DEVELOPING A WEB-BASED ONTOLOGY FOR EXPERT DECISION SUPPORT SYSTEMS

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Abstract—Expert systems were originally developed to solve ill-defined problems and well-defined problems that are not efficiently solved with algorithmic approaches. This technology provides an innovative and robust techniques to capture and package knowledge. Its strength lies in its ability to be put to practical use when an expert is not available. This technology has proven to be especially effective when the task is in a rapidly changing environment. On the other side, ontology is the foundation of describing a domain of interest and it consists in a collection of terms organized in a hierarchical structure that shape the reality. The main objective of using ontologies is to share knowledge between computers or computers and human. Most of the usages of ontologies in the field of artificial intelligence are related to knowledge based systems and intelligent systems. These types of ontologies include a small number of concepts and their main objective is to facilitate reasoning tasks. This paper presents the developing of web-based ontology for expert systems technology. The developed ontology was encoded in OWL-DL format using the Protégé-OWL editing environment.

Keywords—Ontological Engineering, Expert Systems, Artificial Intelligence, Knowledge Engineering, Web Technology

I. INTRODUCTION

Ontologies provide a common vocabulary of an area and define, with different levels of formality, the meaning of the terms and the relationships between them. During the last decade, increasing attention has been focused on ontologies [11, 22]. The main benefits of using ontological engineering approach are: (a) to share common understanding of the structure of information among people or software agents (b) to enable reuse of domain knowledge (c) to make domain assumptions explicit (d) to separate domain knowledge from operational knowledge (e) to analyze domain knowledge. At present, there are applications of ontologies with commercial, industrial, biology, medical, education and research focuses [9,13,14].

On the other side, artificial intelligence (AI) technology includes the following sub-technologies (or applications): general problem-solving, expert systems, natural language processing, computer vision, robotics, education and games. The recent fruits of artificial life include the following AI technologies: (a) Software Agents: may be able to act autonomously learning how to solve problems, (b) Software Code: automatically evolves using genetic algorithms, (c) Complex Computer Simulation: predict environmental, social and biological trends and (d) Biological Robots: programmed to mimic the reasoning of insects may learn to find their way. In this paper we focused our discussion on the expert systems technology.

In this paper our goal is exploiting the ontological engineering approach to develop a web-based ontology for expert systems technology. Section 2 presents an overview of the general features of the expert systems. Section 3 discusses the ontological engineering approach from the perspective of computer science. Section 4 introduces the research issues for building ontologies. Section 5 presents the developed expert systems ontology. Finally section 6 concludes the work.

II. EXPERT SYSTEMS

An expert system (ES) is an intelligent system incorporating a knowledge base and inference engine [20]. It is a highly specialized piece of software that attempts to duplicate the function of an expert in some field of expertise. The ES acts as an intelligent consultant or advisor in the domain of interest, capturing the heuristic knowledge of one or more experts. Non-experts can then tap the ES to answer questions, solve problems, and make decisions in that domain [3].

Expert systems will make knowledge more widely available and will help overcome the age-old problem of translating knowledge into practical, useful results. And perhaps best of all, it is a new more way that technology is helping us get a handle on the information glut. All AI software is knowledge based as it contains useful facts, data, and relationships that are applied to a problem. From the AI point of view, expert systems include the following topics: (a) Knowledge-representation techniques, (b) knowledge engineering tools and shells, (c) intelligent programming languages, (d) inference techniques, (e) reasoning methodologies, (f) machine learning and (g) user interface technologies.

A. Knowledge representation for expert systems

The first step in constructing AI software is to build a knowledge base. In order to act intelligently, a computer must have knowledge about the domain of interest. The knowledge of the domain must be collected and codified. It
must be organized, outlined, or otherwise arranged in a systematic order. This process of collecting and organizing the knowledge is called knowledge engineering. It is the most difficult and time-consuming stage of any AI software development process. Although a variety of knowledge representation schemes have been developed over the years, these representation schemes share two common characteristics. First, they can be programmed with computer languages and stored in memory. Second, they are designed so that the facts and other knowledge contained within them can be manipulated by an inference system, the other major part of an AI program. The inference system uses search and pattern matching techniques on the knowledge base to answer questions, draw conclusions, or otherwise perform an intelligent function. A brief overview of each of these schemes is presented in the following subsections.

- **Logic**

Logic is the oldest form of knowledge representation technique. For a computer to perform reasoning using logic, some method must be used to convert the deductive or inductive reasoning process into a form suitable for manipulation by a computer. The result is what is known as symbolic logic or mathematical logic. It is a system of rules and procedures that permit the drawing of inferences from various premises using a variety of logical techniques. These methods are generally known as computational logic. There are two basic forms of computational logic, propositional logic and predicate logic. Since propositional logic deals primarily with complete statements and whether they are true or false, its ability to represent real world knowledge is limited. Consequently, intelligent tutoring training technology uses predicate logic instead. Predicate logic gives added ability to represent knowledge in finer detail.

- **Lists and Trees**

Lists and trees are simple structures used for representing hierarchical knowledge. A list is a series of related items. Objects are divided into groups or classes of similar items. Their relationships are shown by linking them together. The simplest form is one list, but a hierarchy is created when two or more related lists are combined. On the other hand, a tree is a graphical structure of hierarchy, it is simply a way of illustrating lists and other hierarchical knowledge.

- **Semantic Networks**

Semantic networks are basically graphical depictions of knowledge that show hierarchical relationships between objects. A semantic network is made up of a number of nodes, which represent objects and descriptive information about those objects. Objects can be any physical items such as a book, car, desk, or even a person. Nodes can also be concepts, events, or actions. The nodes in a semantic network are also interconnected by link or arcs. The arcs show the relationships between the various objects and descriptive factors. Some of the most common arcs are of the is-a or has-a type.

- **Frames**

A frame is a relatively large block or chunk of knowledge about a particular object, event, location, situation, or other element. The frame describes that object in great detail. The detail is given in the form of slots which describe the various attributes and characteristics of the object or situation. Frames are normally used to represent stereotyped or knowledge based on well-known characteristics and experiences. With frames, it is easy to make inferences about new objects, events, or situations because they provide a base of knowledge drawn from previous experience. For example, the items of the components of any automobile or the animal kingdom can be represented in frames format.

- **Scripts**

A script is a knowledge representation scheme similar to a frame, but instead of describing an object, the script describes a sequence of events. Like the frame, the script portrays a stereotyped situation. Unlike the frame, it is usually presented in a particular context. To describe a sequence of events, the script uses a series of slots containing information about the people, objects, and actions that are involved in the events. Some of the elements of a typical script include entry conditions, props, roles, tracks and senes.

B. **Expert systems types based on the reasoning methodology**

The field of reasoning is very important for the development of expert systems and all intelligent systems. The research area in this field covers a variety of topics, e.g.:

- automated reasoning, case-based reasoning, commonsense reasoning, fuzzy reasoning, geometric reasoning, non-monotonic reasoning, model-based reasoning, probabilistic reasoning, causal reasoning, qualitative reasoning, spatial reasoning and temporal reasoning. This subsection is dealing with rule-based and case-based reasoning systems.

In rule-based expert system, the inference engine contains a set of formal logic relationships which may or may not resemble the way that real human expert reach conclusions. The knowledge base is structured in a if-then organization. The rules have to be defined in a limited number of formal ways. Typically they may be a set of some hundreds of if-then (or if A and B but not C then D) types of relationships that describe all the domain specific knowledge used by the human expert. The most difficult and time consuming part of the developing a rule-based expert system is the extraction of knowledge form the head of an acknowledged expert (or a group of experts) and then transforming it into a form acceptable to the expert system knowledge based structure.

Case-based expert system (CES) uses the case-based reasoning (CBR) methodology as an efficient method for inference instead of the production rules in the traditional rule-based systems. CBR is an analogical reasoning method provides both a methodology for problem solving and a cognitive model of people. It is consistent with much that psychologist have observed in the natural problem solving that people do. Decision makers tend to be comfortable using CBR methodology in dynamically changing situations and other situations were much is unknown and when solutions are not clear.

The methodology of CES can be summarized in the following two main processes:
• **Case-search process**: In this process the system will search its Case-Memory for an existing case that matches the input problem specification. If we are lucky (our luck increases as we add new cases to the system), we will find a case that exactly matches the input problem and goes directly to a solution. If we are not lucky, we will retrieve a case that is similar to our input situation but not entirely appropriate to provide a complete solution.

• **Case-adaptation process**: In this process the system must find and modify small portions of the retrieved case that do not meet the input specification. The result of case adaptation process is (a) completed solution, and (b) generates a new case that can be automatically added to the system's case-memory for future use.

The technology of CBR directly addresses the following problems found in rule-based technology.

- Knowledge acquisition: The unit of knowledge is the case, not the rule. It is easier to articulate, examine, and evaluate cases than rules.
- Performance: A CBR system can remember its own performance, and can modify its behavior to avoid repeating prior mistakes.
- Adaptive Solutions: By reasoning from analogy with past cases, a CBR system should be able to construct solutions to novel problems.
- Maintaining: Maintaining CBR system is easier than rule-based system since adding new knowledge can be as simple as adding a new case.

### III. ONTOLOGICAL ENGINEERING FROM THE COMPUTER SCIENCE PERSPECTIVE

According to Sowa [17], the components of ontology are: (a) concepts, terms; (b) relations between concepts, terms; (c) properties, attributes of the concepts; and (d) rules, axioms, predicates, constraints. The main objective of using ontologies is to share knowledge between computers or computers and human. Computers are capable to transmit and present the information stored in files with different formats, but they are not yet compatible to interpret them. To facilitate communication and intelligent processing of information, it is necessary that all actors of the digital space (computers and humans) have the same vocabulary.

Most of the usages of ontologies in the field of artificial intelligence are related to knowledge based systems and intelligent systems. These types of ontologies include a small number of concepts and their main objective is to facilitate reasoning. For example, in a multi-agent systems, the knowledge representation is accomplished through a basic ontology, private ontologies and a knowledge base. Private ontologies of the agents are derived from the basic ontology. The names of the concepts used in private ontologies of the agents are unknown, but their definitions use terms from the basic ontology.

### IV. ONTOLOGICAL ENGINEERING RESEARCH ISSUES FOR BUILDING ONTOLOGIES

Ontological engineering refers to the set of activities that concern the ontology development process, the ontology life cycle, the methods and methodologies for building ontologies, and the tool suites and languages that support them[6,16].

#### A. Methodologies

Ontological engineering is still relatively immature discipline; each research group employs its own methodology. Ontology methodologies differ according to the strategy of identifying concepts. The well known three possible strategies for identifying concepts are: (a) bottom-up from the most concrete to the most abstract; (b) top-down from the most abstract to the most concrete; and (c) middle-out from the most relevant to the most abstract and most concrete. The last one is the most common strategy.

#### B. Ontological Languages and Tools

A great range of languages have been used for implementing ontologies during the last decade; e.g. LOOM, OCML, FLogic, CARIN, OKBC, Telos, Cyc [1,2,10]. These languages are in a stable phase of development, and their syntax consists of plain text where ontologies are specified (many of them have a Lisp-like syntax). Recently, Web-based ontology specification languages have been developed in the context of the World Wide Web. These languages have had great impact in the development of the Semantic Web (e.g. XOL, OML, OIL, and OWL). The syntax of these languages is based on XML, which has been widely adopted as a standard language for exchanging information on the web, except for SHOE, whose syntax is based on HTML.

On the other side, ontological tools have emerged for creating, editing and managing ontologies written in the various languages. These tools usually provide a graphical user interface for building ontologies, which allows the ontologist to create ontologies without using directly a specific ontology specification language (e.g. WebODE, Ontolingua, Ontosaurus, and OntoEdit,OilEd).

#### C. Ontology Interoperability

The domain of ontologies is extremely vast. A lot of ontologies were developed, even different ontologies for the same domain. In order to assure the interoperability between software applications, it is necessary to guarantee the interoperability between their ontologies. In the literature, there are different technologies related to the ontologies’ interoperability, namely: ontology alignment, ontology mapping matching, ontology translation, ontology integration, ontology refinement and ontology unification [18,19].

#### D. Ontology Validation

Validation is the process to determine whether a work product satisfies its requirements. Validation can be performed after the ontology has been developed, but it is
usually better to validate while the ontology is being built. There are several techniques that can be used to validate ontology: (a) Verify the fulfillment of the purpose, (b) Check that all usage examples are expressible, (c) Create examples that are consistent with the ontology, and determine whether they are meaningful, and (d) Check that the ontology is formally consistent. Quality of the ontology is validated based on the following criteria: (a) consistency; (b) completeness; (c) conciseness; (d) clarity; (e) generality; and (f) robustness.

E. Ontology Evaluation

From the ontological engineering perspective, ontology evaluation is based on the following criteria: (a) completeness; (b) correctness; (c) decidability; (d) maintainability; (e) minimal redundancy; (f) rich axiomatization; and (g) efficiency. A more formal ontology evaluation method, proposed by Obrst et al.[12], includes: (a) development of an ontology and ontology tool competition; (b) principled certification of ontologies by a reviewing organization or community; and (c) the development of an ontology maturity model.

V. DEVELOPING A WEB-BASED “EXPERT SYSTEMS” ONTOLOGY

Our methodology for developing the web-based “Expert Systems” ontology are summarized in the following steps:

- Step 1 Organizing and scoping: Determining the objectives and defining the boundaries of the ontology.
- Step 2 Data collection: the raw data needed for ontology development is acquired. In our study data was collected from AI and expert books [5, 8, 15].
- Step 3 Data analysis: the ontology is extracted from the results of data collection. This step includes the following tasks: (a) define the classes and class hierarchy, (b) define the properties of classes (slots), (c) define the facets of the slots (e.g. domain and range of a slot, cardinality, slot-value type), and (d) create individual instances of classes.
- Step 4 Development of initial ontology: a preliminary ontology is developed (i.e. classes, relations and properties). This process was done by using OWL-DL language using the Protégé-OWL editing environment.
- Step 5 Ontology refinement: the initial development is iteratively refined.
- Step 6 Ontology validation.

Figure 1 shows the semantic net of expert systems (identifications of main object of interest and relationships between objects). Figure 2 shows the developed expert systems ontology encoded in OWL-DL format using Protégé OWL editing environment. In this ontology four main superclasses namely (a) expert system tools; (b) knowledge base; (c) inference mechanism; and (d) user interface. Expert system tools have four subclasses: (a) programming languages (b) knowledge-engineering language; (c) system-building aids; and (d) support-environment tools.
Figure 2. a Expert systems applications ontology

Figure 2. b Expert systems tools ontology

Figure 2. c Expert System architecture ontology

Figure 2. d Expert System architecture ontology: encoded in OWL-DL format using Protégé OWL Editing Environment

Fig 2 (b) Expert systems tools ontology
Ontologies are now ubiquitous in many information-systems enterprises. They constitute the backbone for the Semantic Web as well as they are used in all applications of e-activities technologies (e.g. e-Government, e-Learning, e-Health, e-Business). Ontological engineering approach is an effective methodology to manage and represent knowledge. Ontologies were developed in intelligent learning systems to facilitate knowledge sharing, refine, search and reuse. These ontologies may be used as an assessment procedure. For example and from the educational point of view, candidates show their knowledge and understanding while creating ontologies. Knowledge entities that represent static knowledge of the domain are stored in the hierarchical order in the knowledge repository and can be reused by other candidates. At the same time those knowledge entities can be also reused in description of the properties or arguments of methods of another knowledge entity. Moreover, ontology approach enables to solve the complexity and the incertitude of the instructional systems. An intelligent learning system based on a multi-agent approach consists in a set of intelligent agents, which have to communicate. They collaborate through messages. Software agents can understand and interpret the messages due to a common ontology or the interoperability of the private ontologies.

VII. CONCLUSION

Our contribution in this paper are summarized as follows:
1. Building Sensitive Net of the Expert System Technology: we built the semantic net of expert systems technology which defines the main objects of interest and relationships between objects.
2. Determination the Main Components of the Semantic Net: we determine the classes and its hierarchy, the properties of classes (slots), the slot’s domain and range, and the individual instances of classes.
3. Developing the Web-based Ontology for Expert Systems Technology: To achieve this aim, we proposed a new methodology for building this ontology using the ontology web-based language (OWL) and the Protégé-OWL editing environment.

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