An Organisational Memory Information System using Ontologies

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Abstract

In the recent years, much has been said about ontologies and their applications in different research fields. The ontological discipline emerged from artificial intelligence as a form of knowledge representation that would minimise the problems of knowledge sharing and reuse between people and between software. Apart from the view that portrays an ontology as a syntactic and semantic standardisation of knowledge structures, other approaches apply this discipline as a means to represent informal and semi-formal data structures. This paper presents ontologies as a design approach to represent organisational knowledge and ultimately to create an Organisational Memory Information System. This approach acknowledges the dynamics of the organizational environments, wherein the traditional design of information systems does not cope adequately with these organizational aspects. Knowledge management practices within the organizations, and the role of domain modelling with ontologies are also discussed in this paper.

Keywords: Organisational Knowledge, Knowledge Management, Information Systems, Organisational Memory, Ontology, Enterprise Modelling and Integration.

1 Introduction

Traditional approaches to the design of enterprise information systems (IS) identifies a need, designs a set of application requirements, and applies software engineering techniques to build and deliver an IS solution. Typically, these solutions are based on existing database management tools, such as online analytical processing tools, data mining techniques, and data warehousing solutions that are often hard to implement and do not integrate easily with existing practices, legacy systems, and changing requirements. Another problem the IS specialist has to face is that when a specific information system is delivered, the organisational model at that time is frequently different from the initial model due to dynamic nature of organisations and changes in the environment.

An approach to tackle these problems is presented in this paper. This approach is based on ontology-driven information systems design. The objective is the creation of a dynamic framework for enterprise modelling and integration. By modelling the domain, one can expect that application requirements can be served as needed, since minimal commitments were made concerning specific uses of the information and knowledge. The vision is to model what we term an organisational memory information system (OMIS) that can be ontologically tailored due to the dynamics that occur in every organisational domain. The IS approach presented in this paper is suitable for knowledge intensive organisations, where tangible and intangible data and information needs to be managed, and where the main concern is to manage the organization's knowledge [Brown 1998, Krogh 1998]. It is also expected that this approach can be adopted to satisfy information needs at the operational, managerial, and strategic level.

The rest of this paper is organized as follows: section 2 discusses knowledge intensive organizations, by characterising their specific needs; section 3 discusses Information Systems design and Knowledge Management; section 4 presents ontology-driven information systems; section 5 presents our proposal of Organizational Memory Information Systems; and in section 6 we close with our concluding remarks.

2 Knowledge Intensive Organisations

Knowledge in an organisation is the collection of expertise, experience, and information that individuals and workgroups use during the execution of their tasks. Organisational knowledge is stored in individual minds, or implicitly encoded in organisational processes, services and systems. Besides labour, capital, and land, knowledge has been recognised as an important productivity factor for organisations [Abecker & Decker 1999].

Solving problems in organisations is a complex, knowledge-based activity. It entails taking decisions in a dynamic environment using different sources of information. In such a dynamic work environment, people increasingly recognise that the management of organisational knowledge is a key factor for business process effectiveness. Knowledge-intensive companies employ highly skilled people, knowledge workers, who are faced with problem-solving tasks using knowledge that needs to be extracted from existing information sources and from other people [Nonaka & Konno 1998].

In the context of a knowledge intensive organisation, knowledge intensive tasks, such as dealing with complexity, uncertainty and abstraction (e.g. recognising patterns of organisational behaviour), involve an effective combination of corporate competencies. Knowledge intensive organisations need to manage their skills efficiently, create mechanisms to elicit innovation, and gather ideas, suggestions and other sources of information to tackle their processes. They often face restructuring and high rates of personnel turnover, which can lead to problems of knowledge retention. Furthermore, the dynamic nature of organisational work in such companies requires rich computer models to support information technology.

The objectives that underlie this quest are the development of more effective practices, the improvement of the business effectiveness, and ultimately to promote group and organisational innovation.

3 IS design and Knowledge Management

The problem of managing knowledge in large companies has grown with the increasing complexity of organisations and the quantity of information that flows within and between organisations. An organisation's knowledge is built upon the experience of their human resources and the lessons they learn. The effective management of this knowledge is a significant challenge.

These problems are addressed by ongoing research in the field of knowledge management [Applehans et al. 1999, Dieng 2000, Lindgren & Wallstrom 2000]. In this context, knowledge management is seen as new dimension in the definition of enterprise information systems. Knowledge management sees knowledge as an asset to be managed and aims to reduce the problems of knowledge sharing and use.

Traditional IS approaches allow the representation of the tangible and relatively static aspects of the organisational domain, such as administrative information, financial information, product and sales details, and customer profiles. The challenge is the representation of the less tangible aspects of the organisation, such as individual and group know-how, accumulated expertise, professional experience and related heuristics [Kimble et al. 2001]. The representation and manipulation of these highly dynamic aspects of the organisation requires a semantic-rich approach with short development cycles to allow a constant evolution and IS redefinition [Macintosh et al. 1998].

4 Ontology-driven information systems

Ontology-driven information systems is a trend in current research that envisions the development of information systems where domain experts, knowledge and software engineers, and ontologists (ontology's experts) work together in the definition of domain and general ontologies to support organisational processes [Guarino 1998]. Ontological tasks, such as mapping among ontologies, merging ontologies, creating domain taxonomies, and classification systems should be co-ordinated to define and maintain an high-level representation of the organisational knowledge [Noy et al. 2000].

4.1 Ontologies

The term ‘Ontology’ has its origins in metaphysics and philosophy. In this context, ontology is used to explain the nature of the reality. In computer science, there are at least a dozen of definitions of ontologies in the literature (e.g. see [Uschold & Gruninger 1998]). One of the most recent ones states that an ontology provides the skeletal knowledge and an infrastructure for integrating knowledge bases at the knowledge level, independent of particular implementations [Fensel 2000]. This definition assumes a particular importance in this research in terms of the necessary mechanisms to represent, share, and reuse the existing organisational memories.

4.1.1 Ontology definition

A consensual definition of an ontology states that it is a high level formal specification of certain knowledge domain: *a formal and explicit specification of a shared conceptualisation* [Gruber 1993]. A domain conceptualisation is a particular and abstract view about real entities and events and their relationships. Formal refers to the fact that an ontology is a form of knowledge representation and has a formal software specification to represent such conceptualisations, i.e. an ontology has to be machine readable. Explicit means that all types of primitives, concepts, and constraints used in the ontology specification are explicitly defined. Finally, shared means that the knowledge embedded in ontologies is a form of consensual knowledge [Benjamins et al. 1998], that is, it is not related to an individual, but accepted by a group.

4.1.2 Ontology semantics

Ontologies provide syntactic and semantic terms for describing knowledge about a domain. Although differences exist between ontologies, general agreement exists about several issues related with the structure and behaviour of real world objects [Chandrasekaran et al. 1999]:

- There are *objects* in the world
- Objects have *properties* or *attributes* that can take *values*, i.e. they can be represented as triplets (Object –> Attribute –> Value)

- Objects can exist in various *relations* with each other
- Properties and relations can change over *time*
- *Events* occur at different *time instants*
- There are *processes* that occur over time in which objects participate
- The world and its objects can be in different *states*
- Events can cause other events or states as *effects*
- Objects can have *parts*

The following figure shows an example of a formal object definition using Ontolingua, a language and environment for creating ontologies [Farquhar 1996]:

```
{;;; class
(Define-Class class (?class)
"documentation"
[:def
(and
        {(superclass ?class)}
        [(Individual ?class)]
        [(Superclass-Of {subclass})]
        [(Has-Instance ?class {instance})]
        [{(Has-At-Most ?class relation max_cardinality)
        (>=Value-Cardinality ?class relation min_cadinality) |
        (Has-One ?class relation) |
        (Has-Some ?class relation)]}0^n)]
[:axiom-def (Exhaustive-Subclass-Partition class
                        (Setof {subclass}1^n))])}1^n
```

Figure 1: An example object definition

4.1.3 Ontologies and Semantic Networks

An ontology can also be seen as a domain representation in the form of a semantic network [Weinstein & Birmingham 1999]. The nodes are concepts or entities, and the arcs represent relationships or associations among the concepts. This ontological network is augmented by logic axioms, which represent a set of attributes, functions, relations, constraints and rules that specify the structure of the concepts and the representation of their behaviour. In this ontological network, the concepts are categorised and classified in taxonomies through which inheritance mechanisms can be applied. Some of the work in this area is influenced by Artificial Intelligence techniques [O'Leary 1998].

4.2 Information vs. Knowledge Systems

In the current organisational environments, where downsizing, reengineering, restructuring and high rates of organisational turnover are common, enterprises are beginning to find that it is easy to loose a vital element of their intellectual property: shared corporate knowledge. Knowledge gained during the normal execution of daily tasks is often lost in the dynamic business environment. Those who stay in the company are often unaware of key resources that are 'hidden' in the heterogeneous knowledge repositories [Dzbor et al. 2000], but that depend on a particular expertise to be found and used; technical knowledge is often an example of how dependent information systems are on the expertise of the people using them.

As people transform data, information and past experience into effective corporate knowledge, the management of individual competencies will become more important in knowledge-based firms [Michellone & Zollo 2000]. According to Bahrami (1996), developing versatile employees and leveraging their capabilities and competencies in order to cope with different corporate needs is a matter of pivotal importance for knowledge intensive companies. The employees' competencies in the form of technical and cognitive capabilities mainly affect the organisation's knowledge creation ability [Curtis et al. 1995, Curtis et al. 1997].

Based on these knowledge resources, this research will show that an organisational information system can be dynamically developed both by IS specialists and with IS users in order to achieve an organisational knowledge system (or organisational memory information system). In order to apply and preserve the organisational workforce capability in the dynamic evolution of organisational information systems, this paper presents an ontology-driven approach. IS designers along with IS users should use effective ontological tools to develop and adapt the organisational domain to their needs.

5 Organisational Memory Information Systems

The notion of organisational, or corporate, memory (OM) focuses on the persistence and maintenance of knowledge in an organisation [Heijst et al. 1997]. The metaphorical view of an OM claims an infinite storage, retrieval, and distribution of organisational knowledge [Ackerman 1994]. In its simplest and computational view, an OM is seen as a mechanism that enables the continuous storage and manipulation of organisational knowledge. Relevant pieces of knowledge that are assumed to contribute to the performance of an organisation could, and should, be stored in the OM. Some knowledge-based features are summarised below:

- The ability to store dispersed and unstructured corporate knowledge, such as corporate competencies characteristics, project experiences, and documents contextual knowledge.
- The ability to semi-automatically assist user queries and support related decision making tasks by providing a guidance structure based on proposing hints and alternatives, showing the reasons 'why' and 'why not', or presenting future perspectives on existing information;
- The ability to perform context-based information retrieval, presenting contextual (or situational) knowledge about information sources, and assisting the execution of business and problem solving tasks;
- The ability to perform reasoning upon the conceptual structure (e.g., based on ontological descriptions) and its particular instantiation in order to categorise (create) and classify new corporate knowledge assets.

Figure 2 shows a schematic view of an Organizational Memory.

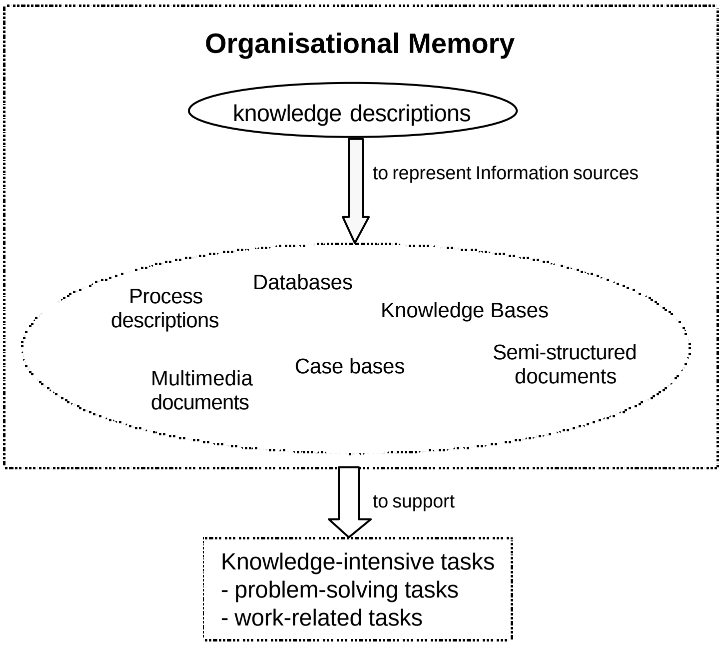

Figure 2: Organisational Memory overview

Organisational memories should comprise the knowledge of an organisation collected over the time [Klemke 2000]. It includes a model to describe information sources and the context in which these sources are created. It also includes factual, declarative, and procedural knowledge in the form of personal memories of employees: e.g. their knowledge, heuristics, experiences and related expertise.

The information stored in an OM should be useful, addressing important needs in the organisation, where its members retrieve relevant knowledge about ongoing activities. This organisational memory itself should be accessible to all members. To make an OM effective, its building, development, and maintenance need to be closely integrated with the existing business tasks and related daily work steps, and consequently with the overall organisation culture.

Organisational knowledge may consist of problem-solving expertise, experiences of human resources, process experiences, technical aspects, and related lessons learned. The coherent integration of this dispersed organisational knowledge in a single computer system is called an OM information system, or OM for short, and it is regarded as a central prerequisite for effective corporate KM [Abecker et al. 1997]. In this paper, an OM Information System (OMIS) is seen as a natural evolution of an organisational IS, wherein tangible information (such as administrative data) is integrated with less tangible knowledge (such as people's competencies, as in [Liao et al. 1999]). Figure 3 shows a layered architecture of an OMIS.

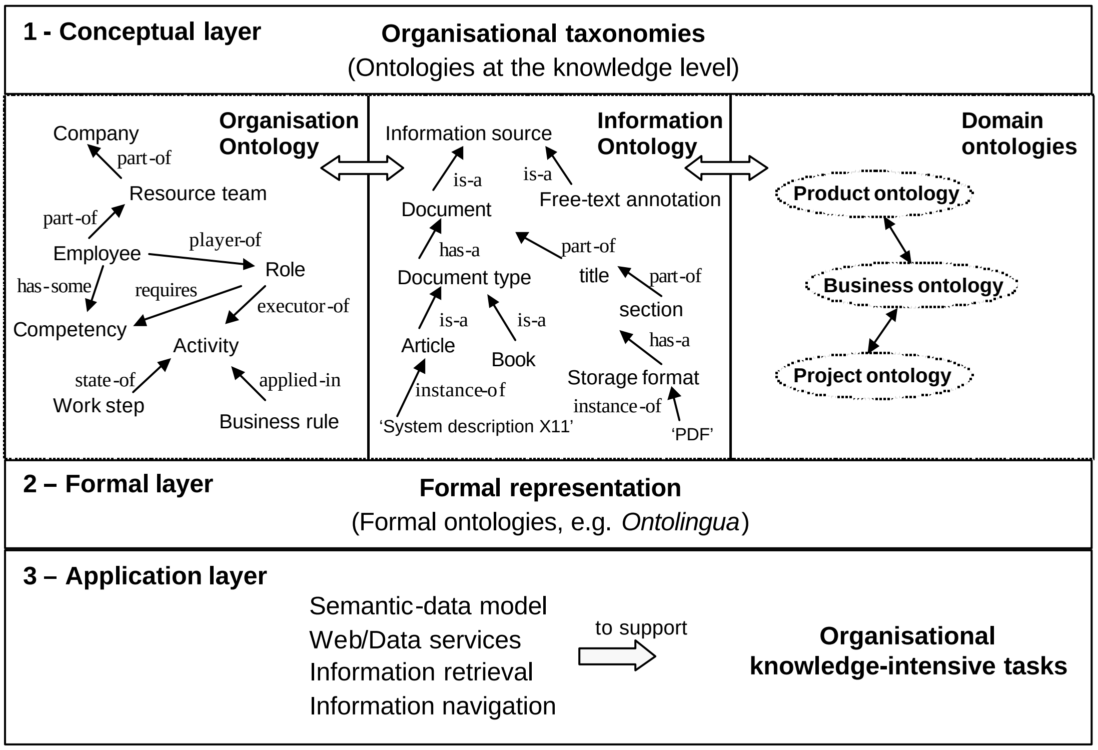

Figure 3: Layers of an Organisational Memory

The layers of an Organizational Memory are interpreted as follows. The conceptual layer (layer 1) represents the organisational knowledge in an informal way which can be interpreted by different OM developers, such as domain experts, knowledge engineers, and software engineers. This layer aims to create a shared understanding of the organisational knowledge. The creation of a common vocabulary facilitates communication in design and maintenance issues across people with different professional backgrounds. In the figure, this layer is made of domain and general ontologies. For example, the Information and the Organisation ontologies can be reused in several domains, since the concepts they define are likely to be used almost universally.

The formal layer (layer 2) enables the reuse of domain terms and constructs from other ontologies in order to facilitate future OM system maintenance tasks. The ontological descriptions provide a common vocabulary for knowledge engineers in order to develop further applications in this domain, such as an inference layer and the related reasoning mechanisms. This layer is essentially a format layer, where translators to multiple languages and environments can be hooked.

The application layer (layer 3) uses the encoded domain knowledge. The knowledge encoded with ontologies can be used in different application systems within an organization. This layer is the interface with the users, and can be tailored to different needs; as it is independent of a particular syntax and application model, changes at the previous layers do not have much impact at this layer.

5.1 The definition of a meta-model

In a previous OMIS implementation [Vasconcelos at al. 2001] the interface of the application layer is semi-automatically generated "on the fly", presenting the user with a standard Web page. The main goal is the definition of a unified meta-model for building organisational memories, and to allow for particular instantiations.

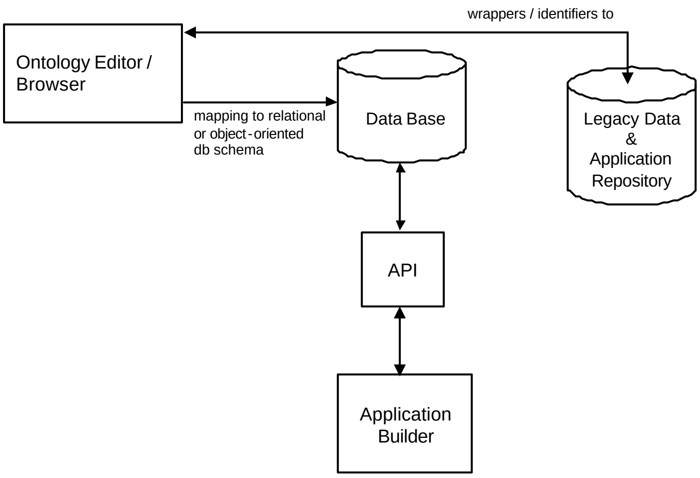

Figure 4: Ontology development environment

The integration of ontologies (formal knowledge) with data models (semi-formal knowledge) can have major benefits for the definition of precise and concise domain models. This OMIS development environment (figure 4) includes an ontological editor to specify and manage the OM ontology library. Using such an editor, the goal is to develop ontologies at the knowledge and formal levels to assist in effective data model design. This OM architecture should also include an automatic or semi-automatic tool, based on exhaustive mapping criteria, to translate ontological constructs and instances into the proper data model elements whenever possible. The creation of this meta-model is a key requirement for the effective maintenance of an OM.

In our current development environment, ontologies are translated and stored in a relational database, as tables. A set of functions was written as an Application Programming Interface that hides the relational/object conversion from the programmer. By modifying the meta-model it is possible to tailor the development environment to different needs, such as, for example, having two meta-class *class* types: one where instances are created locally (local classes), and another which refers to remote instances (remote classes), which could be located in legacy systems.

5.2 Organisational memory specification and architecture

The preservation and integration of different but related organisational knowledge is a key requirement for an effective development of organisational memories. Different knowledge areas within the organisation should be properly classified and integrated (see figure 5).

An OM should provide means to preserve and integrate organisational information from different organisational sources. The OM design and development should be prepared to handle different types of information and related levels of information representation [Abecker et al. 1998]. Therefore, semi-structured information, structured information, and formal information need to be integrated in a coherent way. Examples of semi-structured information are file documents in the form of notes, suggestions, and hints. Examples of structured information are file documents in the form of manuals and technical reports. Additionally, the existing data stored in databases and data warehouses can be viewed as a particular type of structured information. Examples of formal information are business rules, design and process guidelines, and corporate information that represent internal (organisation) rules and procedures concerning business processes and organisational behaviour [Vasconcelos et al. 2001].

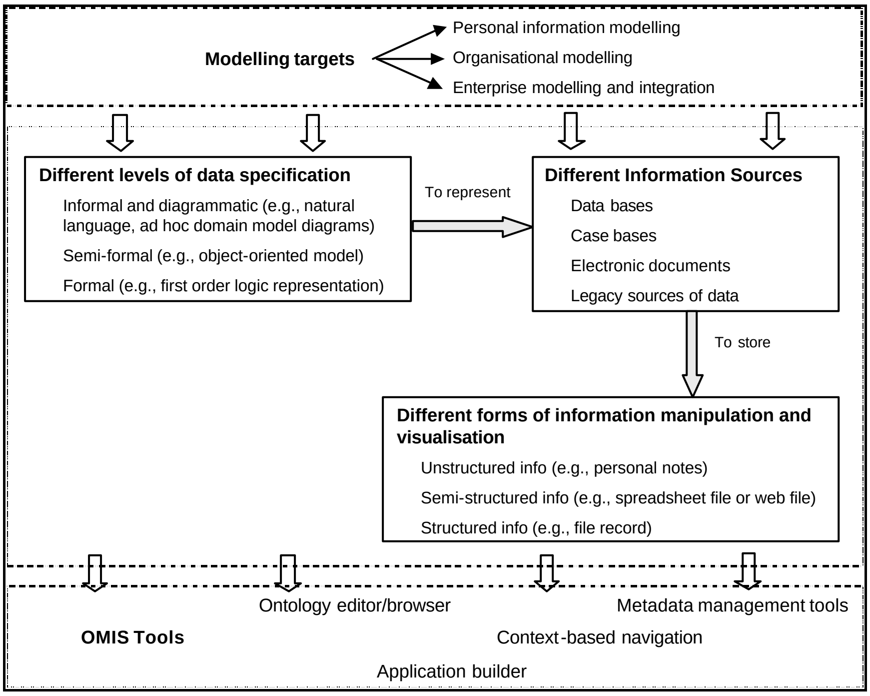

Figure 5: OM specification and architecture overview

In addition to the integration level of organisational information, an OM should be engineered in order to be integrated with the existing organisational environment. An OM system should have an architecture suitable to be integrated with the existing IS infrastructure, i.e., it has to fit into the flow of information that is already happening in the organisation [Conklin 1996]. This requirement is crucial for the acceptance of the users of the OM system.

6 Final remarks

In this paper we have presented an approach to the development of enterprise information systems based on ontologies. The emphasis of the approach is on modelling the domain, rather than the applications that are needed, since the domain model should be 1) more stable over time as the domain information is less likely to change frequently, 2) independent of the particular users' requirements in a given period.

We tested this approach by designing and developing an organizational memory for a telecom equipment manufacturer, a case where employee's competencies and know-how were the key for successful performance of the company. Among the experience we gathered, the following deserves a mention: 1) short system development cycles are a key issues in dynamic and competitive environments; 2) user needs as managers of information change, but the information design itself doesn't so often; 3) simple project goals, and low initial commitment on early design stages contributed significantly to the success of the organizational memory development; 4) and finally, integration with existing data sources and legacy applications is mandatory.

The next step in our project will be the development of standard ontology libraries which can be used in several domains, and the development of generic task and process ontology libraries which will let developers of enterprise information systems quickly adapt to specific domains by reusing existing designs. We believe that non-transactional information systems, such as organizational memories, will be based on the kind of models we described in this paper.

This research is a step forward in the development of organisational memories integrating formal and semi-formal notations. However, an effective integration of ontologies and data models in a unified meta-model is subject of further research and so is considered a future research endeavour.

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