Reasoning in corporate memory systems: a case study of group competencies

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Abstract:

Organisations with significant intellectual capital must create an environment that facilitates better reuse and deployment of existing corporate knowledge in decision-making processes. Advances in information technologies and telecommunications and emerging trends in knowledge management and organisational memories, are enhancing the ability of people to communicate and co-ordinate among business processes. In order to categorise and classify such organisational knowledge for future reuse, appropriate tools must be developed. The practical result of this research work is the design and implementation of a group memory system to manage heterogeneous and distributed knowledge embedded in business process activities. The emphasis of this paper will be on the representation and reasoning upon organisational processes in order to provide an integrated enterprise vision to allow an efficient management of corporate competencies. The proposed group memory was designed using an ontology-based model of a domain specific business process and related individual and group competence elements. Examples to illustrate the application of such group memory system in a real organisational setting are provided.

The theoretical support for this research involves aspects of knowledge management, knowledge modelling, organisational memories, and ontologies. The emphasis of this research work relies in the design and development of reasoning facilities in corporate memory systems. The corporate competencies are analysed at the individual and group level within the organisation. The group memory system (GMS) is interpreted as an instantiation of a corporate memory system where a specific organisational group and their business processes are being investigated.

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Knowledge based-systems (KBS) are nowadays part of discussions of the potential value of information and communication technology for KM [Hendriks 1999]. The KBS approach of this research work focuses on knowledge modelling and for the purpose of this paper KBSs are defined as systems that capture conceptual structures and their behaviour with some form of knowledge representation formalism. In other words, the KBS effectiveness depends on the degree in which knowledge is successful modelled in its knowledge base. In this context, ontologies (section 3) are the underlying knowledge representation formalism that is being used to model the organisational domain in analysis.

The main difference between a traditional database management system and a system that can be mentioned as knowledge-based is an additional inference layer that must be incorporated. For the purpose of this paper, the proposed inference mechanisms will assist specific corporate activities in the competence management context. Such inference layer will assist semi-automatically a systematic categorisation and classification of individual and group competencies including their levels of granularity. Underlying this hierarchy of competencies and the related project experiences, competence gaps can be identified within the organisation. In this context, the proposed GMS are being developed in order to enhance competence management activities.

Although the theoretical foundations for this research work are multidisciplinary, involving aspects of knowledge representation and ontologies, knowledge management and organisational memories, process modelling, and design rationale [Vasconcelos et al. 2000], the bulk of this paper will be a report on, and analysis of, the ongoing development of the prototype GMS system. A case study is presented centred on business process and activities of knowledge workers, such as project managers and requirement engineers, where background knowledge is distributed across the whole company.

1. Corporate competence management

KM has a long way until it reaches some consensus within the scientific community. Hence, in the context of this research work, KM is related with the organisational value of knowledge and it is interpreted as a cross-disciplinary research field where several theoretical and practical notions are incorporated.

The application area of this research work is related with the management of organisational competencies. A competency is taken to mean a characteristic of an individual or group that is required to produce an effective organisational performance. That is, competency is related to the underlying knowledge and skills needed to perform a role within an organisation. According to [Nonaka 1994] the core competencies of an organisation include tacit and explicit knowledge, and should be conceived of as a mix of skills and technologies. In this context, the concepts of knowledge and competence are closely related [Lindgren 2000].

A seminal reference in competence management is the *People Capability Maturity Model* released by the *Software Engineering Institute* [Curtis et al. 1995]. This model was initially designed to help software organisations to focus on the improvement of the capability of their workforces [Curtis et al. 97]. Corporate maturity in the people capability maturity model represents an organisation's ability to improve the knowledge, competencies, and related skills of its workforce and align performance with the organisation's business objectives.

1.1. The Knowledge Management Approach

Several views of knowledge have been explored in Knowledge Management (KM) literature, most of them in the form of opposites, e.g. tacit/explicit [Nonaka and Konno 1998]; know-what/know-how [Brown and Duguid 1998], cognitivist/constructionist [Krogh 1998]. Kimble et al [Kimble et al. 2001] differentiate between 'hard' and 'soft' knowledge stressing that these should not be seen as mutually exclusive opposites but as two parts of a duality. That is all knowledge is to some degree both hard and soft.

This paper takes a predominantly 'hard' view of KM, that is that KM is principally concerned with acquiring, structuring, maintaining, and disseminating knowledge across the organisation [Applehans et al. 1999], [Macintosh et al. 1998]. This viewpoint addresses the managing of knowledge from the perspective of Knowledge as an asset of a business organisation, and relates the management of business knowledge assets to business processes and objectives in order to enhance the corporate competence management (CM) activities.

1.2. Features missing in existing KM systems

In existing enterprise KM systems significant functions are missing [Lindgren 2000 and Wallstrom 2000]. For example, at the corporate CM level, the applications can be described as traditional human resource systems, complemented with features that store competencies. Other CM approaches are using simple skill databases with keyword text facilities. In order to achieve higher levels of modelling expressiveness, we are using ontologies as the conceptual layer of specification for representing and manipulating corporate competence tasks.

As for almost any business organisation, looking for experienced people with specific expertise and skills is a perennial problem for the case study company,. In the context of knowledge, management, individual and group competencies of experienced employees are one of the most important knowledge assets of knowledge-work oriented enterprises [Liao et al. 1999]. The competence management approach sees personal competencies of employees as an important knowledge resource in the group memory. In this context, competence elements are to be modelled and retrieved like other knowledge assets of the group memory.

One idea of this research is the adaptation of some principles of the capability maturity model and as other studies and research projects in the CM area [Lindgren and Wallstrom 2000], [Liao et al. 1999], [Lang & Pigneur 1999] to the GMS framework. To this end, we have established an architecture for a group memory system and specific organisational evolutionary tasks in order that a company might manage its employees' competencies in a more efficient and effective way.

2. Ontologies as the form of knowledge representation

Ontologies are formal theories supporting knowledge sharing and reuse mechanisms [cf. CYC (Lenat 1995), *Ontolingua* (Farquhar et al 1996)]. The ontological discipline promotes the reuse of knowledge structures in the form of ontology libraries. The main objective of an ontological library is the description of consensual knowledge related with several knowledge domains. A typical example of such library is the *Ontolingua Library* from the Knowledge Systems Laboratory in the University of Stanford.

Ontologies provide a shared and common understanding of a domain in order to facilitate the communication between people and applications systems [Uschold and Gruninger 1996]. In

this sense, this paper discusses the role that ontologies play in corporate competence management. In this context, the major reason for their choice is that formal ontologies provide a way of sharing and reusing knowledge among people and heterogeneous application systems [O'Leary 1998], [Abecker et al. 1998].

Ontologies can be used to explicitly represent the semantics of semi-structured information, i.e. an ontology provides an explicit conceptualisation (meta-information) that describe the semantic of the domain data in analysis [Abecker et al. 1998], [Fensel 2000]. Ontologies have a similar function as a semantic data model, such as a conceptual data schema, but are a more expressive way of information modelling. The main differences between a conceptual data schema and an Ontology are [Meersman 1999]:

- A language for defining ontologies is syntactically and semantically richer than common approaches for database schemas;
- The information described by an ontology can be presented in different levels of formalisation: using a semantic network notation, semi-structured natural language, and formal definitions including logic axioms. Most of the conceptual data schemas are just tabular information.
- An ontology uses a shared and consensual terminology which makes it suitable for information sharing and reuse.
- An ontology provides formal definitions to describe the semantics of the representational constructs, i.e., all the terms used in the ontology specification are explicitly defined.

2.1. Ontology definition

An ontology 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 domain 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 with the individual, but accepted by a group.

2.2. Ontology semantics

Ontologies provide syntactic and semantic terms for describing knowledge about a domain. Although differences exist within 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*

2.3. Ontologies and Semantic Networks

An ontology can be seen as a domain representation in the form of a semantic network. 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.

2.4. Ontology Development Environment

An ontological development tool, *Protégé-2000* [Noy et al. 2000], was chosen to represent the domain knowledge in analysis. The model of this knowledge representation tool is frame-based. The *Protégé* ontology consists of classes, slots, facets, and axioms. Classes are concepts of the domain in analysis, slots describe proprieties or attributes of classes and its instances, facets describe proprieties of slots, and axioms specify additional constraints.

This ontological design environment has been used as a knowledge representation tool in order to define effectively the conceptual design layer of the GMS framework. Towards the GMS prototype development, the ontological descriptions are being mapped in other design layer, an object-relational schema (figure 1). To maintain the expressiveness of the ontological descriptions, a set of mapping criteria is being applied to enable the transition between the ontological design layer into a semantic data model.

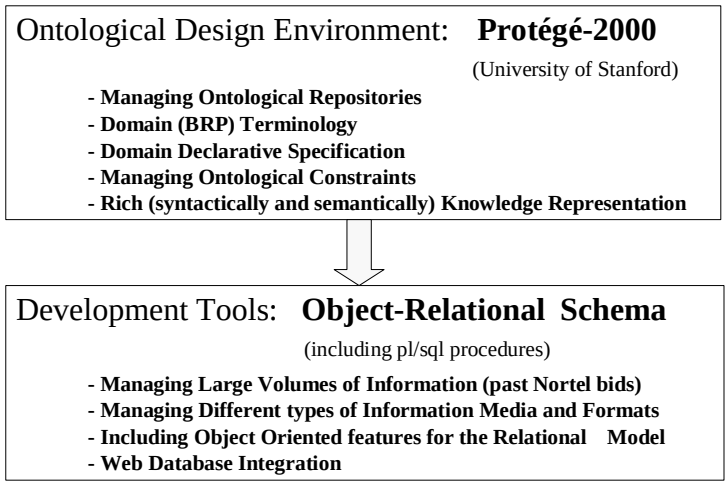

Figure 1: Mapping overview between the ontological descriptions and a conceptual schema.

2. case study: a business process

In order to evaluate the feasibility of this approach, the GMS is being developed and applied in a real organisational setting, a multinational telecommunications company. This company designs, produces and commercialises a variety of telecommunication products and network solutions worldwide.

The underlying case study to support this research approach is centred on the business process activities of knowledge workers such as project managers or requirement engineers. Specifically, the case study addresses a company domain problem in the competitive bidding area: the Bid Response Process (BRP). The work in this organisational setting requires a large amount of background knowledge that is distributed across the whole company.

A process is interpreted as a sequence of activities performed for a given purpose. Activities include all the work that is done to perform the tasks of an organisational unit. The description of an activity includes the tasks, roles, competencies, and necessary procedures to perform such activity. For example, in the case study, the objective of the BRP is the production of an efficient and effective answer to the customer that have asked for a specific bid. The initial customer bid may contain several requirements, such as technical, legal, pricing, national and international standards and regulations, among others compose. Between the initial bid and the final response there exists a set of team interactions, a set of complex interdependent activities, all of which determines the outcome. The BRP will involve many different actors, artefacts, and activities; during the bid response process, several project teams work together in order to find effective answers to the different customer requirements.

This case study will help the evaluation and validation of this research approach according to the actual needs of a large corporation in terms of knowledge and competence management. The results of this work might be used in deriving new trends and techniques in corporate competence management.

3. A Group Memory System for Competence Management

3.1. Group Memory System overview

The GMS described in this paper is related to a specific business process with an associated project team. Following the identification of relevant knowledge, people, processes, and organisational units, the aim is to develop a practical representation or structure to store that knowledge. The group memory is seen as a complex, distributed, and occasionally overlaid set of necessary organisational elements to execute a business process, such as the human actors in terms of their individual and group knowledge, and the used artefacts and their states embedded in the different activities.

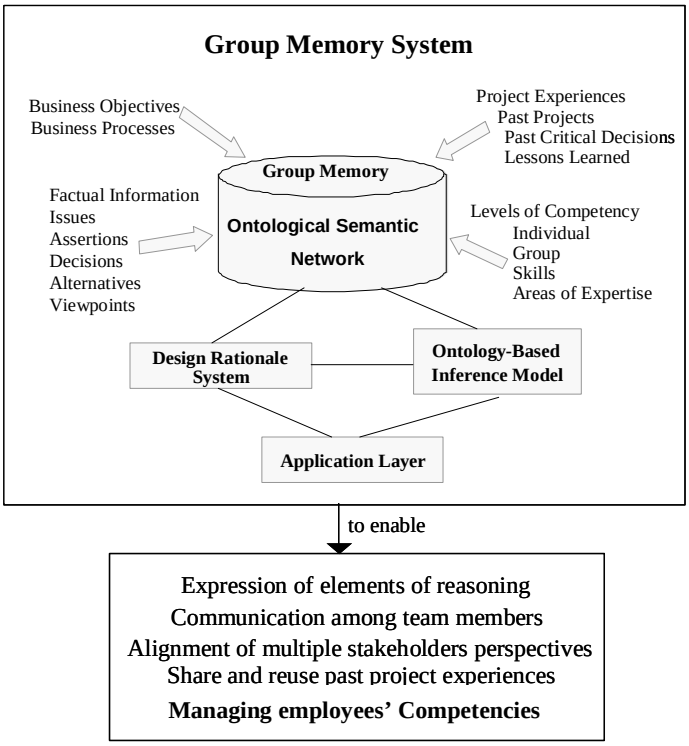

Figure 2- The group memory system: an overview

Figure 2 above gives an overview of the GMS. The high-level layer of this framework is based on Ontologies, i.e. an ontological semantic network that will represent the underlying domain knowledge in the organisational processes. A design rationale system will capture and manage employee's rational elements, such assertions, arguments, positions, decisions or alternatives. Reasoning procedures will be provided by using an ontology-based inference model. A network access model and the related interface will provide the employees of the organisation with a view of the collaborative (group) knowledge.

3.2. Competence Ontology

The competence ontology aims to create a consensual structure of competencies within the organisational group. According a multiple case study developed by [Lindgren and Wallstrom 2000], this task presents some difficulties at the corporate level, concerning the approach of creating a specific (and consensual) structure of competencies. For this reason, the proposed competence ontology should have a set of representative high-level terms and should allow a dynamic evolution of its structure.

In the case study, the competence ontology (figure 3) represents the knowledge and skills needed within the workplace to perform important business functions of the organisation. A competency can be stated at a very abstract level. In this way, competencies can be decomposed to more granular capabilities (or competencies), such as competencies in designing network solutions, or writing product technical documentation. A competency can also be decomposed in the skills required to perform the business processes underlying the business function for which the competency is maintained.

The ontology approach that is being used in this research is based on a (ontological) semantic network level with the related frame description elements. Two abstraction mechanisms will be represented in a standard manner: generalisation / specialisation (*is-a*) with multiple inheritance and decomposition hierarchies (*part-of* aggregations). Other structural links representing associations, dependencies, and other relationship definitions relies on the domain specific modelling process.

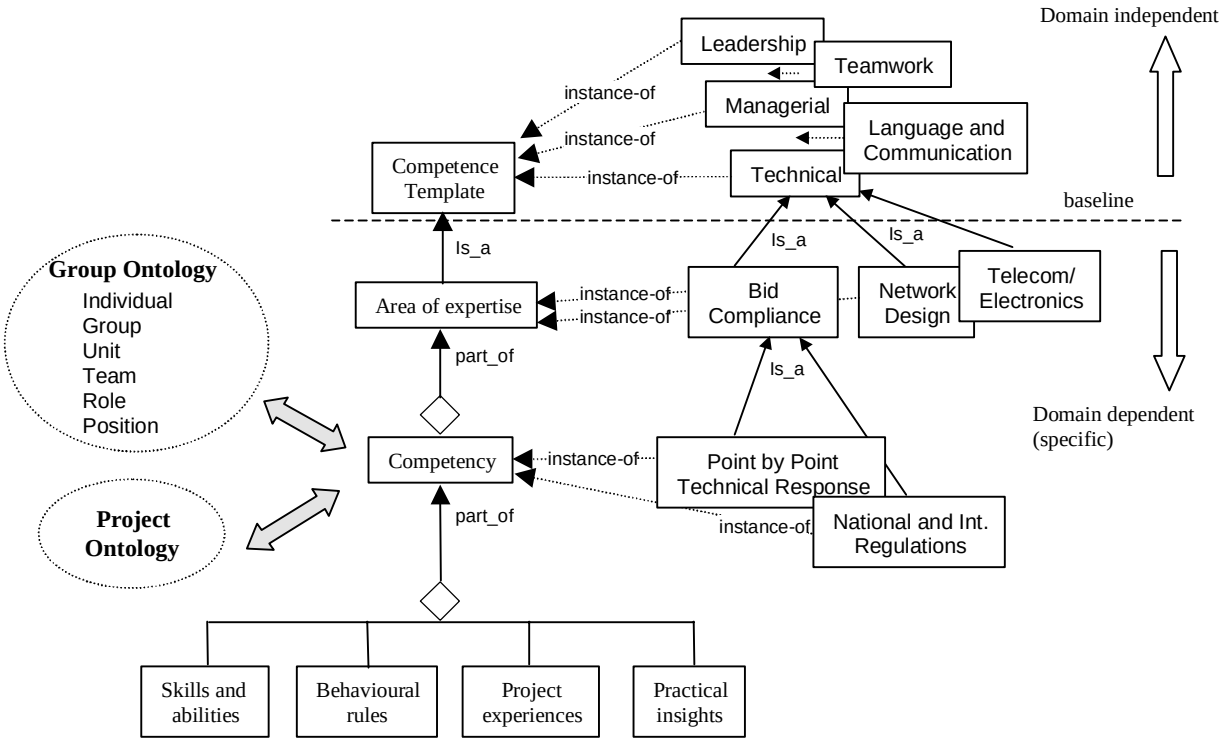

Figure 3 – A part of the competence ontology

3.3. An Inference Model for Managing Group Competencies

Corporate competencies are dynamic, created by technical or organisational needs, people evolution, and by (what is very important) group of people. Due the GMS and its application area of corporate competence management, an individual or group competency is interpreted as a mean to provide an answer to a problem-solving task, such as a technical need. A competence gap is interpreted as a lack of expertise within a specific business process, such as a cluster of technical needs without a prompt answer provided. In the context of the case study in analysis, a competence gap can be stated as a well-defined corporate problem, such as a cluster of technical specifications that are non compliant (or partially compliant) to a certain product or a cluster of products that are not compliant to a certain technical specification.

The proposed GMS is being designed upon an ontology-based model of domain specific business processes and the related individual and group competence elements. This ontology-based approach allows the definition of formal elements of a domain specific ontology. In the context of the previous competence ontology, the domain specific GMS application prototype is intended to provide some reasoning mechanisms, such as the following inferences:

- finding knowledgeable organisational employees needed for company problem-solving tasks;
- routing information needs to knowledgeable people.
- define new competence templates based on project experiences;
- define new competence evolution schemas based on project experiences.
- competency-based practices, such as the semi-automatic identification of competence gaps and its classification. The GMS prototype is being developed to assist the project member (user) through the following steps:
  - Identifying and describing a lack of specific expertise;
  - Providing a set of guidelines to assist the user in such problem-solving task;
  - When possible, giving the solution for the problem (competence gap) reusing past project (bid) experiences and related technical information; and
  - If necessary (and agreed by the project member), a new competency element and its description can be classified in the existing hierarchy of competencies.

These inference mechanisms are thus used to dynamically update the GMS ontologies. We envisage that a user interacts with the GMS in a semi-formal way, where semi-formal queries are translated into formal system commands. The translation is guided by heuristics that specify interpretations for terms used in the query that may have different meanings dependent on the project context. These heuristics can be user-defined or can be inferred from interaction with the user. Algorithms for this task are currently under development.

4. The group memory system Prototype

The GMS prototype implementation is based on a component application architecture where different software layers need to be developed to create the GMS Intranet Application (figure 4). The first layer deals with the user interface through the use of a web browser. The web server is based on the Oracle web server technology to allow the connection between the business logic procedures (stored in the application server) and the user interface application. At the lower level of this software architecture is the database server that provides the necessary data storage and manipulation services.

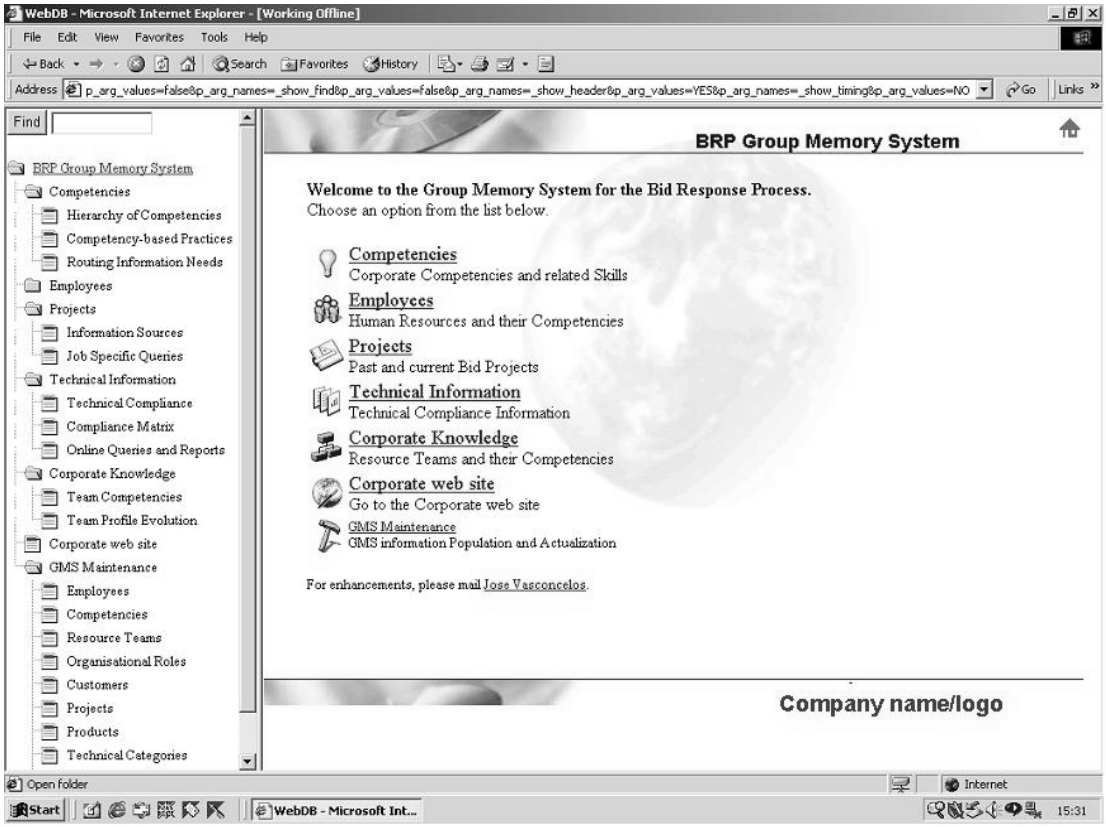

Figure 4: A snapshot of group memory system for the bid response process.

The intranet access model provides a view of the group knowledge that is embedded in the ongoing business processes. The GMS facilitates the access to different sources of organisational knowledge such as individual and group competencies, information sources, such as technical information, past and current bids and their status. The GMS prototype is being developed to provide personalised and consistent mechanism for navigation and intelligent searching. Procedures such as registration, subscription, and broadcasting will be used to enable knowledge capture and dissemination among the project team members.

Reasoning procedures are under development in order to assist some organisational activities. The semi-automatic inference mechanisms will be provided in order to enhance the knowledge development cycle, namely the dynamic creation and application of new corporate knowledge assets.

5. Conclusions and Future Work

To develop effective knowledge management systems, it is becoming essential the definition of shared and common domain structures in the form of organisational memories or shared information spaces. In this context, ontologies are an essential asset in knowledge representation, to describe both the structure and the behaviour of unstructured and semi-structured information.

We envisage the application of the proposed GMS architecture in other business processes within the organisation towards a more comprehensive organisational memory system. As

further research development in order to test and validate this approach, the group memory system as a theoretical concept will have a more coherent result from the current studies within the organisational field setting. Reasoning procedures to assist specific business activities at the competence management level are currently under development. It is expected that complex activities, such as bid compliance and response tasks, involving different people from different departments, geographical locations, and technical background, would benefit from access to such a group memory system.

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