A SEMIOTIC-BASED APPROACH TO THE DESIGN OF WEB ONTOLOGIES

Júlio Cesar dos Reis
Institute of Computing (UNICAMP) and CTI Renato Archer
Rodovia Dom Pedro I, km 143, 6, 13069-901 Campinas, São Paulo, Brazil

Rodrigo Bonacin
CRP Henri Tudor and CTI Renato Archer
Rodovia Dom Pedro I, km 143, 6, 13069-901 Campinas, São Paulo, Brazil

M. Cecilia C. Baranauskas
Institute of Computing at University of Campinas (UNICAMP)
Caixa Postal 6176, 13083 970 Campinas, São Paulo, Brazil

Keywords: Ontology Engineering, Web ontology, Web Ontology Language, OWL, Semantic Web, Semantic Analysis Method, SAM and Organisational Semiotics.

Abstract: Nowadays, Web systems generate an enormous amount of data that need to be organized, managed and retrieved in a more efficient and accurate way. Literature has brought these concerns, trying to develop techniques to allow the use of content by machines through Semantic Web technologies, such as Web ontologies. However these are still insufficient to adequately deal with aspects of information modelling, and knowledge representation. This paper studies and points out the shortcomings of these techniques, and proposes a new approach to better design Web ontologies aided by the Semantic Analysis Method (SAM) from Organisational Semiotics (OS). We have investigated a novel semi-automatic method that can lead to more representative Web ontologies.

1 INTRODUCTION

Communication is a basic element for society evolution for millennia. The writing, written press, radio, television and more recently the Web are some of the greatest inventions of humanity that propitiated the information access and sharing. These inventions have transformed the society and boosted the development of the humanity as a whole. In analyzing the "emergence" and popularization of the Web, it is possible to notice various scientific and technological advances that have made it possible, among them: new physical means of communication such as optic fiber networks and wireless networks, communication protocols, computing devices such as faster processors and displays, rich and standard GUI (Graphical User Interface); and more recently a great concern in better mechanisms for managing and retrieving data and information.

Analysing the evolution of the Web, the Web 1.0 (or first-generation of the Web) provided quick access to large volumes of information. The approach in the Web 1.0 was prevalent for centuries with books and for decades with radio and television, which we had a relationship "one-to-many", *i.e.,* an information producer for many consumers. The so-called Web 2.0, besides a "richer" GUI has also changed considerably the Web 1.0 approach, towards a relationship of "many-to-many", to which there are some information producers and consumers working collaboratively. Social Network Services (SNS), Wikis, Blogs, music and video sharing sites are examples of applications where many people produce and consume information in an interactive process and usually intensively. Nowadays, literature has glimpsed the

Bonacin R., dos Reis J. and Baranauskas M.
A SEMIOTIC-BASED APPROACH TO THE DESIGN OF WEB ONTOLOGIES.
DOI: 10.5220/0003269600600067
In *Proceedings of the Twelfth International Conference on Informatics and Semiotics in Organisations (ICISO 2010)*, page
ISBN: 978-989-8425-26-3
Copyright © 2010 by SCITEPRESS – Science and Technology Publications, Lda. All rights reserved

Semantic Web (SW) as an extension of the current Web, in which well-defined meaning is associated to information, enabling computers and people to work better in cooperation (Berners-Lee *et al.*, 2001).

Web systems generate a large volume of data in various media, with complex structures highly distributed, including the immeasurable cultural diversity present in information produced by people. New opportunities for advance in the Web could be achieved through the efficient management of this information. Nevertheless, the development and use of the Web brings new problems that are dependent on scientific and technological advances in several related areas. The solution for the problem of information modeling in the Web depends on the understanding of information and knowledge "nature", and on the development of complex computational algorithms. The challenge addressed in this paper is to understand how to structure, model, organize, manage and promote means for information available in Web systems be better computationally represented, allowing more efficient ways to access and share information.

In order to deal with this challenge, it is necessary to combine fundamentals, theories and methods aiming at understanding and modeling the process of knowledge generation and sharing with new technological approaches. Conventional solutions and approaches of the SW are based on “Web ontologies”. A “Web ontology” can be understood as a specification of a conceptualization which provides descriptions about knowledge (Gruber, 1993). Literature has shown several semantic problems and limitations related to the use of Web ontology. Therefore, the goal of this paper is to show the major deficiencies in the SW technologies by showing its failure to resolve the main issues; and to present a new approach to design ontologies in the Social Web. In this approach, we discuss how some concepts from the Semantic Analysis Method (SAM) (Liu, 2000) could improve the Web ontology modeling, aiming at developing an expanded and more representative Web ontology towards a ‘Semiotic Web ontology’.

The paper is organized as follows: Section 2 presents the theoretical and methodological background of the paper; Section 3 presents some current problems and limitations of the SW ontologies; Section 4 outlines a new approach to the design of Web ontologies using SAM, and shows a brief illustration and discussion; and Section 5 concludes.

2 THEORETICAL AND METHODOLOGICAL BACKGROUND

In this section we present an overview of the SW concepts and its technological constraints. Besides, as a theoretical-methodological background we present an overview of the SAM from OS.

2.1 Semantic Web and the Ontologies

The main challenge of the SW development is to represent the meaning of the content to be machine interpretable. The way this is done is at the heart of the SW study. According to Uschold (2003) the most widely accepted definition for this feature is content usable by machines. This means having data on the Web defined and linked in a way that they can be used by machines, not just for displaying purposes, although for automation, integration and reuse across applications.

For that purpose, it is necessary to the machine to have a model of "knowledge" about the domain, *i.e.,* the available knowledge must be represented so that the machine can "interpret" it. Tazi (1994) argues that knowledge can be represented with the Sowa's Conceptual Graphs. This approach is based on Peirce's Existential Graphs, and follows the Aristotle’s idea that each concept is represented by a word or symbol, serving as a semantic network in which nodes represent concepts that are related to each other. In the SW, knowledge is represented through computing ontologies. According to Studer *et al.* (1998) ontology is a shared and common understanding of some domain that can be communicated between people and computers; it is a formal specification that should be readable and understandable by machines.

The term ontology is often used to refer to the semantic understanding (a conceptual framework of knowledge) shared by individuals participating in a given knowledge domain. Semantic ontology can exist as an informal conceptual framework of types of concepts, and their relations named and defined in natural language. Alternatively, it could be constructed as a formal semantics taking into account the domain, with the types of concepts and their relationships defined systematically in a logical language. Indeed within the Web environment, ontology is not simply a conceptual framework, but a concrete syntactic structure that tries to model the semantics of a domain (Jacob, 2005). According to Noy & McGuinness (2001), ontology along with a number of different instances of its classes constitutes a knowledge base. The classes are the focus of most ontologies. Classes describe the concepts in the domain. For instance, a class of wines represents all wines; specific wines are instances of this class. The Bordeaux wine is an instance of a class of wines. A class can have subclasses that represent concepts that are more specific than super-classes; *e.g.* we can divide the class of all wines into red, white and rosé wines. Alternatively, we can divide the class of all wines into sparkling wines in non-sparkling wines.

At the core of the SW technology there is a language based on logic for knowledge representation and inference. Computational Languages for ontology description are designed specifically to define ontologies. According to the SW architecture proposed by Berners-Lee *et al.* (2001), the ontology description languages are related to other Web languages such as *Resource Description Framework* (RDF), RDF *Schema* and the *Extensible Markup Language* (XML). According to statistics from Cardoso (2007) OWL (*Web Ontology Language*) is nowadays the most common approach for modeling ontologies in software. OWL has three sub-languages with increasing expressivity: OWL Lite, OWL DL and OWL Full. OWL is currently defined by a set of recommendations of the *World Wide Web Consortium* (W3C) (W3C, 2004).

2.2 Semantic Analysis Method (SAM)

As a theoretical reference of the OS for the proposed approach, we have used the Semantic Analysis Method (Liu, 2000) that comes from the MEASUR (Methods for Eliciting, Analyzing and Specifying Users' Requirements) (Stamper, 1993). The SAM assist users or problem owners in eliciting and representing their requirements in a formal and precise model. With the analyst in the role of facilitator, the required system functions are specified in an Ontology Chart (OC). It is worth to mention that this concept of ontology is different from the SW ontology. Ontology in OS represents a business domain which can be described by the concepts, the ontological dependencies between the concepts, and the norms detailing the constraints at both universal and instance level (Liu *et al.,* 2008). A graphic representation of a conceptual model is called an OC. The OC describes a view of responsible agents in the focal domain and their pattern of behavior named affordances (Liu, 2000). Some basic concepts of SAM adopted in this paper are based in Liu (2000):

“**The world**” is socially constructed by the actions of agents, on the basis of what is offered by the physical world itself;

“**Affordance**”, a the concept introduced by Gibson (1977) is used to express invariant repertories of behavior of an organism made available by some combined structure of the organism and its environment. In SAM (Stamper, 1993) the concept introduced by Gibson was extended by Stamper to include invariants of behavior in the social world;

“**Agent**” can be defined as something that has responsible behavior. An agent can be an individual person, a cultural group, a language community, a society, etc. (an employee, a department, an organization, etc.);

“**An ontological dependency**” is formed when an affordance is possible only if certain other affordances are available. The affordance “A” is ontological dependent on the affordance “B” means that “A” is only possible when “B” is also possible;

“**Determiners**” are properties which are variants of quality and quantity that differentiate one instance from another;

“**Specialization**”, agents and affordances can be placed in generic-specific structures according to whether or not they possess shared or different properties;

OS adopts a subjectivist philosophical stance and an agent-in-action ontology. This philosophical position states that, for all practical purposes, nothing exists without a perceiving agent or without the agent engaging in actions. That is to say, each thing depends for its existence upon the existence of its antecedents. Words and expressions we use are names for invariant patterns in the flux of actions and events which the agents experience. The classical distinction between entity, attribute and relationship disappears to be replaced by the concepts of agents, affordances (the actions or attributes of agents) and norms (for the socially defined patterns of behaviour) related to their antecedents to indicate the ontological dependency (Stamper *et al.,* 2000). The concepts of the Semantic Analysis are represented by means of this agent-in-action ontology.

We have investigated the design of Web ontologies to deal with their problems and limitations, as presented in the next section, inspired on this perspective.

3 PROBLEMS AND LIMITATIONS OF SEMANTIC WEB ONTOLOGIES

Web ontologies (in OWL) have been widely used for many purposes, such as semantic search (Bonino *et al.,* 2004) and content management (Mao *et al.,* 2006). Although literature has shown several semantic problems and limitations related to the use of these artifacts.

According to Carvalho (2005), even with the advent of ontologies, there are still no tools to assist in the organization of the information in a way suitable for human mental operations in an individual or societal way. In order to facilitate the work for the computer, the organization within the ontology is formally made, creating a fixed relation of words. Carvalho (2005) also argues that it is necessary to discuss the whole set of relationships and context of information contained in ontologies. This contextualization is generated from a detailed study of the topics required for understanding the subject in question. The study asks for a number of key concepts, which summarize the knowledge of the area. These concepts need to be organized as a way to produce a “knowledge tree". This tree should be able to translate that subject, representing it as accurately as possible. By establishing a hierarchy between concepts, it is difficult to accurately represent different contexts, which means that the ontology need to be attached to a well-defined domain.

Gärdenfors (2004) argues that if we want to consider how humans deal with concepts and their meanings, the structures of the class relation from SW ontologies have captured only a little part of our knowledge about concepts. For example, we often categorize objects according to the similarity between them, and similarity is not a concept that can be expressed in a natural way in a Web ontology language. Additionally, Gärdenfors (2004) says that a notable characteristic of human thought is our ability to combine concepts and, in particular, understand the new combinations of these concepts. Furthermore, almost all Web applications (*e.g.* systems of question and answering) have inputs in the form of combinations of concepts. Therefore, Gärdenfors (2004) states that an important criterion for the success of the computational semantic model is that it should be able to deal with combinations of concepts. This author also highlights the lack of symbolic grounding in these ontologies. The source of the problem is that each ontology (along with its terminology) works as a free floating island of reeds – it has no anchor in reality. However the "meaning" of the ontological expression does not live on these islands. Thus, Gärdenfors (2004) proposes the establishment of structures called Conceptual Spaces, as a richer semantic structure underlying the representational format. Conceptual Spaces represent information through geometric structures and not through symbols.

The work of Tanasescu & Streibel (2007) describes several arguments in favor of alternative models for knowledge representation in detriment of traditional ontologies, such as: (1) the inadequacy of reasoning based on categories to represent reality; (2) the need for different representations of the same identity according to the context; and also (3) the difficulty for representing psychological concepts, such as Affordances from Gibson (1977) in a hierarchical structure. The authors argue that Web ontologies are not yet flexible enough to match the representational complexity of the human mind; also they are difficult to construct. Tanasescu & Streibel (2007) emphasize that Web ontologies are better suited to the description of scientific fields such as medicine and biology, which are already semi-formal and organized into categories and relationships.

Tanasescu & Streibel (2007) also claim that with the advent of Web 2.0 applications there has been an intensified use of non-structured notes, such as tagging and Collaborative Tagging Systems (CTS). CTS produce different results compared to using default vocabularies for tagging, and provide users with a simple way to make sense (meaning) to their own content. Consequently, the authors argue that while current investigations are still trying to alleviate the practical problems related to the use of ontologies, the WS can benefit from the techniques used by Web 2.0 applications. These techniques have spread out widely and appear to be a way to allow users to describe their own content, since the system cannot determine a priori the meaning of the content. They conclude that for a faster expansion of SW new approaches to semantic acquisition, separated from the centralized ontologies and not developed by experts, need to be explored. Thus, alternatively, they introduce the proposal of Extreme Tagging Systems (ETS), as an extension of CTS, enabling the collaborative construction of knowledge bases over the use of formal and centralized ontologies for knowledge representation.

The work of Obitko *et al.* (2004) proposes an alternative approach which remains using conventional Web ontologies for knowledge representation. They have described a strategy for designing ontologies using Formal Concept Analysis (FCA). This is a theory of data analysis that identifies conceptual structures among data sets. This method allows discovering the need for new concepts and their relationships in an ontology. FCA is based on the philosophical understanding that a concept has two parts: (1) its extension which consists of all objects belonging to the concept; and (2) its intention, which includes all attributes shared by these objects. The crucial characteristic in this method for knowledge representation is that it is not based on a priori definition of classes; nevertheless the concepts are described from their attributes. Instead to create a class and to associate attributes to it, a concept is built from their attributes.

These discussed studies propose both: (1) totally alternative methods to Web ontologies for knowledge representation in the SW; and (2) instead of using completely alternative methods some approaches just propose a differentiated design for ontologies. In the next section we propose a method to the design of Web ontologies based on SAM.

4 PROSPECTING A NEW APPROACH TO THE DESIGN OF WEB ONTOLOGIES

In order to produce immediate and practical results on the SW applications, our approach employs a different method which produces an agent-in-action ontology, and explores how to improve the Web ontologies using concepts from the agent-in-action perspective. In other words, we propose to develop a representational structure towards a 'Semiotic Web ontology'. It is worth to mention that it is not our goal to refute here the SW technologies of nowadays, neither to create a "perfect ontology" from a theoretical point of view; but instead we propose to expand SW techniques with methods and techniques coming from OS.

'Semiotic Web ontology' is a semantic model (computationally tractable ontology) constructed from a semi-automatic method based on SAM. Some theoretical and methodological concepts of SAM are used in conjunction with other technologies from the SW to describe computationally tractable ontologies using OWL. The idea is to incorporate the concepts of particular Agents (roles) and Affordances (patterns of behavior) arising from the SAM into an expanded and more representative SW ontology.

It is also important to emphasize that we do not intend to create an OC (from SAM) in OWL or to substitute the OC at the conceptual or business level. The use of OWL is relevant here since it is at implementation level, thus it gives us opportunities to improve the semantic models used in the existing SW applications and initiatives. We understand that this is a fast and practical way to show direct contributions from SAM to the SW. Semantic Web solutions like semantic search could take advantage of the SAM. Therefore some properties from the OC may not be fully transcribed to OWL at this time, while other aspects such as agent-affordance relationship are emphasized.

From a Semiotics perspective it is assumed that the signs are socially constructed. Thereby, a computational model that represents the semantics from a Social Web application should contain the agents that interpret the socially shared concepts. With this approach we incorporate and take to SW ontologies concerns and possible representations arising from the Ontology in a semiotic perspective. In addition to agents and affordances, we have observed that SW ontologies also do not incorporate in the model (at least explicitly) the idea of ontological dependency relations.

In order to design the Web ontology, we first create an OC using SAM. This intermediate ontology diagram is important to identify the possible agents from the context and their patterns of behavior, and thus pass these to the (computationally tractable) Web ontology using OWL. To accomplish that, a set of specific heuristics is applied to derive an initial OWL ontology. Bonacin *et al.* (2004) proposed a heuristic to construct system design UML diagrams from OC; those heuristics must be adapted to our purpose. This approach does not create an equivalent ontology in OWL; instead it provides some heuristics to support the analyst during the modeling process.

In the 'Semiotic Web ontology' we represent the agents that have behaviour(s) (affordance) in a concept (which can have determiners), and can be important in situations of synonymous and polysemy. For instance the concept of 'crane' can mean a bird or a type of construction equipment, and we can model it using the agents and their affordances; *e.g.* a biologist, who can be model as an agent, probably make studies about birds. To study birds is a pattern of behaviour of a biologist (in other words an affordance). As shown by Figure 1, 'crane' is a concept that can have several different meanings, although in some context, due to the agent and their affordances, the meaning of 'crane' is more closely linked to birds and not, for example, to a construction equipment, that can also be represented in the model.

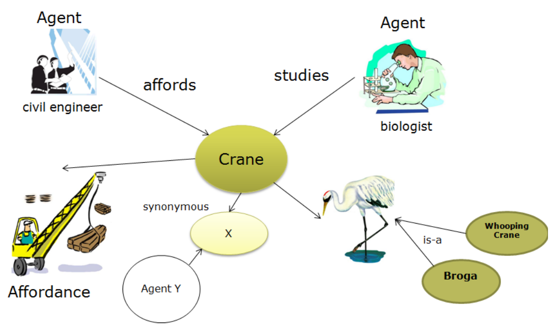

Figure 1: Modeling meanings in an example of polysemy using agents and affordances.

Figure 1 illustrates an example of modeling using this approach in which the 'biologist' and the 'civil engineer' are agents that have affordances connected to specific concepts. Also this model can have relationships of specific 'is-a', *e.g.* 'Broga' and 'Whooping Crane' are specific kinds of 'crane'. This shows that concepts can be related to several agents and affordances, and with other concepts, constituting relations and representations that make more complete ontologies compared to ontologies described purely for a domain.

For instance, 'crane' can mean a construction equipment for a 'civil engineer', as well as anything else to any other agent, or have any synonym that makes sense for an agent 'Y' modeled from the data of the Web system. We can see other examples like 'Manga' (in Portuguese) can mean a fruit, a sleeve as well as a color; and we can model it using the agents and their affordances in a 'Semiotic Web ontology'.

In this approach, we introduce new constructions that represent agents and affordances in OWL ontology. The meanings of the concepts represented in the ontology are relative to the agents. Then, aspects such as polysemy, that is a hard problem for SW applications, could be better treated using this ontology.

4.1 Illustrating the Approach

The use of this approach has been utilized and investigated in a scenario of Social Network Services (SNS). Experiences with users of search engines (Reis *et al.,* 2010) point out that this kind of association, as developed in this approach, could contribute to more precise and adequate search mechanisms in SNS. We illustrate a search scenario in SNS that can be beneficiated with the 'Semiotic Web ontology'. From the user profile in the SNS application, we identify the agents represented in the ontology, and make a connection between them (user and agents). Thus we can prioritize (or even limit) the search space, making a relation between the user with the ontology; *e.g.* if a biologist is logged into the system (we could find that a user is a 'biologist' based on his/her profile) and request a search with the keyword 'crane'. Whether we have a relation between the 'biologist' agent and the term 'crane' in the ontology, the results from announcements of the SNS that could be returned first (ranked first) should most likely be related to the concept of crane as a 'bird', not to other meaning(s) of this word (like a type of construction equipment).

Nevertheless to a 'civil engineer' that makes the search into the system about 'crane', probably the results that most interest him / her are about the construction equipment and not about 'crane' as a bird. We do not mean that other results are not required or may not be returned in response to the engineer search, (may be the engineer could want to know about this kind of bird). In this case the announcements from the SNS on 'crane' as construction equipment must have greater relevance in the ranking of results. However, a user that has a profile which fits a 'biologist' agent, he or she would have the announcements about 'crane' as a bird with highest priority.

The agent-affordance relation is also used to indicate the probable meaning of the terms in an announcement. For instance, we could verify whether the word 'crane' is about 'bird' or 'construction equipment' based on the user that posted such information. In this situation, whether the user who submitted the announcement fits a 'biologist' agent, 'crane' would be most likely about a 'bird'. Otherwise whether the advertiser is a 'civil engineer', in this situation 'crane' would also most likely mean 'construction equipment'. We could have relationships between agents to verify how much an agent is semantically close to another and to indicate the probable meaning based on this aspect.

4.2 Discussing the Approach

The semantic chart (from SAM) delimits the area of operation of the context under study and identifies the basic patterns of behavior (affordances) of the agents. Understanding and modeling the invariants of behaviour of human agents, including how they communicate, interpret the signs and act in society is a key point for the construction of more accurate and flexible ontology models.

It is possible to highlight points which the OS approach deals with the shortcomings of conventional Web ontologies, such as the three deficiencies presented by Tanasescu & Streibel (2007): (1) the reasoning based just on categories to represent reality, in OS is complemented by the identification of agents and their affordances; also (2) there is no different representations of the same identity in the context, since the meaning of the identity is relative to the agent actions, and even (3) there is no difficulty to represent psychological concepts since the concept of affordances (from the cognitive psychology) is the basis for the description of the model. Moreover, with our approach we can build more flexible ontologies, since the concepts are interpreted based on the patterns of behaviour of the represented agents, no matter whether there is a static hierarchy of concepts, because the different contexts can be identified by the agents. Similarity and combination of concepts could be done using also the agent as a way to make disambiguation. Once modeling ontologies is a hard and time consuming task, we believe that constructing geometric structures underlying it, as the Gärdenfors (2004) proposes, could be not viable on a large scale. Regarding ETS approaches, they may not be feasible in some contexts in which non expert users have no ability to create and manage tags.

The understanding and modeling of ontologies using methods and techniques grounded on human cognition and behavior are also needed to build a Web with focus on human agents (and not just artificial agents). Furthermore it is important to emphasize that we want to consider the technological work already done, looking for new modeling methods that will complement and boost the proposal of the SW. Several applications may benefit of this approach, such as new possibilities for semantic search engines in SNS that include the agents, and create new ways to more appropriate search for users.

In SNS contexts, Mika (2005) has already pointed out the general advantages of incorporating the social context into the representation of ontologies. According to Mika (2005) creating the link between actors and concepts into the model of ontologies brings benefits in terms of more meaningful and easily maintainable conceptual structures. Mika proposed the extension of the traditional concept of ontologies (concepts and instances) with the social dimension, extending this traditional bipartite model by incorporating actors. Mika's proposal aims at modeling networks of folksonomies using the idea of connecting the real user with the concept and their objects. By using our approach with the agents' concept and their affordances a more general and wide-ranging of applications is possible; moreover, it is based on a formal method to find out the agents, affordances and the agent-affordance relationship.

Although concepts and theories from SAM can bring benefits to the SW models, we argue that OWL models and OC do not replace each other. They present distinct views and have different proposals. While OC concerns human perception and patterns of behaviour, and can be empirically refuted, OWL concerns are the computer interpretable constructs and efficient models. In our approach, it is responsibility of the analyst to interpret and decide how to construct better computer interpretable models (such as OWL) from the OC. Tools and heuristics can be used for supporting the analyst during this process, however only the analyst is able to connect the models and examine their consistence with the real world.

5 CONCLUSIONS

The evolution and use of the Web over the years have brought new challenges on modeling and representing information. A better organization, management and retrieval of digital content have become a critical point to allow new opportunities for knowledge access and sharing in the Social Web. Therefore, there is a growing need for solutions that deal with semantic aspects in Web Systems trying to understand the meanings from the information and improve their use. The Semantic Web view brings practical techniques and solutions trying to create content usable by machines. Nevertheless due to the amount and complexity of data, these technologies are still insufficient to really deal with this problem, resulting on more sophisticated and adequate solutions from the point of view of human agents. As presented in this paper, literature has pointed out some deficiencies of conventional Semantic Web approaches. The main goal was to raise it with a discussion for a long term work.

Hence, new approaches to better understand and model the semantic aspects of digital content in the Web are necessary. This paper presented an approach based on Organisational Semiotics (OS) to build Web ontologies. Our proposal is to design Web ontologies aided by Semantic Analysis Method

(SAM). We discussed how some concepts from SAM could improve the modeling of Web ontologies. We showed the possible contributions to improve it, indicating the practical and immediate results which the approach could be empirically demonstrated. Further work involves to develop an expanded and more human-representative Web ontology, as well as to present a practical example illustrating the use of the approach. Next steps in this research include to explore other concepts from SAM in the modeling using OWL, as well as to develop a semi-automatic software tool that materializes the ideas of the approach to create the 'Semiotic Web ontology', including the heuristics to aid creating an initial OWL ontology from the OS chart.

ACKNOWLEDGEMENTS

This work is funded by Microsoft Research - FAPESP Institute for IT Research (proc. n. 2007/54564-1) and by CNPq/CTI (680.041/2006-0). The authors also thank colleagues from CTI, IC (UNICAMP), NIED, InterHAD and Casa Brasil for insightful discussion.

REFERENCES

Berners-Lee, T., Hendler, J., Lassila, O., 2001. *The Semantic Web*, Scientific American.

Bonacin, R., Baranauskas, M. C. C., Liu, K., 2004. *From Ontology Charts to Class Diagrams: semantic analysis aiding systems design.* In Proc. of 6th International Conference on Enterprise Information Systems. 6th International Conference on Enterprise Information Systems, Porto, Portugal.

Bonino, D., Corno, F., Farinetti, L., Bosca, A., 2004. *Ontology Driven Semantic Search.* WSEAS Transaction on Information Science and Application, Issue 6, Volume 1, pp. 1597-1605.

Cardoso, Jorge (2007) The Semantic Web Vision: Where Are We? Intelligent Systems, IEEE Volume 22, Issue 5, pp: 84 - 88

Carvalho, M. L. B., 2005. *Web semântica e semiótica: ontologias e aplicação a permacultura*. Master Dissertation - Centro Universitário Eurípides da Marília (in Portuguese)

Gärdenfors, P., 2004. *How to Make the Semantic Web More Semantic*. In Formal Ontology in Information Systems, Proceedings of the Third International Conference (FOIS), pp. 17-34.

Gibson, J. J., 1977. *The Theory of Affordances*. In Perceiving, Acting, and Knowing. Eds. Robert Shaw and John Bransford.

Gruber, T. R., 1993. *A translation approach to portable ontologies*. Knowledge Acquisition, v.5, n.2.

Jacob, Elin K., 2005. *Ontologies and the Semantic Web*. Bulletin of the American Society for Information Science and Technology. Volume 29 - Issue 4, pp. 19 – 22.

Liu, K., 2000. *Semiotics in information systems engineering.* Cambridge University Press.

Liu, K., Sun, L., Fu, Y., 2008. *Ontological modelling of content management and provision.* In Information and Software Technology, v.50 n.11, p.1155-1164.

Mao, M., He, D., Peng, Y., 2006. *Ontology-Based Content Management and Access Framework for Supporting E-Learning Systems.* In Proc. of International Conference on Web Intelligence and Intelligent Agent Technology. Washington, DC, USA. pp. 220-226.

Mika, Peter., 2005. *Ontologies are us: A unified model of social networks and semantics*. In Proc. of the 4th International Semantic Web Conference (ISWC 2005), LNCS 3729, Springer-Verlag.

Noy, N. F. & Mcguinness, D. L., 2001. *Ontology Development 101: A Guide to Creating Your First Ontology.* Knowledge Systems Laboratory.

Obitko, M., Snasel, V., Smid, J. 2004. *Ontology design with Formal Concept Analysis.* In Proc. of International Workshop on Concept Lattices and their Applications, pp. 111–119.

Reis, J. C., Bonacin, R., Baranauskas, M. C. C., 2010. *Analysing Search in Inclusive Social Network Services.* IC-10-02, www.ic.unicamp.br/~reltech

Stamper, R., Liu, K; M. Hafkamp, Y., Ades, 2000. *Understanding the Role of Signs and Norms in Organisations: A semiotic approach to information systems design.* Journal of Behaviour and Information Technology, 19(1): 15-27.

Stamper, R. K., 1993. *Social Norms in requirements analysis - an outline of MEASUR*. In Jirotka M, Goguen J, Bickerton M. (eds) Requirements Engineering, Technical and Social Aspects. New York.

Studer, R. *et al.* 1998. *Knowledge engineering: principles and methods*. Data & Knowledge Engineering, v.25, n.1/2.

Tanasescu, V. & Streibel, O., 2007. *Extreme Tagging: Emergent Semantics through the Tagging of Tags*. In International Workshop on Emergent Semantics and Ontology Evolution. Busan, Korea.

Tazi, S., 1994. *Using Sowa's conceptual graphs for enhancing hypertext readers performances*. Intelligent Hypertext Workshop, Washington. citeseer.ist.psu.edu/12096.html

Uschold, M., 2003. *Where are the semantics in the semantic web?* American Association for Artificial Intelligence. AI Magazine. Volume 24- Issue 3. pp. 25-36. Menlo Park, CA, USA.

W3C, 2004. *OWL-Web Ontology Language*, Recommendation 10 February 2004, <http://www.w3.org/TR/owl-features>, Accessed October 2009.