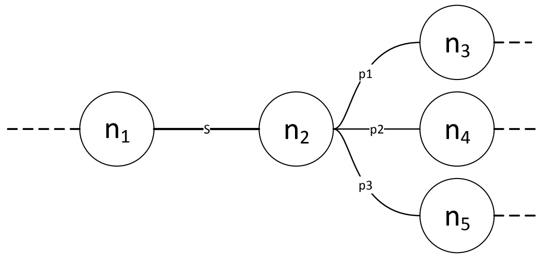

Figure 2: A sample decision edge.

these decision trees inserted into the ontology isolates their work to a degree. In the case an ontology engineer needs advice from a domain expert, rather than communicating with the domain expert, ontology engineer may put decision trees to the necessary points and let the domain expert make the decision later. Moreover, the domain expert can complete his or her design process without any knowledge about ontology design. The tool called WOBE, which we are developing, gives the domain experts a chance of creating decision trees visually via finding marked connections (S edge in the above figure) in a given ontology. Apart from this, domain expert or ontology engineer can analyze the ontology with a three dimensional visualization if they wish (Figure 7).

Another advantage of inserting the decision trees into the ontology as described above is that the domain expert can add question texts (Figure 8), which is not in the written text (regulations), to ease the way to reach to a decision point. Thus, while the general ontology is a literal translation of the original text, the decision trees are more user-oriented, asking questions to find out and construct the customized ontology instance.

It is now also possible to make inferences on the acquired ontology by running standard ontology reasoning engines on it. These inferences will again be presented to the user by the client systems. We will provide this web application within the scope of the Waste Management Regulations that we are developing.

4.1 Sample Scenario

Consider the following rule taken from the written regulation on the Control of Air Pollution Due to Industrial Production of Turkish Environmental Protection Law:

Article 20b: Air dust emissions can not exceed the limits set by the regulation for facilities which are subject to legal authorization for establishment and operation due to the significant impact on air pollution.

Concentration limits are:

- CLASS 1 dust emissions (for emission flows of 0.1 kg/hour and above): 20 mg/Nm^3
- CLASS 2 dust emissions (for emission flows of 1 kg/hour and above): 50 mg/Nm^3
- CLASS 3 dust emissions (for emission flows of 3 kg/hour and above): 75 mg/Nm^3

Limits of mixtures:

- CLASS 1, 2: 50 mg/Nm^3
- CLASS 1, 3 or 2, 3 or 1, 2, 3: 75 mg/Nm^3

(Class 1,2,3 type materials are listed in the law)

First, an ontology engineer converts this article into the general ontology terms (Figure 1 develop phase). Ontology engineer also identifies decision points in the ontology. For example for the above article, dust emission limits can be 20, 50 or 75 mg/Nm3 for class 1, 2, 3 type of materials respectively. We plan to introduce a visual tool for the engineer where he or she can choose and mark decision points in the ontology visually.

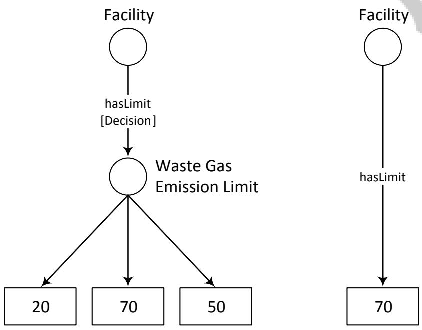

Figure 3: Generic ontology (left) and customized ontology (right).

In the use phase (Figure 3, 4) the end users decide what to do in decision points that are determined in the previous stage. And this is done through a question-answer session on the system. At the end, the ontology will be customized for the end user with specific facts as shown in Figure 3. On the left of the figure we see the decision points based on the generic ontology and on the right side the final statement (customized ontology) for the end user, that is “the facility has gas emission limit 70”.

4.2 System Architecture

The expert system we are designing is a multi-tiered system like all modern information systems. The system consists of mainly the following components as depicted in Figure 5. WOBE, or Ontology Based

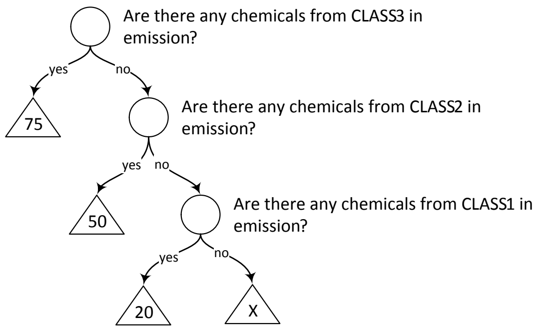

Figure 4: A sample decision tree.

Expert System Workbench, is an integrated development environment (IDE) for ontology engineers and domain experts. It serves as a visual tool for these users at development stage of the expert system building and it has modules for both ontology creation and decision tree building.

Expert System Services is a web service that provides resources for client applications serving the end user customization stage of the expert system. Generic Ontology Framework provides the main functions for data modelling and customization of ontologies. It allows operations like storing, querying, and updating on ontology model and related decision trees.

Datastores layer consists of a NoSQL database for decision trees and a triple store for ontology persistence. Access to this layer is only possible via Generic Ontology Framework layer.

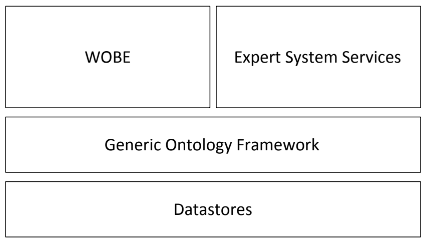

Figure 5: Software components of the ontology-based expert system framework.

4.3 Detailed Architecture

Our initial detailed design is depicted in Figure 6. We have used some of the open source libraries for specific tasks.

Our system uses OWL2[3] standard and is based on Jena Framework[4] for ontology design and manipulation. On top of these, there is another layer we developed, which we call Generic Ontology Framework

[3]OWL2, www.w3.org/TR/owl2-overview
[4]jena.apache.org

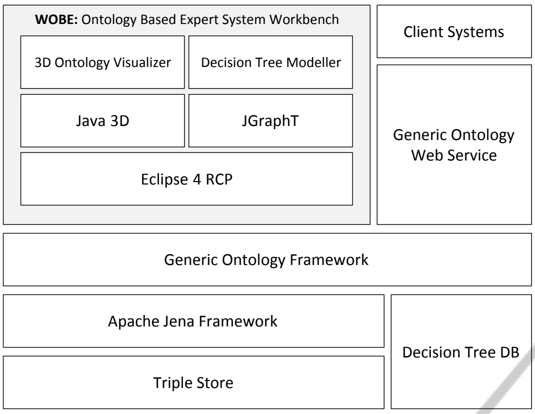

Figure 6: Software components of the ontology-based expert system framework.

(GOF). This layer lets the generic ontologies process using decision trees, save and present them. GOF stores decision trees in a NoSQL database called Decision Tree DB and we use MongoDB[5] in our prototype. We constructed the Generic Ontology Development tool named WOBE on Eclipse 4 RCP platform[6] and used libraries like Java3D[7] and JGraphT[8] for 3D ontology visualization.

4.4 WOBE: Ontology-based Expert System Workbench

This tool is mainly developed for ontology engineers and domain experts for designing a "generic ontology" which is the base ontology for creating user specific ontologies. WOBE is carefully designed to isolate the work spaces of ontology engineer and domain expert from each other. It lets the ontology engineer create the template ontology with the least knowledge about the subject and lets the domain expert add the details having the least knowledge about the ontology. This is one of the main design principles of WOBE, that is the "separation of concerns".

One of the edges in Figure 7 is marked as an edge which needs a decision model. You can see the design screen for the decision tree for that edge, which is used by the domain expert for ontology customization in Figure 8.

[5]www.mongodb.org
[6]www.eclipse.org
[7]java3d.java.net
[8]jgrapht.org

Table 1: Comparison table of WOBE with similiar tools

	WOBE 1.0	GEPHI 0.8.2	Protege 4.3	Neoclipse 1.9.5
Infrastructure	Java Eclipse 4	Java Netbeans	Java	Java Eclipse
OWL2 Support	+	-	+	-
2D Visualization	+	+	+	+
3D Visualization	+	+	+*	-
Decision Tree Support	+	-	-	-
Export to RDF	+	-	+	-
Graph algorithms	+	+	-	-
Reasoning	+	+	+	-
DataStore	TDB	Neo4J*	TDB	Neo4J

*with plugin

5 EVALUATION AND COMPARISON

We are developing WOBE and the expert system software. We plan to evaluate the finished system as follows:

After creating the waste management regulations ontology using WOBE, we plan to evaluate the expert system by user evaluation. For this we employ our clients and employees of TAYTEK company. We will conduct a survey about their experience and the interaction they had with the system after a trial period. Thus we will be able to evaluate our systems' efficiency (usability, correctness, etc.). After making improvements on the system based on the survey results, we will conduct test with outside users as well.

Here we also present a comparison of features of WOBE with other ontology design tools (Table 1). WOBE is not only a graph or ontology development tool. It is a generic ontology production, editing and presentation tool that can be used to develop expert systems for rule-based information management and decision making.

Gephi is a successful tool on graph visualization and graph algorithms but it does not support OWL and RDF standards. Protege is the widely used ontology editor but it has no support for decision tree customization. Neoclipse is an advanced integrated development environment (IDE) among all.

6 CONCLUSIONS

In this paper we presented the requirements for and a prototype design of an ontology-based expert system that is mainly targeting waste management domain. We presented a generic ontology design and customization tool WOBE and compared its features with similar tools. Currently we are developing WOBE. One of the main advantages of WOBE is that it enables ontology designers and domain experts in

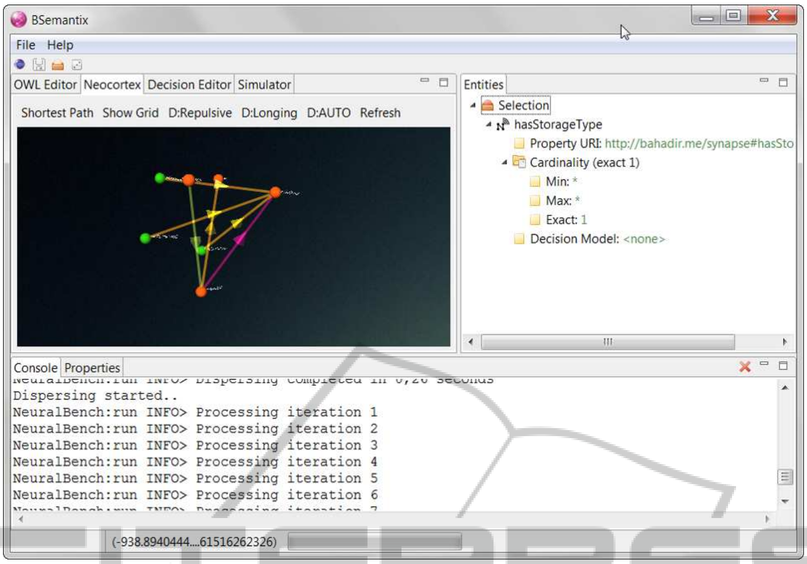

Figure 7: Prototype view of WOBE.

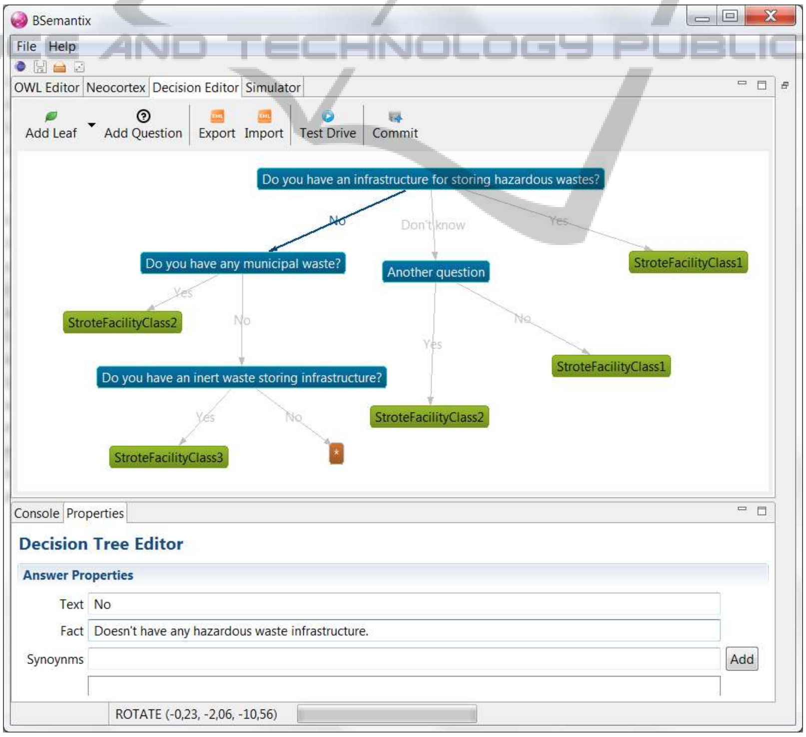

Figure 8: Prototype view of decision tree designer.

specific fields to work together. WOBEs main purpose is to translate concepts, rules, and regulations written in text documents to an information and expert system via an ontology and related decision trees.

WOBE and its relevant systems are planned to be licensed by an open-source license. Thus any company, person or academic foundation can obtain, develop or use freely for building their own expert systems. The tool will be developed on Eclipse 4 RCP that has great acceptance from the community and gives us much more flexibility on extending and developing.

Companies, which aim to optimize or improve their processes such as quality control and management or systems like CRM and ERM, need computer assisted autonomous systems. The tool we are developing can be used to develop expert systems in any area by translating rules and regulations to the system with the help of an ontology engineer initially. Then, domain experts can customize the ontology for specific usage areas (such as decision making). We expect to see more sophisticated ontology-based expert systems in many areas besides legal domain such as healthcare, business, manufacturing, etc. in near future.

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