Ontologies of Organizational Memory as a Basis for Evaluation

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Abstract

This paper proposes an ontology of Organizational Memory (OM) that can guide its design, construction, evolution and evaluation. The upper level of the ontology is described using the generalized concept of Structural Memory (SM), which is a framework of types (e.g., Organizational Memory and Individual Memory) and components (contents and means) that enable the management of "know-how". We demonstrate the feasibility of our approach by constructing the ontology using UML (Unified Modeling Language). The resulting ontology is evaluated for its conceptual completeness. We conclude by showing how this ontological approach can serve as the basis for OM evaluation. This work should prove useful for anyone involved in knowledge management evaluation, and organizational memory in particular.

Keywords

Structural Memory, Organizational Memory, Individual Memory, evaluation, evaluation model, domain ontology, conceptual coverage, case study.

1. Introduction

This paper provides an ontology of organizational memory, i.e., a schema (map) of the knowledge needed for the effective operation of the organization. We believe the ontological approach is key to evaluating Organizational Memory (OM) and more generally to Knowledge Management (KM) evaluation. The use of the memory metaphor in KM implies that organized knowledge is essential for the functioning of the organization. For example, "Knowledge is the key asset of the knowledge organization, organizational memory extends and amplifies this asset by capturing, organizing, disseminating and reusing the knowledge created by its employees" (Concklin 1996). This paper concentrates only on what knowledge is needed and how it should be organized. A generalized solution can then be used to generate a normative design for a specific OM that would form the basis for its evaluation.

All organized activities "give rise to two fundamental and opposing requirements: the division of labor into various tasks to be performed and the coordination of these tasks to accomplish the activity" (Mintzberg 1979, p.2). These requirements rely on communication and information processing that in turn imply a need for an OM (Te'eni 2001). The OM should therefore consist of the knowledge needed for the allocation of tasks to organizational resources and for the coordination processes, which involve mutual adjustments between resources, supervision and standardization of work and skills (tacit or explicit). In other words, an OM should be based on a conceptualization of the essential resources and processes of the organization. Ultimately, the quality of an OM should be judged on the adequacy of the OM to facilitate division of labor and support coordination. A more modest approach to the evaluation of the knowledge management is to judge the adequacy of the conceptualization underlying the OM, which is the approach we advocate here.

Ontology is "an explicit specification of conceptualization" (Gruber 1995). It belongs to a family of concepts and tools, such as metadata and meta-knowledge, used to achieve better content description in context. Ontology provides a set of concepts and terms for describing some domain (Benjamines et al. 1999, Corcho et al., 2000, Gomez-Perez 1998, Guarino 1997, Te'eni and Weinberger 2000, Weinberger and Frank 2001). Domain ontologies as defined by (Guarino 1994) "provide a vocabulary for describing a given domain". Using domain ontology, we can model entities in OM, their attributes, their role and relationships. Indeed, both OMs and ontologies play an important role in cutting edge projects of several advanced research communities today. In addition to our future evaluation goal, the ontology can support both developers and end-users by providing them with a road map of the OM.

The remainder of this article describes domain ontology for OM. The ontology is developed within the Object-Oriented Design (OOD) paradigm using the Unified Modeling Language (UML) (Booch et al., 1999). The second section of this paper reviews developments in OM research and in ontology development and introduces the methodology undertaken in this research. The third section describes the Structural Memory (SM) concept, the fourth section describes the resulting OM ontology, and the fifth evaluates it.

2. Motivation and Methodology

This section briefly reviews OM and ontology related research.

2.1. OM Dimensions

Organizational memory refers to organizational ability to manage "know-how" by means of meta-knowledge (Te'eni and Schwatrz 1999). OM research has evolved in several stages, going from metaphor to construct to system orientation (Ackerman 2000, Boland et al. 1994, Wijnhoven 1998). Indeed, OM literature presents different conceptions of OM and describes preliminary attitudes towards its realization (Ackerman 1998). Stein and Zwass (1995) added the information systems perspective to the memory bins defined by Walsh and Ungson (1991). Abecker (1998) suggested a meta-knowledge architecture. Ackerman (1998) examined the integration of social and technical mechanisms and Schwartz et al. (1999) described three aspects to be included in an Internet-based OM life cycle. In search for a comprehensive view, Wijnhoven (1999) identified two inter-related aspects of OM: content (knowledge and information) and means (processes and media). Yet, currently, there is no comprehensive model for OM, nor are there dedicated tools for OM construction. As for OM life cycle, it is currently less formalized than the existing methodologies for systems development (Te'eni and Weinberger 2000).

OM literature acknowledges three major challenges:

1. Definition of components - the need for a comprehensive model to guide OM development in view of its unique characteristics (e.g., iterative development, dispersed infrastructure and diversified knowledge types).
2. Design of a life cycle - the need for design that supports management of "know-how" (i.e., acquisition, construction, evolution and evaluation).
3. Integration of individual knowledge – the need for a method to guide sharing and reuse of individual knowledge.

In sum, much of the efforts in the investigation and design of OM have been lacking a comprehensive view, which we hope to offer in this paper.

2.2. Ontology Development Methods

There are various ontology development projects that aim at general, domain, and knowledge representation ontologies. In recent years, there is also a variety of languages and tools used for ontology representation, implementation and sharing (Chandrasekaran et al. 1999, Corcho et al 2000). Although ontologies are becoming popular amongst researchers and practitioners, the manner of ontology development is still more of a craft than a science (Dieng et al. 1998, Fernandez 1999, O'Leary 1998). Some guidelines for ontology development are described by (Gomez-Perez et al. 1996), as well as by (Fernandez et al. 1999).

Of the various and recent attempts at ontology development, we mention two initiatives that are of relevancy here. The first is the Enterprise ontology, which provides a framework for enterprise modeling (Uschold and Gruninger 1996). The second one is the Dublin Core metadata element set (Lagoz 1996) which describes standard attributes of documents.

2.3. Ontology Evaluation

There are but initial attempts at ontology evaluation (Gomez-Perez 1995, Gruninger and Fox 1995, Guarino 1997). In evaluating ontologies used for end-users there are two aspects to relate to. One aspect is evaluation of conceptual coverage; the second aspect is evaluation of utility and usability. In section 5 we describe an approach to evaluation used for the SM ontology. In general there are two dimensions to evaluation: verification and validation. Verification is done with relation to the ontology internal features using a set of criteria (e.g., complete statement, granularity, consistency, flexibility, clarity, coherence, extendibility, generality and minimal ontological bias). Validation is carried out with relation to the world that the ontology represents (i.e., the literature, case studies) using a set of criteria (e.g., completeness, efficiency and competence, relevancy). Thus, it provides us with proof of concept regarding the conceptual coverage of the ontology and its utility and usability.

In section five, we describe initial findings regarding validation by concentrating on conceptual coverage.

2.4. Research Methodology

There is no commonly used methodology for the development of OM ontologies. Guided by OM definition and motivated by the end-user perspective, we chose to use Methontology, a methodology for specifying ontologies that was developed by Gomez-Perez at al. (1996) and Fernandez et al. (1999) and UML, a language based on the OOD paradigm.

In view of our needs, UML strengths are in its OOD approach, its visualization capabilities, its standardization process and its domain independence. UML provides a set of notational conventions that can be implemented in various ways. UML diagrams in this paper use the following three UML elements: 1. Classes and class diagrams, 2. Activity diagram, 3. Relationships.

To sum-up, UML combines the benefits of OOD and an iterative process to best answer the needs that arise in the development of an OM ontology.

3. Individual, Organizational and Structural Memory

One of the major obstacles to efficient implementation of KM initiatives is the lack of methodology. Organizations often adopt CSCW systems in hope for materializing knowledge management processes and Organizational Learning (OL), yet they end up using E-mail while failing to find what they need when they need it. It has been observed (Alavi and Leidner 2001) that OM can serve as methodology to guide KM and OL, yet existent models did not investigate the problem of Individual Memory (IM) – its creation and integration in higher-level SMs.

In the approach taken here, types and components comprise the upper-level of the SM ontology for OM. From an ontological point of view, we found it beneficial to generalize the usual OM type, by defining the SM abstract type (see figure 1). SM, as an upper-level classifier, defines attributes and methods common to other sub-classifiers (i.e., use of inheritance). Structural Memory is a new concept. SM is a framework of 1) types (Individual Memory and Organizational Memory) and 2) components (contents and means) that enable the management of "know-how". There are several other SM types that are also considered such as Corporate Memory (CM), Group Memory (GM) and Enterprise Memory (EM) (Abecker et al. 1998, Dieng et al. 1998).

4. Structural Memory Ontology

This section presents the ontology for SM (i.e., the upper-levels), using UML notation. We begin by specifying both the major types of SM (i.e., IM and OM) and the two dimensions of its components: contents and means. The detailed description of the SM life cycle is an integral part of the ontology. Entities in the ontology were defined, at large, following the literature in the domain (Te'eni and Weinberger 2000). Conventions for entities description follow UML conventions.

Figure 1 presents the upper-level of the SM ontology. Any SM ontology should include both the passive (contents) and active (means) view of SM components. The contents dimension includes knowledge and meta-knowledge, and the means dimension includes agents and processes. This classification is derived from Wijnhoven (1999) who identified two inter-related aspects of OM: content (knowledge and information) and means (processes and media). Our understanding was further anchored in the socio-technical perspective of SM acknowledged by (Walsh and Ungson 1991).

In modeling the ontology for SM, we have mapped processes to use cases, agents to UML actors, and contents and means to classes. In the next subsections, we focus on each of the following upper-level categories of the ontology:

- Structural Memory - describing components and types (4.1-4.3).
- Contents - describing knowledge and meta-knowledge resources (4.4-4.6).
- Means - describing processes and SM Life Cycle (4.7-4.9)

The following subsections introduce the SM model. UML class diagrams are used to present the contents and means dimensions of SM. For technical reasons we discuss here but examples of the SM ontology classes, and the description varies from one class to another (i.e., topics described) with relation to: definition, attributes, behavior, and relations. Definition conventions are based on UML conventions as well as on the guidelines suggested by (Fensal 2000).

4.1. Structural Memory

Definition

Structural Memory (SM) is a framework of types (IM and OM) and components (contents and means) that can enable management of "know-how" knowledge. SM is described using four attributes. Two classes, types and components are associated with the SM using the aggregation (i.e., "part-of") relation.

Attributes

1. Name: A statement that refers to the name given to a resource.
2. Goals: A statement that refers to goals defined for the initiative of SM development.

3. Rationale: A statement that relates to the rational behind the initiative of SM development.
4. Philosophy: A statement that relates to the way the initiative is to be realized.

Discussion

The SM concept is motivated by the following assertion:

There exists a reciprocal relation between SM dimensions, components and types and their sub-classes, as between sibling classes within each dimension: Contents is created and managed by Means, which are directed by Types. A diversity of combinations may exist in the lower-levels of various SMs, according to goals defined.

Thus, in order to cater for the need to guide SM development, we need to work out the development process according to a holistic view, following the ontology dimensions (e.g., as in an ecological system) and at the same time acknowledge diversity.

4.2. Components

Definition

The Components class is a classifier that refers to parts of SM: contents and means. It is described using one attribute. The Components class has two subclasses, contents and means associated with it, using the generalization relation.

Attributes

1. Visibility: A statement that denotes the ability to interact with it.

Discussion

The SM components class is a composition of two interrelated resources: knowledge resources and meta-knowledge resources. The first resource is described using the second.

4.3. Types

Definition

The Types class is a classifier that refers to memory structures. It is described using four attributes. It has two subclasses associated with it, Organizational Memory (OM) and Individual Memory (IM), using the generalization association.

Attributes

1. Field of practice: A statement that refers to the field within which it operates.
2. State: A statement that refers to the memory state of evolution.
3. Prevailing culture: A (social-behavioral distinction) statement that refers to the ability of the organization to maintain collectivity.

4. Core competencies: A statement that refers to major expertise of the organization with relation to its domain of practice.

Behavior

Behavior defines the methods needed to manipulate the subclasses.

Discussion

In Types we distinguish between 1. IM (i.e., the collection of actor's interpretations of the relevant world (Boland et al., 1994) which may be included in group/organizational memory, 2. OM (i.e., the collection of types and components that supports strategic renewal), 3. GM (i.e., memory of several individuals working as a team), and 4. EM (i.e., memory of an enterprise – a collection of OMs). We believe the IM to be imperative (e.g., for the operation of knowledge creation and organizational learning) and that in accordance with needs, different SMs might require various OM and GM realizations.

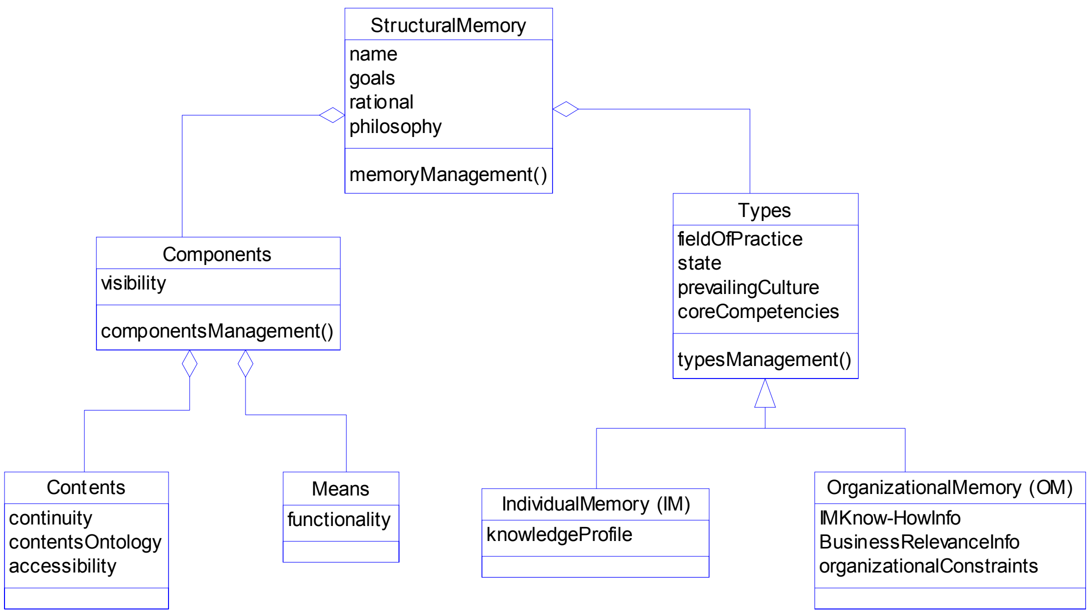

Figure 1: SM dimensions

4.4. Contents

In this subsection, we describe the class of SM contents (figure 2).

Definition

The Contents class includes classifiers that constitute a framework of Knowledge Resources (KR) and Meta-Knowledge Resources (MKR) that are designed to promote organizational learning. The Contents class is associated with its two subclasses using the generalization association.

Attributes

1. Continuity: A statement that indicates the ability of a content object to develop.
2. Contents Ontology: A composition of (20) elements designed to describe contents. Fifteen elements are embedded from the Dublin Core (DC) ontology, three are from the SHOE document ontology (Heflin et al. 1999) and one was taken from the OM literature (Leibowitz 1999) and one attribute was added by us.
3. Accessibility: A statement that refers to the degree of ability (of a user) to interact with the contents.

Discussion

The discussion refers to two attributes: Dublin Core (DC) and Accessibility:

- Dublin Core (DC) - DC is a set of metadata conventions for Web content description (Lagoze 1996). The contents ontology also includes keywords added to DC vocabularies (i.e., adding SM oriented keywords to certain attributes). It demonstrates the importance of applying schema to content description.
- Accessibility - refers to the user ability to approach the contents elements. This is but one example to the connection existing between the active and passive dimensions of SM.

4.5. Knowledge Resources

Definition

Knowledge Resources (KR) is a classifier referring to intellectual assets relevant to organizational tasks. KR is described using one attribute. There are two subclasses associated with KR, using the generalization relation.

Attributes

1. Genre: A statement that refers to the category of the content with relation to organizational activity (Paivarinta 2001).

Subclasses

The Knowledge Resources class is associated with two subclasses: 1. Documents - structured repositories that include best practices, lessons learned, FAQ, stories, guides, proposals and engagements, as well as other documents forms, and 2. Pocket Items - accommodates soft knowledge "passing" in various pipelines, such as bulletin boards, knowledge pockets (expert heads), discussion groups, knowledge centers and knowledge markets.

Discussion

With regard to the deviation of knowledge subclasses, we were guided by the persistent dichotomy treatment of knowledge, in the OM literature, as tacit or explicit (Nonaka and Takeuchi 1995), which is of significant importance especially for practical reasons (e.g., sharing, reuse). Yet, according to fundamental ontological distinctions (Guarino 1994) (tacit and explicit account as non-sort predicates) we could not classify them as classes. We solved this problem by dividing the knowledge resources subclasses between documents - encompasses all explicit sources (includes formal and semi-formal knowledge elements), and pocket items - referring to tacit knowledge (includes non-formal knowledge elements).

4.6. Meta-Knowledge Resources

Definition

The Meta-Knowledge Resources (MKR) class is a classifier referring to structured knowledge assigned to facilitate KR sharing and reuse. MKR is described using one attribute. Four subclasses are associated with this classifier, using the generalization relation.

Attributes

1. Level of Interoperability: The extent of being interoperable between information systems.

Subclasses

There are four subclasses associated with MKR: 1. Descriptive systems, 2. Design standards systems, 3. Rights management systems, and 4. Knowledge representation methods (i.e.,ontologies).

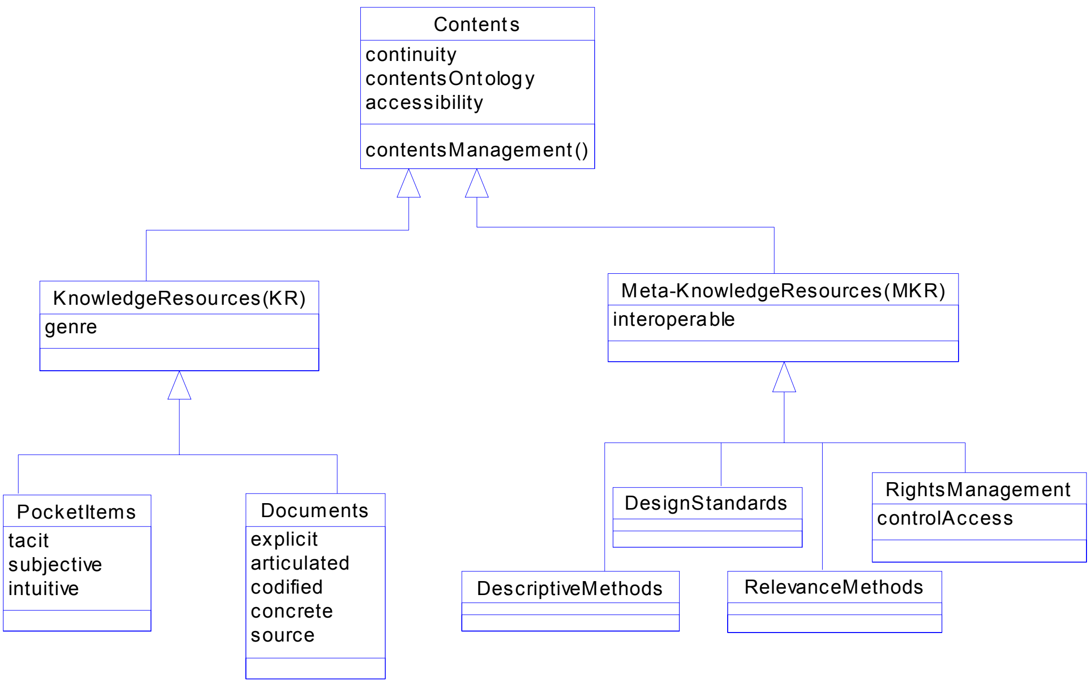

Figure 2: SM contents

4.7. Means

In this subsection, we describe the SM Means class (figure 3).

Definition

The Means class is a classifier referring to agents and processes. It has two attributes (i.e., availability and functionality) and its subclasses are associated with it using the generalization relation.

Subclasses

There are two subclasses associated with means: 1. Agents - Knowledge Technology (KT), and Human Agents, and 2. Processes (see below).

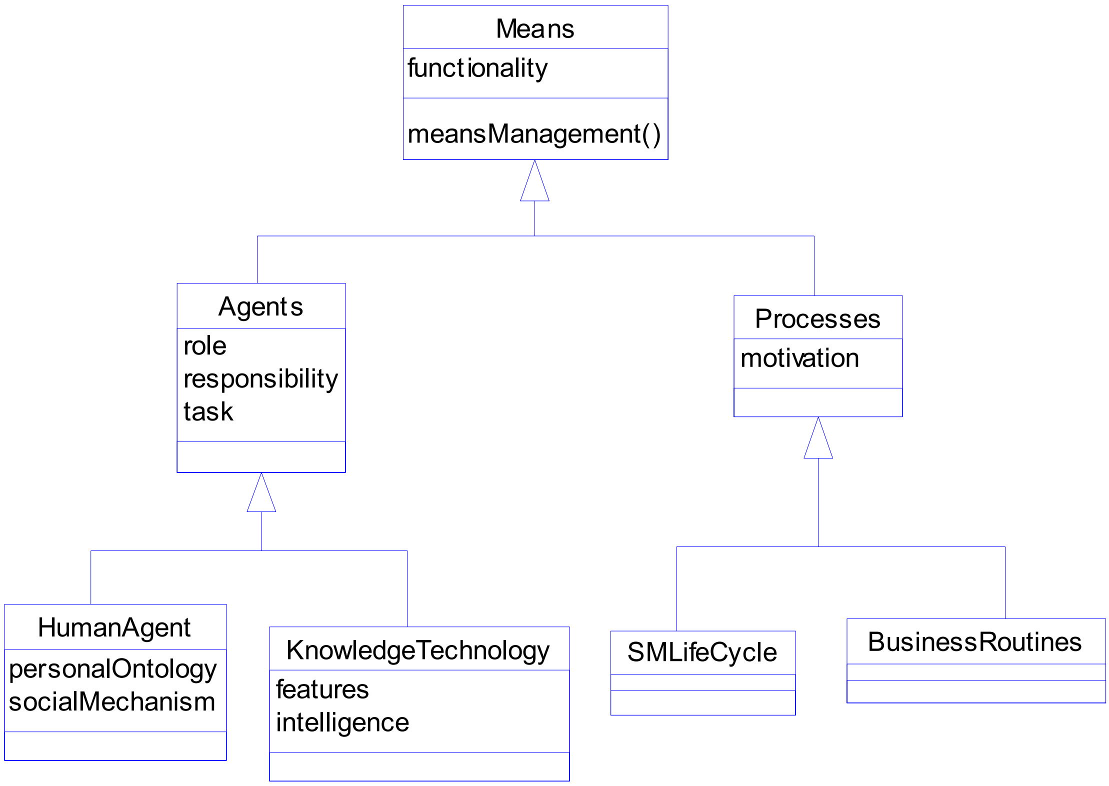

Figure 3: SM means

4.8. Processes

Definition

The Processes class is a classifier referring to SM development processes. It is described using one attribute. Two subclasses are associated with SM processes, using the generalization association.

Attributes

1. Motivation: A statement that explains the excepted outcome for the process.

Subclasses

The Processes class has two subclasses: 1. SM Life Cycle - represents stages and activities in SM development (figure 4), 2. Business Routines - represents an integral part of any organization.

4.9. SM Life Cycle

Definition

SM Life Cycle is a classifier referring to the SM development processes (for a detailed discussion see Te'eni & Weinberger 2000). It is described using the behavior of SM Management. There are seven subclasses associated with it using the generalization relation.

Subclasses

The SM Life Cycle class has seven subclasses: 1. Requirements specification (e.g., identification of goals and needs), 2. Knowledge acquisition (e.g., identification of core competencies, resource mapping), 3. Analysis and synthesis (e.g., classification, review and synthesis of contents), 4. Design, 5. Construction (e.g., creation, implementation and use), 6. Evolution (e.g., knowledge creation, organizational learning, maintenance), and 7. Evaluation (e.g., of system operation, user satisfaction).

Discussion

This is a pattern of activity that guides the development of SM in a cyclic and iterative way. Several stages mentioned here received so far only scant attention (evolution and evaluation) or none at all (analysis and synthesis). It appears that the development process is complete in the way it evolves and iterates to reach its goal, and incomplete, because, metaphorically, it's as dynamic as human memory. Figure 4 describes the life cycle as an Activity diagram.

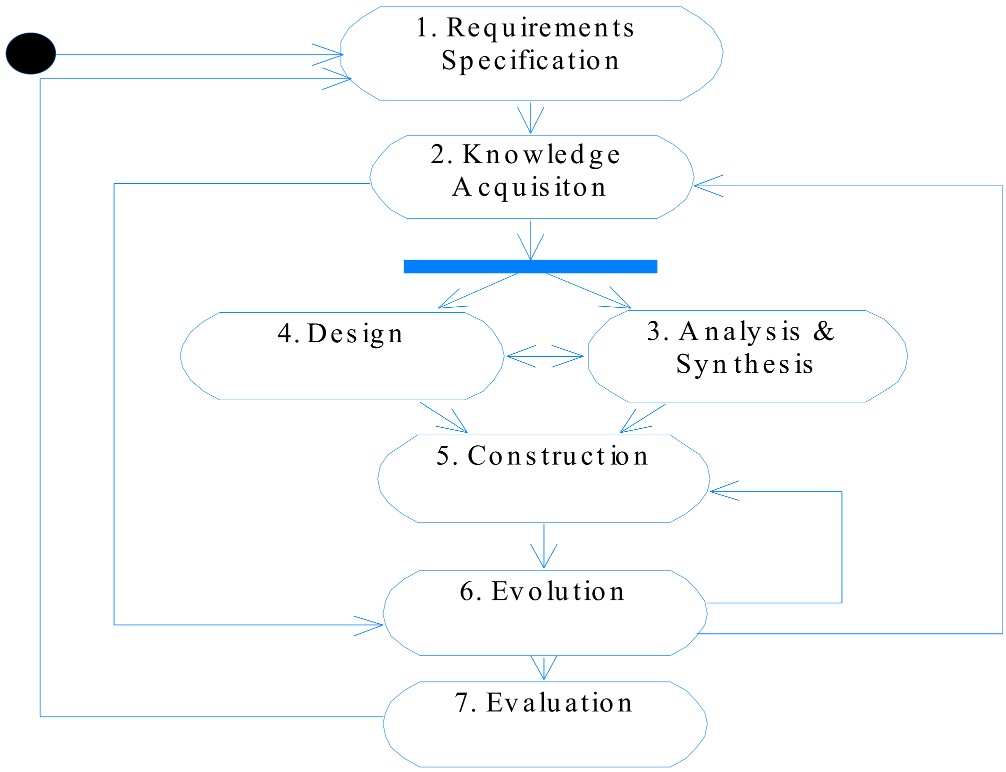

Figure 4: SM life cycle using Activity diagram

5. Evaluation of SM Ontology

Our approach to ontology evaluation concentrates on conceptual coverage. Evaluation of conceptual coverage was conducted on three levels. The first is a theoretical framework of related literature review. The second is a metaphysical frame of reference applied using the Zachman framework (1987) for the evaluation of Information Systems architecture. These two levels were applied to answer the question of completeness with relation to the ontology as a whole. Our claim for conceptual coverage is further supported using a set of ontology design criteria applied to both the individual definition level and ontology upper-level to constitute the third level of the conceptual coverage evaluation.

Additionally, we have applied the SM ontology in several different domains of which the Health Services (HS) example will be herein described.

A methodology of five stages was defined to carry out the case studies: 1. Model presentation and knowledge acquisition, 2. Analysis and documentation, 3. Modeling, 4. Validation, and 5.

Evaluation, of which the organization takes part in two stages (i.e., stages 1, 4). Knowledge acquisition was conducted using a structured questionnaire based on the model entities. It was filled in during interviews with the organizational leading KM practitioners as well as employee representatives.

The evaluation process is described in the following subsections.

5.1. Evaluation of Conceptual Coverage

We started this part of the evaluation by selecting 85 articles in the domain of organizational memory from 1991 onwards. At first we conducted a comprehensive literature review through an exhaustive (though not always inclusive), multidisciplinary literature review (Te'eni and Weinberger 2000). Subjects for literature review were research contributions from Information Systems, Knowledge Management and Organizational Learning, Information Sciences, and Artificial Intelligence research. We used the ontology to represent the concepts presented in these articles.

Several points should be noted before we present the results of this undertaking:

- We did not intend to represent every single concept in these papers but rather focused on selected concepts described herein.
- Some concepts that we found in the literature were not present in the ontology beforehand but could be assigned to higher order classes already in the ontology.
- Some concepts described in the literature were defined here as attributes for reasons described in the previous sections (for example, modeling conventions).
- The concepts surveyed are the core concepts of the domain - they comprise mainly levels 3-5 in the ontology.
- The ontology is comprised of 150 entities, each of which is further described using a set of attributes.

For each publication, we documented the existence of concepts relating to: processes, agents, knowledge and meta-knowledge. We did not include every concept encountered (for example, synonyms – we encountered different concepts used to convey the same meaning).

Having completed the evaluation in reference to the reviewed articles, we turned to the second stage of the conceptual coverage evaluation. The reasons for our selection of concepts are explained using the Zachman Information System architecture evaluation framework, which is a logical structure for classifying and organizing the descriptive representations of a domain that are significant to the management of OM. We will relate here to four ontology evaluation criteria.

- **Completeness** – answers the question: "Does the ontology build a comprehensive description of the domain" (Gomez-Perez 1995).

The positive answer to this question is anchored in three operations: the literature survey described above, the implementation the six evaluation question proposed by Zachman, and the application of a set of ontology evaluation criteria. The framework poses six questions to which the ontology responds:

1. What: what entities exist in OM using a detailed description of model entities (modeled using Class diagrams).
2. How: how the OM functions using a detailed description of model activities (modeled using Use-case diagrams).
3. Where: where model entities are located with relation to other entities.
4. Who: who operates and who uses the entities of the model by describing a set of agents.
5. When: when activities occur by describing sets of development stages and the relationships between them, including priorities.
6. Why: the motivation to perform activities by describing rules, goals and objectives.

- **Granularity –** evaluation of granularity refers to whether or not the upper-level of the ontology reflects the identification of major concepts from the domain. The ontology uses hierarchy to describe the domain, using abstraction and avoiding multiple inheritances. Thus it further supports the claim for conceptual coverage.
- **Competence** – the ontology responds to the question of how to develop an OM, what should be in it, how it should operate and by whom. By doing this, the ontology reaches its goal. Preliminary findings from the HS case study support this claim. The analysis of the case study is done with relation to the SM ontology as previously described. In the figures documenting the HS model, colored areas are used to indicate existent entities.

5.2. HS Case Study

The HS test case represents the major health organization in Israel serving 3.5 million people. It holds hundreds of sub-organizations (e.g., hospitals, clinics, laboratories). It has an EM of internal (e.g., insured people record of treatment) and external (e.g., DSS, BP, LL) resources, Several GM initiatives are underway regarding best practices on several issues, thus support the conversion of tacit knowledge. HS enables (moderated) access to various document forms of external origin (except for elected guides). Pocket Items are made available through communities of practice. An ongoing effort is taken with regard to Knowledge Technology (e.g., expert systems, portals), and forums. The HS Life Cycle activates three stages: requirements specification, construction and ad-hoc inclusion and sharing.

The approach taken towards knowledge sharing culture is supportive, not mandatory. This results in a moderate development of communities of practice – modeled as GMs. Note that GMs rely on professional interests, rather than on organizational units. Although the HS upper-level model expresses the existence of a Life Cycle, its de-facto implementation is partial and thus lacks a cyclic and iterative dimension.

All considered, the HS OM can be described using our SM ontology, as can its future goals (i.e., further development of Types, of "Know-how", etc.). Our initial experience with the HS case study demonstrated the feasibility of our approach to OM evaluation

As mentioned, these are initial examples from the evaluation findings. We believe we have grounds to claim that the model conceptual coverage does have a proof of concept to its goal.

6. Discussion

We have presented the upper-level of the proposed SM ontology and have demonstrated its feasibility. Further research is required regarding detailed definitions and exposure of the lower ontological levels. We believe that the SM ontology can guide the development of SMs but our primary motivation has been to provide a basis for the evaluation of OM. The ontology proposed above can be seen as a desired state of affairs, which can be compared against an actual (or planned) OM. The difference between the two is a measure of the deficiency of the actual system. For example, our encounter with the HS organization showed the relatively meager OM in current use.

OM can be regarded as an information system, but one that consists of knowledge items and therefore should be treated differently. The IM-OM distinction (resulting in the abstraction of SM) is but one example. More generally, the management of knowledge calls for the use of specialized design tools such as ontologies that are embedded in the use of knowledge. These design tools certainly go beyond the traditional notions of database design. Indeed, we have defined a life cycle that supports this view. It guides the development of IM and the transfer of knowledge from IM to OM. Moreover, it defines the need for Meta-Knowledge, which is essential for knowledge sharing and reuse. Thus the comprehensive view introduced and focused by the ontology encourages a more reflective analysis and a more contextualized organization of knowledge, one that is more routed in the life cycle of knowledge management.

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