Knowledge Representation, Ontology, Artificial Intelligence

Cesar SANIN[1], Edward SZCZERBICKI[2], Carlos TORO[3]

# ON THE SEMANTICS OF A KNOWLEDGE STRUCTURE

Collecting, distributing and sharing knowledge in a knowledge-explicit way is a significant task for any company. However, collecting decisional knowledge in the form of *formal decision events* as the fingerprints of a company is an utmost advance. Such decisional fingerprint is called decisional DNA. Set of experience knowledge structure can assist on accomplishing this purpose. In addition, Ontology-based technology applied to set of experience knowledge structure would facilitate distributing and sharing companies' decisional DNA. Such possibility would assist in the development of an *e-decisional community*, which will support decision-makers on their overwhelming job. Our purpose is to explain the development of .an OWL decisional Ontology built upon set of experience, which would make decisional DNA, that is, explicit knowledge of formal decision events, a useful element in multiple systems and technologies, as well as in the construction of the e-decisional community.

## 1. INTRODUCTION

Knowledge is considered an invaluable and incalculable advantage for most purposes in life, for that reason, humanity has tried to make it part of their countable assets. When referring to business, knowledge has been considered as the only true source of competitive advantage of a company [3]. Thus, the focus of managers has turned to knowledge administration and many companies have invested huge amounts of money to investigate technologies that facilitate control of all forms of knowledge. In consequence, the means and the ability of acquisition of explicit knowledge can make the difference between the success and failure of a company in the competitive environment of global economy [12] and knowledge society.

However, knowledge society arrived carrying out all the difficulties that information society had. Characteristics such as unstructured, disintegrated, not shareable, incomplete, and uncertain information represent an enormous problem for information technologies (IT) [4]. Under these circumstances, the process of transforming information into knowledge becomes critical and difficult, because unfortunately, knowledge depends upon information

[1] Engineering and Built Environment, University of Newcastle, Australia.
[2] Engineering and Built Environment, University of Newcastle, Australia.
[3] VICOMTech Research Centre, Spain

[12]. Moreover, Awad and Ghaziri [1] report another difficulty when they affirm that up to 95 percent of information is preserved as tacit knowledge (for tacit and explicit knowledge see [9]). Thus, one of the most complicated issues about knowledge is its representation, because it determines how knowledge is acquired and how knowledge is transformed from tacit knowledge to explicit knowledge. Hence, it is obvious that some kind of mechanism is necessary to transform information into, not just knowledge, but explicit knowledge.

For us, experience, as a form of knowledge, is what most decision-makers principally use for taking decisions. Thus, it is very important to keep a record of earlier decisions events. In consequence, tools for representing and storing formal decision events in a knowledge-explicit way are evidently necessary, understanding that a formal decision event is a decision occurrence that was made following procedures that make it structured and formal [14].

Many technologies work with decision-making in some approaches, however, they do not keep structured knowledge of the formal decision events they participate on. Unfortunately, computers are not as clever as to form internal representations of the world, and even simpler, representations of just formal decision events. Instead of gathering knowledge for themselves, computers must rely on people to place knowledge directly into their memories. This problem suggests deciding on ways to represent information and knowledge inside computers. Set of Experience Knowledge Structure is a combination of filtered information obtained from formal decision events performed by different technologies. Nevertheless, despite the fact that set of experience knowledge structure is already developed, the ways for acquiring its knowledge are supported on the confidence of every technology that performs formal decisions [16]. Set of experience knowledge structure has been developed as part of a platform for transforming information into knowledge named Knowledge Supply Chain System (KSCS) [13].

Different technologies can help in accomplishing such task, but no one like Ontology-based technology, which offers differentiable advantages. Ontology-based applications are probably the fields in which computer-based semantic tools and systems are more extended nowadays for several heterogeneous domains, mainly focused in querying and classification purposes in information sharing and knowledge management contexts. Computer programs can use Ontologies for a variety of purposes including inductive reasoning, classification, a variety of problem solving techniques, as well as to facilitate communication and sharing of information among different systems. In addition, emerging semantic web systems use Ontologies for a better interaction and understanding between different web-based systems using agents.

Once a structure such as set of experience allows constructing the decisional DNA of a company, it is necessary to increase the means for sharing such experience among different agents. Distributing decisional DNA, not just inside a company, but also among many companies, would help on the establishment of a knowledge sharing community, a decisional Community of Practice (CoP), which, if developed through internet, would be called the e-decisional community.

In conclusion, our purpose is to show Ontologies under the view of set of experience knowledge structure, leading onto the creation of a new community of practice named e-decisional community, which would share companies' decisional DNA. In such way, set of experience Ontology-based knowledge structure would have the potential to improve the way knowledge is managed as an asset in current decision-making environments.

## 2. SET OF EXPERIENCE KNOWLEDGE STRUCTURE

As was said above, one of the most valuable intellectual assets is the experience accumulated during processes, and in our case, the experience acquired in making a decision. We develop a knowledge structure to manage formal decision events, a structure that builds up a space of formal decision experiences.

Set of experience has been developed to store formal decision events in an explicit way. Four basic components surround decision-making events: variables, functions, constraints, and rules. They are stored in a combined dynamic structure that comprises set of experience. In this text a concise idea of set of experience and its components is offered, for additional information Sanin and Szczerbicki [13] should be examine.

Variables usually involve representing knowledge using an attribute-value language [7]. This is a traditional approach from the origin of knowledge representation, and is the starting point for set of experience. Variables that intervene in the process of decision-making are the first component of the set of experience. These variables are the centre root of the structure, because they are the origin of the other components.

Based on the idea of Malhotra [8] who maintains that "to grasp the meaning of a thing, an event, or a situation is to see it in its relations to other things", variables are related among them in the shape of functions. Functions, the second component, describe associations between a dependent variable and a set of input variables; moreover, functions can be applied for reasoning optimal states, because they come out from the goals of the decision event. Therefore, set of experience uses functions, and establishes links among the variables constructing multiobjective goals.

According to Theory of Constraints (TOC), Goldratt [5] affirms that any system has at least one constraint; otherwise, its performance would be infinite. Thus, constraints are another way of relationships among the variables; in fact, they are functions as well. A constraint, as the third component of set of experience, is a restriction of the feasible solutions in a decision problem, and a factor that limits the performance of a system with respect to its goals.

Finally, rules are suitable for associating actions with conditions under which the actions should be performed. Rules, the fourth component of set of experience, are another form of expressing relationships among variables. They are conditional relationships that operate in the universe of variables. Rules are relationships between a condition and a consequence connected by the statements IF-THEN-ELSE.

Following the description of the four components of set of experience, its structure is organized taking into account some important features of DNA. Firstly, the combination of the four nucleotides of DNA gives uniqueness to itself, just as the combination of the four components of set of experience offer distinctiveness. Moreover, the elements of the structure are connected among themselves imitating part of a long strand of DNA, that is, a gene. Thus, a gene can be assimilated to a set of experience, and, in the same way as a gene produces a phenotype, a set of experience produces a value of decision in terms of its objective functions. This value of decision is what is called the efficiency of the set of experience. The efficiency or phenotype value is a combination of the objective functions and the effect values of the variables [14].

Furthermore, it is possible to group sets of experience by category, that is, by their efficiency. Each set of experience built after a formal decision event can be categorized, and acts as a gene in DNA. A gene guides hereditary responses in living organisms. As an analogy, a set of experience guides the responses of certain areas of the company. Sets of experience give advice to the company's areas about how to respond. Additionally, suppose two formal decision events have the same characteristics in terms of structure and category, but, are slightly changed in the efficiency value, then both sets of experience can originate a new improved and more precise set of experience. They are transformed achieving an improvement due to a mixing of the efficiency of both sets of experience parents. This possibility opens doors for reformulating sets of experience.

A unique set of experience cannot rule a whole system, even in a specific area or category. Therefore, more sets of experience should be acquired and constructed. The day-to-day operation provides many decisions, and the result of this is a collection of many different sets of experience. Hence, a group of sets of experience of the same category comprise a kind of chromosome, as DNA does with genes. These chromosomes of sets of experience could make a "strategy" for a category, i.e. an area of the company. Each module of chromosomes forms an entire inference tool, and provides a schematic view for knowledge. Such complete group is what we called the Decisional DNA of the company.

In conclusion, set of experience knowledge structure acts as a representation for explicit knowledge according to the world it perceives from formal decision events. It is composed by four components, which are uniquely combined. Sets of experience can be collected, classified, and organized according to their efficiency, grouping them into chromosomes. Chromosomes are groups of sets of experience that can comprise a strategy for a specific area of the company. Moreover, set of chromosomes comprise what is called the Decisional DNA of the company.

## 3. ONTOLOGY-BASED TECHNOLOGY

Following is Tom Gruber's widespread accepted definition of what Ontology is in the Computer Science domain: Ontology is the explicit specification of a conceptualization; a description of the concepts and relationships in a domain [6]. In the context of AI, we can describe the Ontology of a program by defining a set of representational terms. In such Ontology, definitions associate names of entities in the universe of discourse with human-readable text describing what the names mean, and formal axioms that constrain the interpretation and well-formed use of these terms.

Computer programs can use Ontologies for a variety of purposes including inductive reasoning, classification, and problem solving techniques, as well as communication and sharing of information among different systems. In addition, emerging semantic web systems use Ontologies for a better interaction and understanding between different agent web-based systems. Ontologies can be modelled using several languages, being the most widely used RFD and recently OWL. OWL (Ontology Web Language), a W3C Recommendation since February 2004 [21], has been designed to be used by applications that need to process content of information instead of just presenting information to humans. OWL facilitates machine interpretability of web content by providing additional vocabulary along with formal semantics. Ontology modelling can deliver interesting benefits as it allows inferring semantically new derived queries. These queries relate concepts that were not taken into account initially. Modern inference engines and reasoners like Pellet and Racer [18] deliver a highly specialized, yet efficient way to perform such queries via a JAVA compliant API. In the literature, data handling by Ontology-based technology is reported by researchers in different fields [10] [11] [2]. Furthermore, user modelling, task and experience are also possible scenarios for the exploitation of semantic data by Ontology-based technology as it was addressed for example in the IST-Project WIDE [19].

In conclusion, set of experience Ontology-based containing knowledge about formal decision events can be a scenario for exploitation of semantic data, and in such way, it can be used as a shareable structure for helping in the decision-making process. Following, set of experience Ontology-based knowledge structure is exposed.

## 4. SET OF EXPERIENCE ONTOLOGY-BASED KNOWLEDGE STRUCTURE

In this section, we introduce our approach to the modelling of sets of experience knowledge structure from an Ontology perspective. In order to obtain such Ontology, we start from the XML set of experience model presented by Sanin and Szczerbicki [14] [15]. Afterwards, an Ontology model process was performed using the Protégé editor [20].

### 4.1. CLASS, SLOTS AND INSTANCES ORGANIZATION

When developing Ontologies three actions must be taken into account:

1. Initially a set of classes must be modelled with the elements of the domain; these classes contain the abstract concepts and their roles.
2. Every class has properties including name, cardinality (single or multiple) and the data type that describes the property.
3. When the Ontology modelling process is done, it must be instanced. This process can be performed using an Ontology editor like Protégé or programmatically via an API. The instancing process populates every class and the relationships between them with real world values.

## 4.2. SET OF EXPERIENCE KNOWLEDGE STRUCTURE MODELLING – IMPLEMENTATION - VISUALIZATION

For every first level tag of the set of experience XML-knowledge structure, that is, variables, functions, constraints, and rules, a concrete class of the Ontology is created. For second level tags, a slot with the proper cardinality and data type is created. A tag from the XML version of set of experience knowledge structure is shown in its Ontology perspective in figure 1, while the Ontology instancing process using the Protégé editor can be seen in figure 2. Same process was performed on the functions, constraints and rules classes. In figure 3, relationships among the different classes of the Ontology can be seen using a plug-in for visualization of the Ontology model.

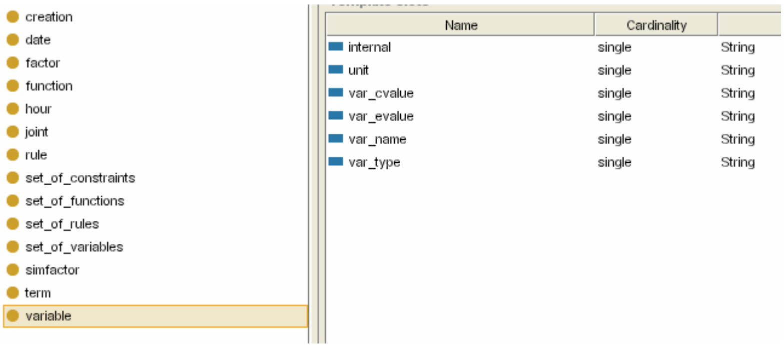



Figure 1: Tag Variable in the Ontology version of the Set of experience Knowledge Structure

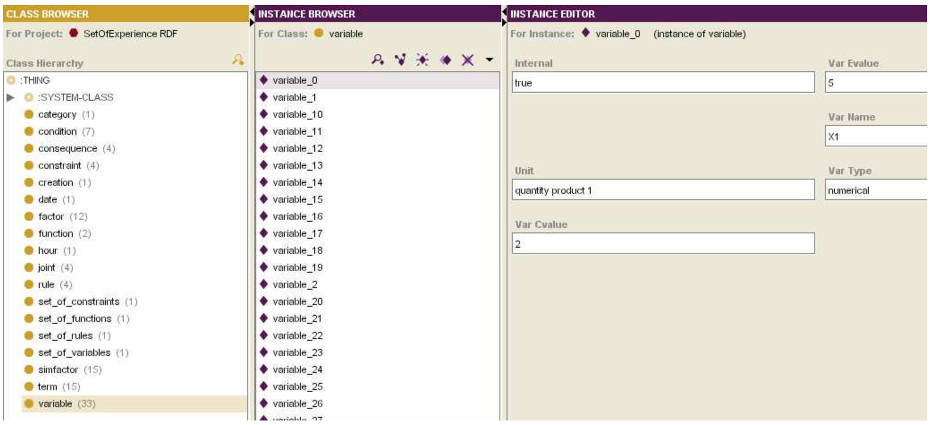


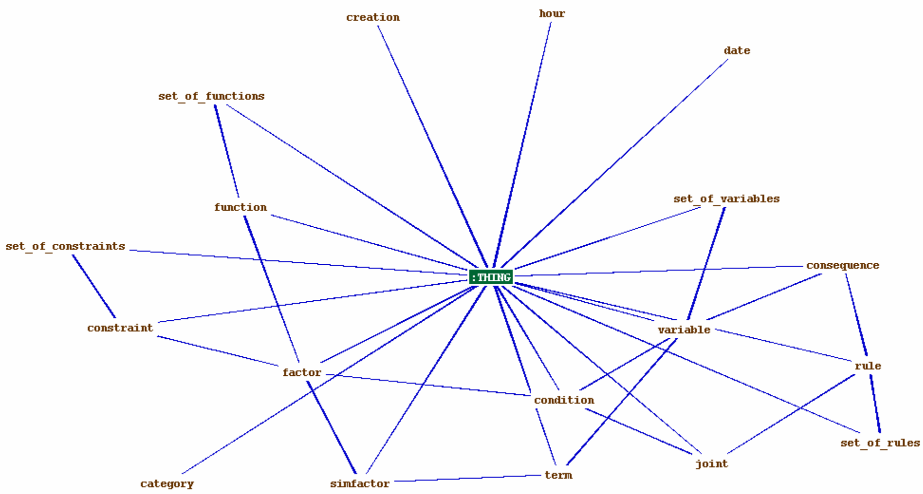

Figure 2: Tag Variable instanced in the Ontology version of the Set of experience Knowledge

Structural changes were not done in the transformation of set of experience XML-knowledge structure to set of experience OWL-knowledge structure. Having finished first and second actions of the Ontology modelling process, the third action continues as it is explain in the next section.

## 4.3. INSTANCING SET OF EXPERIENCE ONTOLOGY-BASED KNOWLEDGE STRUCTURE

Formal decision events can be evaluated via an Ontology API. Using such API programmatically, the Ontology instantiation process can be performed. Furthermore, the API provides several mechanisms to test semantics on the conceptual model and the instanced model as well.

The Ontology model by nature is a Web based application with a predefined namespace. This permits storage of several instanced models in a web server way, allowing the users to interact with the model using a simple web browser, or in our case, a JAVA




application for the handling of the Ontology. Once the Ontology is instanced, the model becomes a shareable explicit knowledge that can be considered a repository.

The model is now ready for instancing with companies' decisional DNA, that is, formal decision events. A repository for sets of experience according to the Knowledge Supply Chain System platform exposed by Sanin and Szczerbicki in [12] can be created. Once this is done, this repository can be accessed through different queries, which would be developed according to similarity parameters [17] and users requirements.

Figure 3: Ontology model relationships

## 4.4. E-DECISIONAL COMMUNITY

Having an Ontology-based repository ready to be feed with decisional DNA produced by the members of the e-decisional community would be the beginning of a new way of sharing knowledge. The e-decisional community would share decisions among its members allowing decision-maker users to improve their day-to-day operation by consulting such repository, and along with this interaction, the e-decisional community would increase and improve the decisional DNA available for being shared.

## 5. CONCLUSION

A shareable set of experience Ontology-based knowledge structure able to store formal decision events, i.e. decisional DNA, would advance the notion of administering knowledge in the current decision making environment. Decisional DNA enables us to distribute experience among different applications, and in that form, and through the e-decisional community, companies that are expanding the knowledge management concept externally, can explore new ways to put explicit classifiable knowledge in the hands of employees, customers, suppliers, and partners.

## REFERENCES


[1] AWAD E. and GHAZIRI H., *Knowledge Management*, Pearson Education Inc., Prentice Hall, New Jersey 2004.

[2] BRANDT S.C., MORBACH J., MIATIDIS M., ET AL, *Ontology-based information management in design processes,* Proceedings of the 16th European Symposium on Computer Aided Process Engineering (ESCAPE) and 9th International Symposium on Process Systems Engineering (PSE), Garmisch-Partenkirchen, 2006.

[3] DRUCKER P., *The Post-Capitalist Executive: Managing in a Time of Great Change,* Penguin, New York 1995.

[4] FERRUCI D. and LALLY A., *Building an example application with the Unstructured Information Management Architecture,* IBM Systems Journal, Vol. 43 (2004), No. 2, pp. 455-475.

[5] GOLDRATT E.M. and COX J., THE GOAL, Grover, Aldershot Hants 1986.

[6] GRUBER T.R., *Toward principles for the design of Ontologies used for knowledge sharing,* International Journal of Human-Computer Studies, Vol. 43 (1995), No. 5-6, pp. 907-928.

[7] LLOYD J.W., *Logic for Learning: Learning Comprehensible Theories from Structure Data,* Springer, Berlin 2003.

[8] MALHOTRA Y., *From Information Management to Knowledge Management: Beyond the 'Hi-Tech Hidebound' Systems,* Knowledge Management for the Information Professional, Information Today, Inc., pp. 37-61.

[9] NONAKA I. and TAKEUCHI H., *The Knowledge-Creating Company: How Japanese Companies Create The Dynamics Of Innovation,* Oxford University Press, New York 1995.

[10] POSADA J., TORO, C.A., WUNDRAK, S., STORK, A., *Ontology Supported Semantic Simplification of Large Data Sets of Industrial Plant CAD Models for Design Review Visualization,* Proceedings of the International Conference on Knowledge-base and Intelligent Information and Engineering Systems, KES, Part I LNCS 3681, Springer, Melbourne 2005.

[11] REWERSE, *Ontology Driven Visualisation of Maps with SVG – Deliverable from the European Project REWERSE,* Project number: IST-2004-506779, Munich (2005).

[12] SANIN C. and SZCZERBICKI E., *Knowledge Supply Chain System: A Conceptual Model,* Knowledge Management: Selected Issues, A. Szuwarzynski (Ed), Gdansk University Press, Gdansk, (2004), pp. 79-97.

[13] SANIN C. and SZCZERBICKI E., *Set of Experience: A Knowledge Structure for Formal Decision Events,* Foundations of Control and Management Sciences, Vol. 3 (2005), pp. 95-113.

[14] SANIN C. and SZCZERBICKI E., *Using XML for Implementing Set of Experience Knowledge Structure,* Proceedings of the International Conference on Knowledge-base and Intelligent Information and Engineering Systems, KES, Part I LNCS 3681, Springer, Melbourne 2005, pp. 946-952.

[15] SANIN C. and SZCZERBICKI E., *Extending Set of Experience Knowledge Structure into a Transportable Language XML (eXtensible Markup Language)*, Cybernetics and Systems: An International Journal, Vol. 37 (2006), No. 2-3, pp. 97-117.

[16] SANIN C. and SZCZERBICKI E., *Using Set of Experience in the Process of Transforming Information into Knowledge,* International Journal of Enterprise Information Systems, Vol. 2 (2006), pp. 45-62.

[17] SANIN C. and SZCZERBICKI E., *Similarity Metrics for Set of Experience Knowledge Structure,* Proceedings of the International Conference on Knowledge-base and Intelligent Information and Engineering Systems, KES, Springer, Bournemouth 2006, (Accepted).

[18] http://www.cs.man.ac.uk/~sattler/reasoners.html, SATTLER U., *Description Logic Reasoners*.

[19] SMITHERS T., POSADA J., STORK A., PIANCIMORE M., ET AL; *Information management and knowledge sharing in WIDE,* Proceedings of the European Workshop on the Integration of Knowledge, Semantics and Digital 2004.
[20] http://protege.stanford.edu/index.html, STANFORD MEDICAL INFORMATICS, *Protégé.*
[21] http://www.w3.org/TR/2004/REC-owl-ref-20040210/, W3C, *OWL Web Ontology Language Reference: W3C Recommendation, 10 February 2004*.