Collaborative Ontology Specification

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Abstract. The use of methodologies in the development of ontologies is a common practice. Until now several methodological proposals have been presented for building ontologies. Ontologies are forms of a priori social agreements on concepts. Therefore, reaching those agreements is a fundamental step to their success. Traditionally, the ontology engineering field has laid a lot of emphasis on the "specification of the conceptualization" as an engineering task, but the work developed about the social construction of the conceptualization itself has been scarce. In this paper, we present the state of the art in the collaborative ontology anthology specification and a comparative analysis of the several existent approaches based on some criteria defined. The main conclusions are that up to now there are few detailed proposals for the collaborative construction of ontologies in (distributed) groups of human actors and there is no completely mature approach to support the collaborative specification.

Keywords: Ontology Engineering, collaboration, ontology specification, comparative analysis.

1 Introduction

Due to the industrial and economic environment, collaborative networks will tend to be formed and to exist for short periods of time, i.e., the time needed to complete a business opportunity. How to structure the information for purposes of supporting the activities of temporary collaborative networks will therefore be a major difficulty in the establishment of the semantic agreements that will be the cornerstone for sharing information and knowledge. In the last decade, research in this field has shown ontology engineering as the most promising technology to attain semantic interoperability of systems [5]. However, ontologies are forms of priori social agreements made about a conceptualization of a given part of the world. Therefore, reaching those agreements is a fundamental step to their success. Traditionally, the ontology engineering field has laid a lot of emphasis on the "specification of the conceptualization" but work developed about the social construction of the conceptualization itself has been scarce. This is even more noticeable in the application of ontology engineering to collaborative network contexts.

Ontology creation needs a social presence as it requires an actor to predict reliably how other members of the community will interpret the concepts of an ontology just

based on their limited description. By incorporating the notion of semantics into the web architecture, we thus transform the users of the system themselves into a critical part of the design.

As it is known the word ontology was taken from philosophy, where it means a systematic explanation of being. In the last decade, as it was referred above, the word ontology became relevant for the knowledge engineering community. Today, many texts about what an ontology is can be found in the literature of several scientific areas, and it is possible even to trace how those definitions evolved over time. Today, many texts about what an ontology is can be found in the literature of several scientific areas, and it is possible even to trace how those definitions evolved over time.

Despite of this, one of the first definitions still reflects accurately the essence of ontologies as applied to the information systems area: "an explicit specification of a conceptualization" [11]. This definition gave origin to many other, and it is the reference definition in this paper.

One of the more comprehensive studies on what an ontology is [3] concluded that "ontologies aim to capture consensual knowledge in a generic and formal way, and that they may be reused and shared across applications (software) and by groups of people. Ontologies are usually built cooperatively by a group of people in different locations". This conclusion considers the importance of including the collaboration principles in the ontology development process, more precisely, in the specification phase. Other aspects already mentioned and considered as fundamental for our research work are the need of a social construction of the conceptualization and the application of ontology engineering to collaborative network contexts, reinforce the need of collaboration in this process.

Making an analogy with the information systems development process, the specification and conceptualization phase of an ontology is similar to information systems analysis which include the following activities: requirements elicitation, analysis and negotiation, and documentation. In this work, conceptualization and specification of an ontology are considered as one single phase, named specification.

For us, the specification phase includes the identification of the concepts to include in the ontology, their characteristics, definition and relationships, as well as the knowledge organization and structuring using external representations independent of the implementation language and environment.

The focus of this paper is not in the methodologies for building ontologies, but the study, in a detailed way, of the specification phase of each collaborative methodology existent. The other phases are not part of the goals of this work. Hence, this paper presents the state of the art in the collaborative ontology specification and a comparative analysis of the several existent approaches. The rest of the paper is structured as follows: Section 2, shortly reviews the most relevant methodologies for building ontologies and refers the importance of the specification phase in the development process. Section 3, presents a brief description of the work developed in this area up to now and finishes with a definition of collaborative ontology specification and some principles for collaborative specification. Section 4, presents a comparative analysis. Section 5, presents a brief discussion about the approaches for collaborative ontology specification. Section 6, provides some conclusions of this work and proposes future directions.

2 Ontology specification vs ontology development methods

An ontology can be developed collaboratively by distributed individuals and organizations with different expertise, goals, and interactions. Various communities of experts and practitioners examine problems from different angles and are concerned with different dimensions of the semantic contents and representation. These individuals all need to properly understand each other and meaningfully communicate their views of domain knowledge to form meaningful higher-level knowledge: the ontology [5].

An ontology development methodology comprises a set of established principles, processes, practices, methods, and activities used to design, build, evaluate and deploy ontologies. Several such methodologies have been reported in the literature. From the analysis of some surveys [8] concluded that: 1/ most ontology development methodologies that have been proposed focus on building ontologies; 2/ some other methodologies also include methods for merging, reengineering, maintaining, and evolving ontologies; and 3/ yet other methodologies build on general software development processes and practices and apply them to ontology development. The authors present two important observations that result of their brief survey of ontology development methodologies: 1/There are many common points in the various methodologies. Steps in different processes may be named differently, may also be of different granularity, or may only partially overlap, but the processes are still very much alike; 2/ Many of the principles and practices of ontology development are analogous to those of software engineering [8]. [7] present the following conclusions: it doesn't exist a completely mature methodological proposal for building ontologies, since there are some important activities and techniques that are missing in all of these methodologies; not all of the methodologies have the same degree of maturity; presents Methontology as a very mature methodology; although the work to unify proposals can be interesting, maybe several approaches should coexist and refer the lack of detailed description of the techniques used to build ontologies in all methodologies. They refer also the lack of approaches for collaborative development.

Just as in the information systems development the analysis and specification phase has great influence, or maybe it is the one that has more influence, in the success of the system. When we speak about ontology development, the question is the same, the specification phase is, in our opinion, the main responsible for the quality and success of the created ontology. Therefore, research questions proposed here relative to current ontology development methods are: 1/ how structured and how detailed is the specification process defined? 2/ which methods, techniques and tools are proposed? 3/ which actors and associated competencies are considered? 4/ how is collaboration considered within the specification process, including the characteristics of the used artefacts and the actors involved? The several definitions of ontology [3] sent for a process of collaborative conceptualization of the domain. This is fundamental if we want to apply ontology engineering to collaborative network.

3 Collaborative ontology specification: the state of the art

[12] reinforce the need of methodologies to support the phase of knowledge acquisition. The need of tools that support the knowledge conceptualization and that starting from this generate the code of the ontology. These authors consider that the ontology developers frequently pass directly from the knowledge acquisition to the implementation phase of the ontology. When most of the knowledge has been acquired, the ontologist has a lot of unstructured knowledge that must be organized. They present Methontology as a methodology that was created for building ontologies either from scratch, reusing other ontologies as they are, or by a process of reengineering them. The Methontology framework enables the construction of ontologies at the knowledge level. It includes: the identification of the ontology development process, a life cycle based on evolving prototypes and the methodology itself, which specifies the steps for performing each activity, the techniques used, the products to be output, and how the ontologies are to be evaluated. Related with the ontology specification it deals with the following aspects: the specification states why the ontology is being built, which are its intended uses and who are the end-users; a conceptualization that structures the domain knowledge as meaningful models at the knowledge level; the reutilization of other ontologies that are already available [3], [7] and [12].

[14] and [15], present the On-To-Knowledge methodology that is the result of the project with the same name. This methodology includes the phases of feasibility study, kickoff phase, refinement phase, evaluation phase and maintenance phase. In the kickoff and refinement phases the activities involved in the ontology specification are performed. The kickoff phase is then where ontology requirements are captured and specified, competency questions are identified, potentially reusable ontologies are studied and a first draft version of the ontology is built. The output product is an ontology requirements specification document. The goal of the refinement phase is to produce a mature and application-oriented target ontology according to the specification given by the kickoff phase.

The approaches selected in this review are those that consider, in some way, the collaborative ontology specification. The Methontology methodology was just selected because it is considered in the literature as the most complete and mature, although, in our opinion, it doesn't consider the collaborative ontology construction. The methodology On-To-Knowledge was selected because there is a report of at least one case study in which it was used to support a collaborative ontology construction, as described bellow.

[4] describe OntoShare, an ontology-based system for sharing information among users in a virtual community of practice and describe the deployment and evaluation of OntoShare in a particular community as part of a case study within the project On-To-Knowledge, OntoShare has been applied and evaluated using the On-To-Knowledge methodology. In this study it is interesting to analyze how the kickoff and refinement phase was executed, given that it is in this phase that the ontology is specified. The kickoff and refinement stages of the methodology were carried out at a workshop with key people from the user group. This was held at the company's premises and run by a knowledge engineer. It was very much brainstorming oriented during the kickoff phase [4]. The group was able to produce the ontology at the

workshop which meant that most of the refinement stage had been carried out in tandem with the kickoff stage.

[9] based on the work of [10] reviewed some of the most representative methodologies to build ontologies and claim to have identified good guidelines that may be applied in the Conceptualization, Knowledge Acquisition and Knowledge Representation phases. After doing the survey of methodologies and starting the conceptualization phase, they found several problems and needs: the lack of understanding of the domain terms and the lack of experts; the need to facilitate the ontology definition, using a formal representation language, by domain experts (users) that are not computer experts; and the need to structure the whole process of guidelines, tasks and support materials. To address these requirements the authors propose the following solutions: to obtain relevant concepts by processing written sources of knowledge, used as a guide for the next phases, using information retrieval and document structure processing techniques; to support human communication through conceptual structures, by representing knowledge by means of two layers: a user layer with an easy graphical language (CMAPs) and an internal layer with a formal representation language (Description Logics); to build up the ontology in an incremental manner, they define a refinement cycle based on the three main conceptual strategies, top-down, bottom-up and middle-out applied in different phases of the cycle. The tasks of the refinement cycle are repeated until all the participants reach a consensus for the semantic of the ontology.

[13] and [16] presents the DILIGENT that comprises five main activities of ontology engineering: build, local adaptation, analysis, revision, and local update. In DILIGENT methodology an initial ontology is made available and users are free to use it and modify it locally for their own purposes. This initial ontology is built by a small group of builders. There is a central board (the board should have a well balanced and representative participation of the different kinds of participants involved in the process that maintains and assures the quality of the shared core ontology. This central board is also responsible for deciding to do updates to the core ontology. However, updates are mostly based on changes re-occurring at and requests by decentrally working users. Therefore the board only loosely controls the process. Due to the changes introduced by the users over time and the on-going integration of changes by the board, the ontology evolves. The ontology goes on being developed in an iterative and incremental manner. A central ontology exists together with several local ontologies, and the central ontology goes being readjusted in agreement with the local ontologies. [1] and [2] propose a three-phased ontology construction procedure in which the knowledge engineer mediates between the differing conceptions experts or users may hold about a knowledge domain. This work approaches the question of the direct participation of the members of the organizations in the creation of the shared ontology. The procedure presented is derived from conflict mediation approaches and consists on three main phases: generation, explication and integration. The main objective of the procedure is the integration of contradictory knowledge and the establishment of a shared conceptualization as well as a sustainable ontological commitment among human users. In our perspective this is an interesting approach that addresses explicitly the social aspects of ontology development such as negotiation. The whole process described belongs to the ontology specification phase.

A quite recent methodology that addresses the question of the shared conceptualization is DOGMA-MESS [6]. The authors present DOGMA-MESS as a methodology that supports the process of organizational ontology engineering and the rapidly changing of collaborative requirements and the DOGMA-MESS (Meaning Evolution Support System) as a state-of-the-art system built on the DOGMA framework for scalable ontology engineering. The model suggested by the authors for Interorganizational Ontology Engineering (a generic model) is a conceptual model of the interorganizational ontology engineering process sufficiently specific, according to the authors, to derive and organize practical methodological guidelines, yet generic enough to represent and compare many different approaches and techniques from an application point of view. This model is the basis to the development of DOGMA-MESS methodology. This model shows that an interorganizational ontology consists of various related sub-ontologies. The engineering process starts with the creation of an upper common ontology, which contains the conceptualizations and semantic constraints that are common to and accepted by a domain. Each participating organization specializes this ontology into its own organizational ontology, thus resulting in a local interpretation of the commonly accepted knowledge. In the lower common ontology, a new proposal for the next version of the interorganizational ontology is produced, aligning relevant material from the upper common ontology and various organizational ontologies. The part of the lower common ontology that is accepted by the community then forms the legitimate upper common ontology for the next version of the interorganizational ontology.

[3] presents an overview of the main methodologies, tools and languages to build ontologies. In this work they present CO4 (Collaborative construction of consensual knowledge bases) as a single method that includes a proposal for collaborative construction. CO4 is a protocol to reach consensus between several KBs (knowledge Bases), which are organized in a tree. Its goal is for people to discuss and agree in the knowledge introduced in the KBs of the system. These KBs are built to be shared, and they have consensual knowledge, hence they can be considered ontologies. The user KBs does not obligatorily have consensual knowledge. Each group KB represents the consensual knowledge among its children (called subscriber KBs). A KB can subscribe to only one group. A human user can create several KBs (possibly subscribing to different group bases) representing different trends, and knowledge can be transferred from one KB to another. Also, it is possible that several human users share the same KB. When the users of a KB have enough confidence in a piece of knowledge of their KB, and they want to reach consensus about their knowledge with the rest of the users, the CO4 process is executed. The steps are repeated until all users accept the proposal, or some users definitively reject it. If a user makes a proposal that does not satisfy the other users, the users and the groups agreeing with the modification can add it to their KBs (see [7]).

[7] present CO4 and KA^2 as the methodologies for collaborative and distributed construction of ontologies. They say that the goal of the Knowledge Annotation Initiative of the Knowledge Acquisition (KA) community, also acknowledged as the (KA)2 initiative, is to model the knowledge acquisition community using ontologies developed in a joint effort by a group of people at different locations using the same templates and language. According the authors, KA^2 is an open-joint initiative where the participants are actively involved in the distributive ontological engineering

development. The ontology is generated with base in the knowledge introduced using the templates.

As we can see, few works exist in the area of collaborative ontology construction. Analyzing the specification phase of the main methodologies we verified that this question is still unsolved. Although some initiatives exist in this field, none of them seem sufficiently solid, complete and tested. The procedure presented by [1] and [2], the DOGMA-MESS methodology and DILIGENT methodology deserve in this area special attention.

A collaborative ontology specification process is defined as a set of practices and activities used to obtain a shared conceptualization of the domain with the participation of all stakeholders. Comprise the identification of the concepts to include in the ontology, their characteristics, definition and relationships, the knowledge organization and structuring using external representations independent of the implementation language and environment. In our opinion, a collaborative ontology specification/construction process should contain the following principles that should be considered the core values on which all of the collaborative ontology specification methods are designed: 1/ active participation of all interested parties; the process requires constant collaboration between the development team and the other stakeholders; 2/ propose efficient and effective methods to support the negotiation process, methods that support the consensus or agreement obtaining between groups of human actors about the ontology content; 3/ propose mechanisms that allow working with the several users perspectives presented; 4/ propose tools to support collaboration (communication, cooperation and coordination), for example, tools to support a graphic visualization of the contents proposed for the shared conceptualization during the negotiation process; 5/ propose a notation or language to be used by all to represent their perspectives (this can be supported by one tool); 6/ propose techniques for concepts/terms elicitation; and 7/ propose mechanisms that support the semantic and syntactic analysis of the ontology concepts, to guarantee a correct interpretation of the contributions of the several stakeholders, for example, how to work with situations where it exists the possibility of multiple definitions for the same concept (homonymy).

4 Collaborative ontology specification: comparative analysis

Considering the most representative approaches presented in the previous section, the activities of the specification phase of each one, the definition and principles by us proposed for collaborative ontology specification, we present in table 1 some aspects of the comparative analysis of the several approaches used in the collaborative ontology specification. Given the allowed number of pages for the paper we opted by presenting some of the criteria used in the comparative analysis, trying to present the one that we considered to be the most relevant.

Table 1. Analysis of the different approaches for collaborative ontology specification.

	"Two-layered approach to knowledge representation using conceptual maps and description logics" [9]	**On-To-Knowledge methodology [14], [15] and [4]**	**DILIGENT methodology [13] and [16]**	**"The knowledge mediation procedure" [1] and [2]**	**DOGMA-MESS methodology [6]**	**CO4 [3] and [7]**	**KA^2 [7]**
Actors	Clients; domain experts and knowledge engineers	Domain experts, User group representatives (some key people representing the interests of the user groups), knowledge engineers	Ontology users, domain experts, knowledge engineers, ontology engineers and control board editors	Knowledge engineer, human experts, direct or indirect ontology end-users	Core Domain experts, participating organizations (domain experts) and knowledge engineers	KB Users	Ontopic agents and ontology coordinating agents
Extraction of domain knowledge (concept elicitation techniques)	Interviews + Document Processing	Workshop + brainstorming techniques + competency questionnaires	Not specified	Brainstorming + use of automatic thesaurus generation tools	Templates	Not specified	Templates
Use of informal representation language to represent the actors proposals	Not proposed	Not proposed	Not proposed	Not proposed	Not proposed	Not proposed	Not proposed

Methods to reach consensus or agreements about the content should be included in the ontology		Repeat the refinement cycle until all the participants reach a consensus about the ontology semantics	Not proposed	Not proposed	Proposed the use of conflict mediation approaches	Not proposed	Steps 2, 3, 4 and 5 of CO4 protocol are repeated until all users accept the proposal, or some user definitively rejects it	Not proposed
Treatment ways of the several users perspectives		Not proposed	Not proposed	Allow the existence of local ontologies that result of the adaptation of core ontology by end-users	Not proposed	Each participating organization specializes the interorganizational ontology into its own organizational ontology, thus resulting in a local interpretation of the commonly accepted knowledge	Allow the existence of several KBs	Not proposed
Conceptual strategies use	**Top-down**	Interviews with the experts	Not proposed	Not proposed	Not proposed	Not proposed	Not proposed	Not proposed
	Bottom-up	Interviews with the clients	Not proposed	Not proposed	Not proposed	Not proposed	Not proposed	Not proposed
	Middle-out	Document Processing of the written documentation to extract the most relevant terms	Not proposed	Not proposed	The generation of terms is performed with a middle-out approach	Not proposed	Not proposed	Not proposed

5 Discussion

The comparative analysis presented in the previous section allows us to reflect about the current state of the approaches for collaborative ontologies specification. A conclusion to this analysis is that there is no completely mature approach to support this task.

The analysis led to conclude that the use of concept elicitation techniques is not consensual among the several proposals. There are presented structured techniques (templates and interviews, e.g.) and no structured techniques (simple sending of messages, e.g.). Will the structured techniques the right approach in what concerns collaborative specification? Of the presented proposals, workshops and brainstorming seem to be the more adjusted. No approach proposes tools to support the decision process of the concepts to include in the shared conceptualization. What decision criteria to use? For instance, something as simple as, in situations where agreement or consensus doesn't exist relatively to a concept, where several proposals exist, a system can support the decision, for example, showing the result of the use of the several concepts proposed in documents produced by the involved organizations. The extraction of knowledge concepts of the domain from organizational documents and systems to complement the capture of knowledge performed joint the human actors was not considered relevant for the great majority of the approaches. The use of techniques for graphic representation of the reached conceptualizations was little explored. The use of informal languages to represent the several proposals presented by the human actors, as well as the possibility of creating automatically a formal specification of the ontology and respective code based on these informal models was not yet explored. The use of informal languages, in our opinion, will help the visualization of the different perspectives proposed by the several actors and the obtaining of consensus or agreements during the ontology conceptualization phase. Few proposals approach the question of the reutilization of existent ontologies in the development process. However, this reutilization can make the ontology content completer and richer. The creation of support documentation as a result of the specification phase is out of the goals of the majority approaches proposed, that also hinders the future reuse of the resulting ontology, because most of the times this only exists codified. The social aspects involved in the ontologies construction have not been factors considered. The main concern of the existent approaches is focused on the engineering tasks, leaving to second plan the social questions. Up to now it was given little attention to the methods to support the negotiation process among human actors. However, analyzing the social questions involved in the ontologies specification, such as the need for approaches to support in the consensus or agreements obtaining, as well as ways to treat the different perspectives presented for the several users, the answer to the questions may pass through a detailed study of the techniques and strategies proposed by the social sciences for the consensus and agreements construction and the appropriate choice of them. In a large part of the approaches the generation of terms is accomplished without the resource to any conceptual strategy. The subjects related with the linguistic representation of the

knowledge (semantic and syntactic analysis of the concepts and relationships to include in the ontology), that can help in the negotiation of meanings among human actors continue without being explored. The semantic analysis that can be defined as a method for elicitation and knowledge representation about organizations, in the perspective of the cognitive semantics (part of the cognitive linguistics) has been forgotten. However, the study of linguistic methods (cognitive semantics) during the knowledge elicitation can be a road to proceed. These models of the cognitive semantics can support in the consensual specification of the meaning and terms for the ontologies development, to support in the negotiation of meanings among human agents that belong to different communities and to establish consensus in a community that needs to adopt a new term (concept). Theories and approaches as conceptual blending theory, image schema theory, idealized cognitive models, conceptual metaphor theory, mental space theory, among others can have an important role in the negotiation of meanings, in the definition of the concepts to include in the ontology and in the generation of new concepts.

6 Conclusions

This reflection allows us to make an analysis on the current state of the approaches for collaborative ontology construction. Our main conclusion is that there is a long road to travel in this area. Up to now, there are few detailed proposals for the collaborative construction of ontologies in (distributed) groups of human actors. Some subjects that we intended to continue studying are: 1/ techniques of informal representation of the different perspectives presented by those involved and results reached during the collaborative process of ontology conceptualization; 2/ application of social sciences approaches to support in the consensus or agreements obtained about the content that should be included in the ontology and in the definition of ways to treat the different perspectives presented by users; 3/ approaches and theories of the cognitive linguistics (cognitive semantics) to support the consensual specification of the meaning and terms (concepts) to include in the ontology; 4/ creation of tools that support the knowledge conceptualization/specification and that starting from the reached conceptualization generate an ontology requirements specification document and the code of the ontology. These tools should support all the collaboration (all interaction existent) among the participants, as well as the whole negotiation process. Some of the ideas to explore were presented already in the discussion section.

Our main goal is to develop a tool to allow the creation of a shared taxonomy/ontology, developed almost exclusively by their users, quickly and efficiently.

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