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ONTOLOGY ENGINEERING FOR ENTERPRISE INFORMATION SYSTEMS: DELINEATING A METHODOLOGY TO DEVELOP ONTOLOGIES WITHIN THE DOMAIN OF TELECOMMUNICATIONS

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ABSTRACT

The informative requirements of information systems and more precisely, corporate information systems can be met by means of ontology. The Semantic Web uses this tool to solve problems arising from an information over-abundance by enabling easy data exchange and improving the relevance when recovering information.

Keywords: Ontology; Enterprise Information Systems; Methodology; Data and Information Interchange; Semantic *Web*.

INTRODUCTION

The frenzied pace set by our Information Society gives rise to the need to control all the information available. However, the actual amount of information and the lack of technologies and skills to select relevant data make this impossible. The growing volume of technology breakthroughs and the ongoing increase in data to be

managed makes it even harder. We require an enhanced information representation to enable more advanced applications (LACY, 2005).

The information culture inside a company is quite scanty, especially concerning issues such as management methods, who manages the information and how they do it, the cost it entails to create and manage an Information Service, etc. Companies are not aware of how an appropriate documentation management contributes to the value of the company, and this in fact, should be among the company's principles. Knowledge management becomes vital for the maintenance of light and agile structures that may support the directives of any company. We require a knowledge management system (BUSTELO RUESTA, 2000). In Spain, the companies that actually plan information systems (documentation centres, archives, libraries, etc.) are large multinationals which have already implanted those systems in their original countries, such as the United States, Canada or Great Britain. They created an information service to channel the information and make it easily accessible to satisfy all needs.

Our main target was to create an ontology for knowledge management in the information service of a private company (domain of telecoms). Our study is based on the Information Science. Likewise, we will address other disciplines, including Computer Science, Philosophy and Linguistics. We will also study the use of OWLs to create this tool, answering the need of management, knowledge, and reusability information exchange in the interest of organizations.

In pursuance of our purpose, we first address the information system issues from the point of view of the Information Science. We then set out the main issues on ontologies for an information system and how we can build an ontology satisfying de informational necessities. We will highlight issues related to the reuse of knowledge derived from taxonomies, thesauri and other ontologies.

2 KNOWLEDGE MANAGEMENT IN CORPORATE INFORMATION SYSTEMS

In the early 90s, the Library and Documentation Science – as well as Computer Science among others –, has represented an important conceptual revolution in terms of technical breakthroughs. This change originates with the arrival

of the Information Society and/or the Knowledge Society. It not only depicts a technological revolution, but also a reason and consequence of the information increase. This revolution confers the Information Society a major interdisciplinary concept, which was unconceivable ten years ago.

The increase in research is significantly changing scientific research and the available tools in terms of quantity and quality. At first, knowledge sharing was confined to the community of knowledge acquisition area. Today, however, this has become a multidisciplinary issue (STAAB; STUDER, 2004). The mere transmission of knowledge is no longer sufficient, since the amount of information is greater to assimilate. There is a strong need for the use of new management methods and tools in order to manage knowledge and avoid limiting said management to computer experts.

A wide interdisciplinary community has done a U-turn in the study of ontologies and its areas of application, including e-commerce, documentation management and the recovery of information (GÓMEZ-PÉREZ; FERNÁNDEZ-LÓPEZ; CORCHO GARCÍA, 2004).

We are witnessing the transition of the traditional Web towards a semantic *Web*. The ontologies proposed will solve some of the problems arising from the massive and unorganized volume of information. They are able to interact with users, answering their questions whilst they check documents in an intelligent manner. Also, they will be able to represent knowledge with an extraordinarily large informative content.

In an information system, an ontology will be a useful tool in the decision-making process by providing an idea of the company's condition. Furthermore, it will also enable the exchange of information with other information systems, in order to recover and reuse the knowledge of a particular domain, thus improving the results based on a semantic reasoning.

Information systems are those systems where – leaving the technological factor to aside – the raw material and the transferred and stored product are the actual information (GARCÍA GUTIÉRREZ, 1998).

An information system is the department entrusted to provide information and ensure it is usable (MOREIRO GONZÁLEZ, 2005).

We agree with these authors that an information system is an integral structure ordered to provide information to users exploiting the maximum content of documents, with the intention of extracting knowledge and transferring it to other structures. An information system can be the basic structure of a library or a documentation centre, a platform from which information is distributed, or the global structure of all of them.

We must highlight that there is a great difference between a library, archive or a documentation centre within a multinational company, although in small and medium companies there is no terminological or conceptual boundary regarding the name of its archives, libraries or documentation centre. When the volume is not excessive, tasks are carried out by a few people, the information professionals. They ensure no mistakes take place over the nature of each document and its typology. They are also take charge of collecting and storing these documents. This set of tasks, which is carried out by experts in information to enhance knowledge availability for other users or information communities, is what we know as an information system service.

2.1 Corporate Needs Regarding Information, Internal Flow and Knowledge of the Environment

Information is a resource that requires suitable administration. In private companies, it is a resource that must be exploited adequately to improve the economic and strategic situation. A correct exploitation of the information, considered as a resource, could provide exceptional benefits to the company, increasing its profits, strengthening its competitive position in the market, helping them discover knew niches of market, and being aware of other competitors' innovations.

There is a need to sensitize companies to the benefits of using information as the best way to ensure a strategic position for the future, as well as a source of generating competitive advantages in a changing and integrated economy (PALOP; VICENTE, 1999).

We agree with the authors that the company must have an organized service which will observe and analyze the information, not only as a secure means of survival but as the main support to all those activities that can provide the company

an advantageous situation in relation with their competitors. We also believe that the internal flow of information and the management of all the daily generated documentation in a company are equally important. The flow of information between departments that finally heads towards an information system is essential for the correct operation of all those gears that comprise the enterprise structure. The Human Resources Department will not be able to live isolated from the Consultancy Department or the Commercial one. The reason is that its source of intelligence and its destination are external to them.

We consider the company as a macrostructure made up by a framework of average structures, which in turn are made up by microstructures. Here, the average structures are the departmental units, and the microstructures smaller units or even the own individuals that dedicate their professional work to specific tasks in conformance with the policy of the department, and therefore, of the company itself. These companies, just as any other organization or institution, require a flow of information to satisfy the information necessities of the departmental structures.

► MACROESTRUTURE	**► COMPANY**
● STRUCTURE	**● DEPARTAMENTAL UNITS**
▪ MICROESTRUCTURES	**▪ SUBDEPARTAMENTS/INIDIVUAL**

Information systems act as part of the production line of the company, and as a support structure. This double conception of the system depicts these functions:

- It is part of the company's support, since it will host and protect all the information that independently derives from the daily activity. It acts as an archive for all the departments. An example of the support given by the information system is its role in the Purchase Department where they receive and issue requests, incidences, invoices, inventories, etc., among other documentation. Therefore, we can conclude that this information is reliable proof of certain activities within a department or company, and having not been altered, it can be considered gross information.
- It is part of a production chain. If the information can be potentially used as knowledge to provide a competitive advantage or to confront new situations, it comprises the production chain. This research has several steps including the search, selection, collection, summary and processing

of information. At the end all the information is recycled to be conceived as a whole framework. The result is a new document that has been subject to a process of selection, extraction of contents or summaries or any other type of alterations to satisfy a need answering to the criteria and skills of Information experts.

In addition to establishing the information flow between departments, there must be certain guarantees of the integrity and confidentiality of the information. It must be protected against loss, illegal use and/or unauthorized spreading.

The departments managing information systems help people use, share and leverage information in a convenient way. All in all, they help preserve the company's memory beyond the individuals that work there and to boost the content value reflecting their experience (BUSTELO, 2000).

3 ONTOLOGIES FOR A CORPORATE INFORMATION SYSTEM

The need to capture the conceptual domain and to have sources of knowledge has led many researchers to develop methods supporting ontologies. We can highlight three main paths approached by researches in this área:

- To guide and support the process of ontology development;
- Development of tools to support the process of construction (engineering ontology);
- Development mechanisms of inference for large ontologies.

Few works have focused their efforts on those three areas (SURE; ANGELE; STAAB, 2005).

Taxonomies evolved towards more complex forms as thesaurus, and these in turn now find the need to evolve towards more complex systems: ontologies. These are capable of answering questions encircling an extraordinary quantity of information with a more relevant semantic load. Ontologies allow the interaction between human beings and machines. A person will ask questions that the ontology will try to answer.

In the Knowledge Society, ontologies are instruments that technologists, architects and information professionals will apply as a solution to the information

over abundance. These are useful tools for Knowledge organization and management in any Information System. The development of an ontology with OWL language in the area of telecoms will allow to acquire the conceptual domain in which its documentation is enclosed; will solve problems encountered by the managers of traditional databases; will allow the interoperability of information and document processing; and will answer to questions based on logical deductions.

One of the most common ontology applications is in the field of e-commerce, where users can ask the ontology for products, models, prices and other items.

3.1 Conceptual Frame

The term ontology has been and is being used in many areas of Knowledge: in Philosophy – and more precisely in Metaphysics –, in Computer Science Engineering for artificial intelligence, and in the Information Science, by knowledge managers and information professionals (STAAB; STUDER, 2004). The common characteristic in the use of this concept is that the term ontology makes reference to the concepts of a sphere and the relations that strike up between them. Depending on the area where they are used, they will acquire their own characteristics.

Philosophical concept: the concept ontology was translated by Johannes Clauberg in 1647 from Greek to Latin. The Aristotelian Greek philosophy says that it depicts the ways it is grouped in ten categories to link a predicate with a subject: (i)Substance or essence, (ii)Amount, (iii)Quality, (iv)Relation, (v)Place, (vi)Time, (vii)Situation, (viii)Possession, (ix)Action, and (x)Passion. Subsequently, Leibniz reduced these relations to five categories: (i)Substance, (ii)Amount, (iii)Quality, (iv)Relation and (v)Action or Passion. Knowledge representation systems such as thesauri or ontologies, have previously integrated in their construction, the relations mentioned by Aristotle, Leibniz or Kant. In order to provide these systems with the semantics they lack, these categories are addressed in the information, setting the properties and making the inferences in the classes that answer questions.

Computer Science concept: The term ontology was used for the first time in the eighties in the area of Computer Science Engineering, and more precisely, in artificial intelligence. An ontology consists of a set of axioms, relations of

subsumption between classes and properties (STAAB; STUDER, 2004). The axioms make the affirmations, the subsumption or equivalences with respect to equivalences or to the possible classes. OWL is the language by which they are standardized and the ontologies become viable. Ontologies play a role similar to that of data base schemes, they provide with semantics to be processed by machines, the sources of intelligence throughout the collections of terms and their relations (LACY, 2005). The University of Stanford has a definition which adjusts to the reality we want to convey. Thomas R. Gruber, knowledge researcher from Laboratory Systems, in 1993 made reference to the concept:

> An ontology is an explicit specification of a conceptualization […] For AI systems, what "exists" is that which can be represented. When the Knowledge of a domain is represented in a declarative formalism, the set of objects that can be represented is called the universe of discourse. This set of objects, and the describable relationships among them, are reflected in the representational vocabulary with which a Knowledge-based program represents Knowledge. Thus, in the context of AI, we can describe the ontology of a program by defining a set of representational terms. In such an ontology, definitions associate the names of entities in the universe of discourse (e.g., classes, relations, functions, or other objects) with human-readable text describing what the names mean, and formal axioms that constrain the interpretation and well-formed use of these terms. Formally, an ontology is the statement of a logical theory (Gruber, 1993).

Therefore, we can consider an ontology as the explicit specification of a conceptualization. As for artificial intelligence systems, when its existence can be represented; and when a field of knowledge is represented, we know it as universal of the speech. Gruber in this definition – although applied to the world of Computer Science Engineering –, is who best depicts the concept we have in mind. From our point of view, an ontology will be the tool enabling us to represent the classes and relations between themselves, the properties or functions, the inferences. The information contained in documents is automatically processed by the intelligent agents based on logical theories. We understand that an ontology is a formally described specification from a field of interest, a collection of terms that can be processed by machines, and the relations between them. A field can be divided in classes and concepts to specify the different types of relationships.

Concept in the Information Science: ontologies result from people devoted to Artificial Intelligence who adapted the work of philosophers. Ontologies arise from an

increase of internal and external documents, the great amount of information available, and the low cost of electronics (GILCHRIST; BARRY MAHON, 2004). A knowledge-base with formal representation is based on the conceptualization of objects and organizations that exist in the different areas of interest and the relationships between them. The ontologies are applied to the categorizations of elements, they are explicit specifications of conceptualizations that include vocabularies of terms and that contain or establish their properties and the relationships between them (MOREIRO GONZÁLEZ, 2004). The taxonomies have are a legacy from librarians and information professionals. The same goes for thesauri, although it does seem that these have experienced a greater development and implementation by information professionals, than in the field of Computer Science.

The term ontology can be startling, it can be considered as something bizarre, with a high level of abstraction, so high, even librarians can fail to understand it, as if it originated in the Computer Science. But we do consider that ontology does not belong to only one science or another. Both sciences should collaborate and contribute with their Knowledge. Certainly, in order to understand, design or develop an ontology, the professionals of our area require a high degree of abstraction, although attainable. Ontologies are the logical evolution of taxonomies and their passage to thesauri. They all act as a means to classify Knowledge, although the ontologies have a higher potential, as their main objective it to exchange Knowledge and its representation.

3.2 Parts of an Ontology

Ontologies comprise:

- Classes-subclasses: one of the pillars on which the ontology is constructed. One is the class-object. According to Lee Lacy, this class is related to the object concept class in the object-oriented programming and the tables of the RDBMS (Relational Management Database Systems). The classes represent a set of "individual" elements that have the same properties or similes. Another is the concept that represents a reality. In an

ontology for an integral information system of a deprived company, a class can be "portable Projects", "Client", "Equipment", "Networks", "Employees", "Telephones", etc.

- Properties or slots: attribute or quality of somebody or something. A class has its properties, attributes, values, etc. In computer science terms, it's a binary association that relates an object (instance) to a value. They are similar to the accessory methods in the object oriented programming that provide values with class objects or fields in a table of a SGBD. The value can be a date, measurement, name, price, etc. Following with our ontology, properties of our classes could be "client", "date", "model", "price", etc. A property of a project can have "2 clients", who entail "costs" and "benefits".
- Instances: One is the real representation of the classes in a field, the individual, object or "thing" itself. There are as many physical representations as virtual ones of the objects, the real instances of a class. It is very easy to mistake an instance for a class, since an instance can be both things. Regarding our ontologic example, an instance can be a determined model of a portable telephone, for example, "motorola 320".

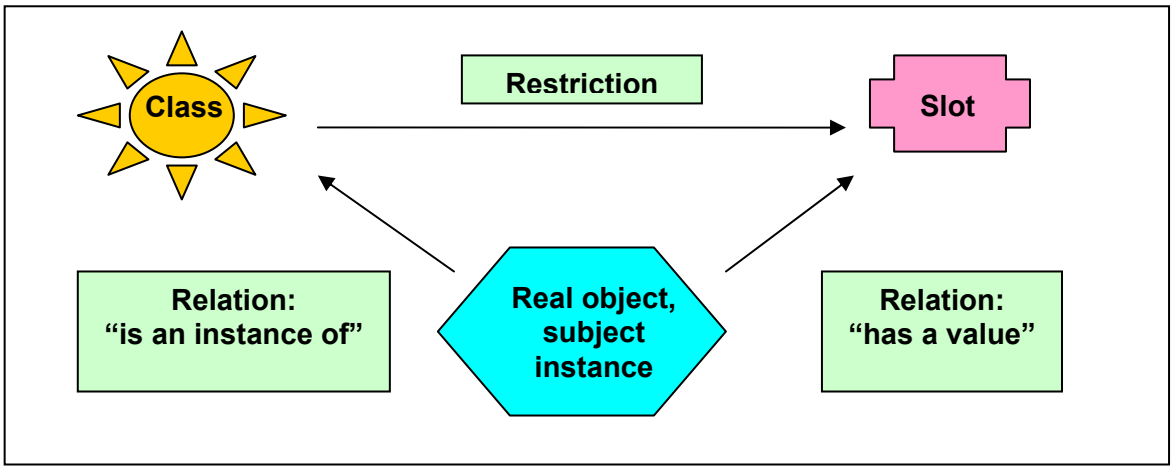

Figure 1: Relations and Restrictions between Classes, Slots and Instances.
Source: Elaborated by Rodríguez Barquín.

Based on the service that the enterprise information system renders, there will be diverse types of ontologies. These can be: (i) Informative Ontologies: they

describe the different types of intelligence sources, their structure, the access rights, and the format properties; (ii) Domain Ontologies: They represent the content of the sources of intelligence; (iii) Company Ontologies: They represent the context of an organization, work process etc. Based on this types of ontologies, we considered that a good corporate information system must study the possibility of constructing these three typologies, since they will be unavoidably interrelated (ABECKER, 2004).

According to Gruber, the five basic factors required to design an ontology are: clarity, coherence, extensibility, minimal encoding and minimal ontological commitment.

The ontology that we have designed has tried to respect these five basic criteria. It is to be understood that the ontology must be applied to any corporate information system from the telecoms field, as we have not determined a specific company. It is an ontology which could be applied to any company of this sector. We have tried to be as coherent and consistent as possible avoiding contradictions in the inferences and the axioms. This is one of the aspects that need be especially considered throughout the phases of construction: if there are any inferences that can contradict an axiom. It must bear in mind the user, we must foresee situations they may experience or questions that may arise.

The field is as restricted as the users. In the first ontologic design, we have to consider that the tool must respond to the informative necessities of its users. Determining the user's needs, will be the first step in engineering an ontology. If we are able to capture all the company's requirements, we will be advancing in the construction of the domain we seek. This will provide us a guide to reuse existing knowledge (thesauri, taxonomies, even other existing ontologies) and the usage situations.

The objective of our example is to create an ontologic model satisfying the information requirements according to Abecker. We have used this to consider the characteristics of informative ontologies, domain ontologies, and company ontologies.

Our model of informative ontology describes the types of intelligence sources, typology and properties by means of slots. As we can observe, this

corresponds to the part of classes that address documentation. The structure is formed by:

>Documentation
>>Management Documentation
>>>News bulletins information
>>>Memories
>>Technical Documentation
>>Administrative Documentation
>>>Bills
>>Publications
>>>Magazines
>>>Books

As an example of domain ontology on the content of intelligence sources, it is represented by the adaptation of a small part of the Thesaurus of Networks of Computers (Architecture and Design of Networks) and a fragment of the generic product classification of The United Nations Standard Products and Services Code (UNSPSC) (Telecommunications and Broadcasting of Communication Technology).

The company ontology we have adapted to the possible context of an organization following the representation of a departmental structure, through the projects that may be carried out in a company.

One of the objectives of building an ontology is allowing it to interact with the user by answering questions. According to M. Uschold and M. King, authors of “Towards a methodology for building ontologies”, in Sure, Angele and Staab to define the characteristics of an ontology, the competency questions (CQ) are important, since each CQ defines a question that the ontology will be required to answer and to define explicit characteristics for our ontology. The logical action is to remove these CQ from interviews with the help of experts on the subject who can help structure the knowledge domain. This could be helpful for the initial design of our ontology. But we have to assume that each CQ contains valuable information on the domain ontology, and would therefore be removing excellent concepts and relations.

Once we have made the semi-formal description, the following step consists of the complete formalization to make it comprehensible and enable its processing by machines. The knowledge reusability represents a vital point. As we come indicating, we will reuse the knowledge represented in taxonomies or thesauri, and semantically integrate them in an inference model. According to researchers of the National Cancer Institute (NCI), one of the most important steps to transform the thesaurus

into an ontology is to represent concepts and their connections in a way that they may be processed by machines. In the ontology that they develop, each concept has a formal description and the relations among them are formalized based on the ontologic language.

We have reused the knowledge generated by the United Nations for the product classification and services, available in http://www.unspsc.org. The code United Standard Nations Products and Services Code (UNSPSC) is a hierarchic convention that is used to classify products and services.

Adopting the UNSPSC codes of classification for corporate information systems can be profitable. The benefits achieved in terms of costs and benefits when launching products in the market is easily calculated by means of the classification codes. We have used a UNSPSC fragment with one that corresponds to the Thesaurus of Networks of Computers elaborated by the University of Murcia, in the Group Information Technologies available in the network. The part of the ontology corresponding to the informative domain (documentation) and to the company (projects) is based on the group's experience in private companies.

In order to evaluate our application, we deem it necessary to address two questions:

Ontology evaluation. As with other applications or projects developed, the ontology must be evaluated. This one, must be done through an evaluation of its contents, mainly if it may be reused or be used in another context. An evaluated ontology, does not guarantee the absence of problems, but it will make its use more secure. According to the authors, the first research on contents evaluation began in 1994, and increased in 2001 as ontology engineers started to show a growing interest. The evaluation of an ontology entails judging the content of the ontology in relation to the necessities, competency questions (CQ) throughout the different phases from construction and maintenance of the tool. The elements requiring special attention are the definitions and axioms, related definitions (if there were any) and definitions inferred from others. Another aspect to value is the validation: the correct construction of the ontology and its real application. The main benefit of evaluating this lies in validating the ontology, which means the real world model, which exists and is known to us, is correctly represented in the world we have

formally modeled. From our experience in the ontology evaluation, it is worth mentioning the OntoClean methodology, which was cradle to the philosophy of slight Knowledge. It performs a cleaning process in the taxonomies and it has been applied to clean upper levels of WordNet. According to this methodology, there are 4 fundamental ontological types of slight Knowledge: rigidity, identity, unit and dependency (GÓMEZ-PÉREZ, 2004).

Evaluation of the user's satisfaction. We used the method proposed by Saracevic and Kantor. It is a method to evaluate and calculate the information value, and more precisely the ontology. According to Saracevic and Kantor, there are three levels to check when valuing the services an information system offers. Applying it to our enterprise structure to value the service an Information system offers its company, these three levels would be:

1. Social Level: is the value these systems provide to the society or community. Users may respond to the question on how they will use the service and how satisfactory it is, they are the potential users. Social parallelism with the company, we found it in its macrostructures, we found it in the managing team, partners or directors who report to a higher authority in the company. These take part in the decision-making team and take actions of greater implication, the users of that key information, and the ones who protect the integrity of the company, its correct operation and expansion if possible.
2. Institutional/Organizational level: this corresponds to the value deemed by the organisms or institutions that maintain it. We see a clear parallelism with the departmental units or the structure that supports the company. They have to report to those people who, without having a significant role in the decision-making of the company's operations, are responsible for a department or for a certain activity in the company.
3. Individual Level: this is the value considered by each user, which includes critical analysis of incidents, surveys and interceptions of its users. It would correspond to the microstructure of the company, the human capital of the company, the employees who request information.

The most frequent or potential users, in terms of information supporting the company.

CONCLUSIONS

Ontology provides a conceptual domain encircling all documentation generated. In the case of a corporate information system, it will be the tool that allows an easy and speedy knowledge management as it processes the contents of documents and answers questions by means of logical deductions.

The information in a company plays a very important role because it is a main tool to be used in the decision-making process, which unavoidably entails large financial actions leading to success or failure. It takes years for companies to acquire an information system that will give horizontal support in general. This service is a resource in the production system but was not included in most companies. This idea has changed with the changes in the Information Society. It is now those who own information and who generate knowledge, who have the key to position the company strategically, taking the lead over its competitors. The information requirements are internal (need of information flow between the enterprise structure and the hierarchic levels) and external (need to obtain data on the market and competitors).

Valuating the information service and their own information or knowledge, either in ontologies or any other type of asset, contributes to achieve the highest quality in the corporate world since it improves operations at different levels and hierarchies.

Although the advantage of the existing knowledge for the ontology design facilitates its construction, we must pay special attention to the inferences, reused axioms or definitions, since it can impact on the ontological consistency.

The role of ontologies as a means of excellence in the Semantic Web and their use in knowledge management is increasing. The proliferation of publications and researches on the area is proof of this increase.

The use of ontologies is multidisciplinary. There is a converging trend in different disciplines towards finding methods and instruments that will enable the recovery and organization of the contents.

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