

A Multi-Aspect Architecture with Co-alignment between Layers for Intra-Organizational Knowledge Networking Purposes

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Abstract-In this paper, architecture is proposed for the new emerging concept of knowledge networks. This architecture is based on a multi-aspect view to the problem of starting such a network in an organization. By integrating infrastructure, knowledge and business layers mounted on two aspects of human-based and organizational supportive conditions in a layered architecture, we proposed a novel architecture that contains intra-layer built-in assessment mechanisms as well. These assessment mechanisms ensure the gradual refinement of the network as the structure of each layer becomes fixed. In this paper, it has been discussed that how a multi-layer architecture with minimum amount of dependency among layers (that has the ability of interaction in business and knowledge layers) may facilitate knowledge management processes. The architecture can also give some guidelines on how to start such networks in inter-organizational level. One of the main applications of this architecture is to propose appropriate guidelines for the development of required sub-systems of intra-organizational knowledge networks. Therefore, at the end of this paper, the method of extracting these guidelines on the establishment of one of the key sub-systems for managing explicit organizational knowledge (e.g. Document Management system) is explained in details. These recommendations are based on a well-known standard of this domain. As the proposed extraction method is originated from the layers independency and self-assessment mechanism between layers, it can purposefully be re-used for collaboration/experience/process management systems as well.

Keywords- Architecture, Knowledge Network, Knowledge Management, Business Strategies

I. INTRODUCTION

Knowledge has been identified as the most important source of competitive advantage by modern organizations. However, the key to obtain this advantage is not in the administration of existing knowledge. Actually, it is believed that the ability is related to constantly generate new knowledge thus to move on to new products and services. Therefore, it is strongly believed that at least two aspects are crucial about knowledge management in an organization [1]. First, knowledge management should comprise a unified view of knowledge which is the integration of both explicit and implicit knowledge. Second, knowledge management should take the former view on where and how knowledge is being created and transferred. So, an integrated approach that includes both, explicit and implicit (tacit) knowledge is a need. However, as the implicit knowledge is deeply rooted in personal experiences, internal insights and communication, dealing with it is really difficult. Moreover, to realize this integrated scheme, we may look at managing knowledge—mainly creation and transfer—to occur in the context of architecture, rather than in a traditional organizational perspective. Since we believe this architecture perspective is the key for the future of knowledge management, an integrated view of what we call knowledge networking in an architectural perspective is conceptualized in this paper. By a multi-aspect architecture, we try to emphasize on the following issues; (i) every aspect of organization should be affected by the knowledge network, and (ii) the knowledge network would better be used in a wide range of organizations.

Here, *knowledge networks (KN)* may be defined as social networks between knowledge players, which allow the creation and transfer of knowledge from individuals to the groups. A knowledge network represents a number of people, resources, and the relationships among them, which are assembled to accumulate and use knowledge, primarily through knowledge creation and transfer processes, for the ultimate purpose of creating value [2]. Obviously, this social network is supported by ICT infrastructure. Knowledge network is actually an instance of organizational environment in which knowledge management activities or processes take place. In such networks the knowledge and experience of employees are made available in order to make effective use of knowledge. Merging the concept of networking and knowledge management brings great benefits such as

openness and richness of networks that facilitates creation of entirely new knowledge. Furthermore, depending on networks has an undeniable transforming effect on all participants. Those positioned in a network adopt more innovations and are likely to do so sooner.

In this paper, we have proposed an integrated multi-aspect architecture for knowledge networking purposes in an organization and describe the structure of each layer in detail. To propose this architecture a number of technical, cultural as well as human-based aspects are integrated together. The structure of this paper is as follows: in section II, a brief review first on well-known KM models and then on few knowledge networks established in academic societies are given. Then, in the next section, the proposed multi-layer architecture is explained. Afterwards, an example is given on how this architecture works. Specifically, it is on the development of an Organizational Knowledge Management subsystem (here DMS¹). Finally, the benefits of the model as well as our future steps are discussed.

II. RELATED WORKS

The whole studies of knowledge management can be roughly categorized into two individual groups: 1) theoretical models, 2) more applied cases. Based on this view to the problem, the review section is divided into two main parts: 1) numerous knowledge management models and frameworks, and 2) few knowledge network implementations that are more applied than theoretical. While reviewing knowledge network models, we first review a specific knowledge network model that our proposed architecture is originally inspired from it. Then, two case-studies on scientific knowledge networks of India and Japan are given.

A. Review and Comparison of KM models and frameworks

In knowledge management area, several KM models and frameworks have been proposed. These models and frameworks reflect the diversity of disciplines contributing to KM. Selected models are reviewed from [3] to [13] and compared according to the degree of coverage of knowledge issues such as knowledge types, knowledge processes and knowledge management context features.

¹Document management system

Table 1- KM Models and their comparison from some knowledge perspectives (modified from [16])

☒ means not covered, ☐ means partially covered and ☑ means fully covered

Models	Alavi&Leidner (2001)	Davenport&Prusak(2000), Grover&Davenport (2001)	Despres& Chauvel(200)	Fowler(2000)	Handzic(2001)	Holsapple and Joshi (2004)	Newman and Conrad (2000)	Nissen (2002)	Nonaka (1994)
Knowledge Types									
Explicitness	☑	☐	☑	☑	☑	☑	☑	☑	☑
Reach	☑	☑	☑	☐	☒	☑	☑	☑	☑
Abstraction level	☑	☑	☑	☐	☑	☑	☑	☑	☑
Propositionality	☑	☒	☒	☑	☑	☑	☑	☒	☒
KM Processes									
Operational Processes	☑	☑	☑	☑	☑	☑	☑	☑	☐
Planning, modeling and control processes	☐	☑	☑	☐	☒	☑	☐	☑	☒
KM context									
Strategy	☐	☑	☒	☒	☒	☑	☒	☒	☐
Organization	☐	☑	☒	☒	☑	☑	☒	☒	☐
Culture	☐	☑	☒	☐	☑	☑	☒	☒	☐
Leadership	☒	☐	☒	☐	☑	☑	☒	☒	☐
Human resource management	☐	☑	☒	☐	☐	☑	☒	☒	☐
Individuals and behaviours	☐	☑	☒	☐	☐	☑	☒	☒	☐
Information technologies, techniques and methods	☑	☑	☒	☐	☑	☑	☑	☐	☐
environment	☐	☐	w	☐	☐	☑	w	☐	☐

According to the importance of each dimension in every model shown in Table 1 and the aspects considered in previously introduced models, we have considered a number of important aspects to organize the proposed architecture.

B. Review of Knowledge network models

Knowledge network is an almost novel concept in the area of knowledge management. In fact, it is a real need to utilize the already existing knowledge of different sources that may be distributed all over an enterprise with diverse set of goals in order to make different knowledge sources more and more integrate-able, accessible and ultimately usable. As it can be observed from the review in the previous section, there are numerous models and frameworks for knowledge management. But, unfortunately there are few researches done on characterizing knowledge networks.

1) Review of the Original model of proposed knowledge network architecture

The proposed model in this paper is originally inspired from the Knowledge network framework proposed by [2]. It conceptualizes knowledge networks on three layers including *facilitating conditions*, *knowledge work processes* and *knowledge network architecture*. In this framework the upper layer so called "facilitating conditions" covers structural and cultural dimensions of an organization. "Knowledge work processes" as the middle layer is defined in three main categories; locating and capturing knowledge, transferring and sharing knowledge, and knowledge creation. This layer encompasses two main elements actors as individuals, groups and organizations and relationships between the actors that can be categorized by forms, content and intensity and the bottom layer, "knowledge network architecture" includes organizational and ICT tools. As it is mentioned, this model has been the primary trigger for the proposed model. We have tried to enhance and complete this original architecture specifically by:

- Decoupling the newly introduced key layers to bring more independency for each layer (for probable future modifications in the level of organization)
 - Considering diverse critical supportive factors in a unified view
 - Inter-connecting and integrating layers using an assessment mechanism to provide modification feedbacks to all layers
- 2) Sample Case-Studies on Establishing Scientific Knowledge Networks

In [14] the National Knowledge Network (NKN) is proposed by government of India, ministry of ICT in 2009. It is planned to inter-connect all knowledge institutions through high speed data communication network. NKN would encourage sharing of knowledge, specialized resources and collaborative research among scientists, researchers and students from diverse spheres across the country to work together for advancing human development in critical and emerging areas. In fact it is going to play a great role in facilitating e-Learning. In [15] the Science Information Network (SINET) which is an information communication network connecting universities and research institutions throughout Japan is proposed. It is designed to promote research and education as well as the circulation of scientific information among universities, research institutions, and similar entities. The Science Information Network is also connected to research networks such as Abilene in the U.S. and GÉANT in Europe to facilitate the international dissemination of research information and to promote collaboration with research networks overseas. SINET3 began operations in April 2007, and it replaces the previous SINET and Super SINET. SINET3 plays an important role as the core component of the Cyber Science Infrastructure (CSI). These two sample



knowledge networks solely cover the explicit knowledge and have nothing with the tacit type of knowledge which is believed to be highly important in a modern organization.

C. The Proposed Multi-aspect Architecture

1) Basic Concepts

In this section, the unified multi-aspect knowledge network architecture has been proposed and the layers, components, and relations are explained in details. First of all, there are some reasons behind proposing a layered architecture. The first reason is to propose a unified view to manage the complexity of the knowledge network design by minimizing the dependencies among layers. This will cause that the changes on one part of the system do not greatly affect the other parts. Moreover, components of a layered architecture can be reused, maintained, standardized, ported and assessed separately thus more easily. As it was mentioned before, this model is an enhanced version of the one briefly reviewed in previous section[2]. The main deficiency of the original model in [2] is its lack of cross-layer assessment and feedback that confines its applicability in dynamic environments. This feature has been added in order to gradually enhance the network structure. From the management viewpoint, we consider the following necessities to yield remarkable benefits for managing knowledge in the network (see Fig.1):

- Interconnect business strategy layer and knowledge layer to make business goals and organizational knowledge activities aligned.
- Interconnect knowledge and infrastructure layers to facilitate the access and provide security.
- Interconnection of all three layers through supportive conditions.
- Integration of the layers through an explicit technical integration mechanism by considering the necessity of employing well-known standards and representation mechanisms.

In the following subsections, each layer is described in detail.

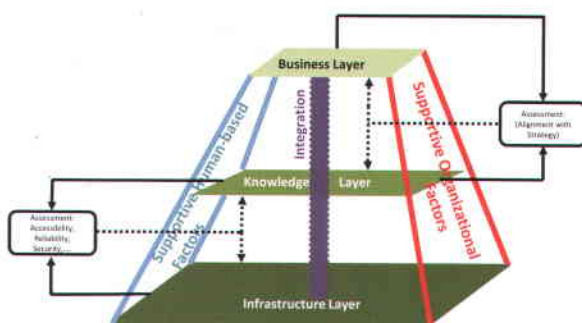


Fig.1- The Proposed Unified multi-aspect architecture for knowledge network

One of the main objectives of starting knowledge network in an organization is to manage the explicit knowledge which is massively distributed in different nodes of such network. This operation can be effectively realized through designing any of these systems to manage the explicit organizational knowledge: Content Management, Record Management, Workflow Management, and Document Management Systems (DMS). However, the tacit portion of the organizational knowledge is usually managed through employing any of the following systems: Collaboration Management, Experience Management, Interaction Management systems and so on. In this paper, we however have focused on Document Management System for both its simplicity of explanation and its extensive applications in today's organizations.

2) Business Layer

In [2] it has been implied that the discipline of knowledge management is most successful, when it considers both middle- and long-term goals of the organization. As it is shown, the pyramid of enterprise goals can be divided into three parts: Business', Team's and individuals'. (See Figure 2)

The alignment of the knowledge activities with all the business units' objectives helps to carry out the strategy of the company. We mention three main business layer goals: 1) Efficiency improvement, 2) Learning and training through an efficient knowledge network 3) Pursuit inter-organizational business strategy and mission.

a) Efficiency improvement in an enterprise implies improving the speed of work processes, getting the required types and amounts of essential knowledge and improving decision making through knowledge management. In this respect it is also essential to learn from partners and competitors, how to efficiently manage the business processes.

b) Learning and training: Organizational learning approaches are based on the viewpoint that change in organizations are connected with collective or interpersonal processes of learning. Individual experiences and learning potentials are organizationally connected in groups. The groups' learning results are then turned into organizational learning success.

c) Pursuit inter-Organizational business strategy and mission: This capability is needed to make the business layer's activities aligned with each other. Moreover, it brings about the required capabilities of organizational learning which are definitely required to purposefully percept the outer-organizational environment in an agile manner thus adjust the inner strategies and missions accordingly.[18]

It should be notified that the potentials of knowledge networks are not limited to what mentioned above but we have simply selected these three important benefits. For

example, the results of the cost-benefit analysis of both the tangible and intangible assets in the business layer, could be used in design or selection of required Document/Collaboration Management Systems (as it is discussed in III)



Figure 2- The Business Layer Pyramid

3) Knowledge Layer

In the knowledge layer which is shown in Fig.3, we have posed three types of key knowledge elements: 1) Explicit knowledge resources, 2) Tacit knowledge resources and 3) Knowledge key document, tools and services. The main idea behind the first two elements is that basically there are two sides of KM in every organization: human-oriented and technology-oriented approaches [1]. The other class of elements –so called tools and services– is considered to support and enhance knowledge-intensive processes, tasks and ultimately to support knowledge work in organization.

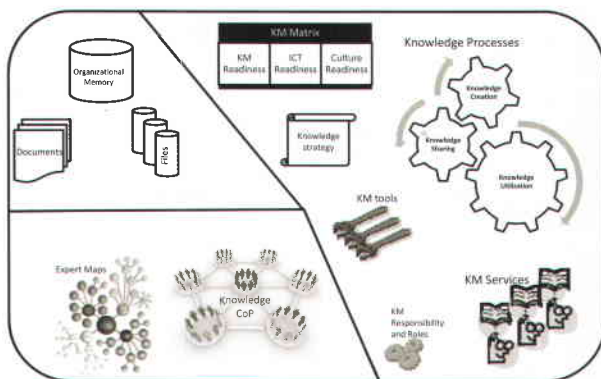


Fig.3- Knowledge Layer

In *Explicit knowledge pool*, these items are considered critical: files, documents, as well as the organizational memory. The basic idea of the organizational memory are that learning, whether individual or organizational, is not possible without memory. It simply means that employees, written records, or databases “contain” knowledge that is readily accessible.

In *implicit knowledge pool*, the focus is on experts map and knowledge CoPs². Participant users play the roles of

²Community of Practice

active, involved participants in knowledge networks and communities of knowledge workers that “own the knowledge” and decide what and how to share. Knowledge maps can be used to aid access to knowledge, to knowledge sources or to knowledgeable persons. The basic goal of such maps is creation of corporate knowledge directories which visualize and support more efficient access and handling of knowledge. Main objects of mapping are experts, project teams, networks, white papers or articles and lessons learned.

In the last pool, knowledge strategy (covers from initial knowledge need analysis to implement a series of strategic and tactical initiatives), knowledge management matrix (mainly to evaluate the organizational readiness) as well as enough facilities for collaboration, knowledge sharing and learning have been provided in support of knowledge processes in order to increase the productivity of knowledge work.

This layer has an obvious correspondence to the key KM subsystems such as Content Management, Record Management, Workflow Management, Document Management, Collaboration Management, and Experience Management Systems. As it is discussed in III, this layer is clearly redefined for a DMS in section IV of the paper.

4) Infrastructure Layer

Obviously, such a knowledge network requires an idealized conceptual representation that organizes ICT components that support knowledge layer structure, functionalities and its ultimate goals. Infrastructure layer of the knowledge network can be composed of all typical layers of the layered architectures of which the ISO/OSI reference model is the one of possible theoretical perspective. A number of critical characteristics that should be considered in this layer are mentioned below:

- a) Networking Capabilities to make different networks inter-operable.
- b) Creating a secure environment to make a trusted and reliable atmosphere.
- 3) Adaptive Infrastructure to make compatibility with other networks
- c) Supporting service-oriented/agent-oriented infrastructures to support common types of services

The main considerations and guidelines of designing the required system (e.g. functional/Non-functional requirements, objective/behavioural/ structural modeling requirements specification, the techniques of requirements elicitation, logical/physical design) is extracted in this layer as it was discussed in section III.

5) Supportive conditions: Human level and Organizational Level

Supportive conditions are related to the environment in which the knowledge network operations take place. They can enable or hold back the knowledge network



related issues. On the other hand, the companies should actively develop and maintain supportive surroundings, in order to enable and support effective knowledge flows. We have divided such conditions into two categories: 1) Human-based factors and 2) Organizational factors.

• Human Level Factors

Tolerance for mistakes, need for help, trust, culture, motivation program, reliability, shared objectives, openness, care and responsibility are human-level factors that can highly affect the knowledge network establishment both in positive and negative directions.

• Organizational Factors

Leadership, training and education programs, collaborative tools and rewarding mechanisms can be considered supportive conditions. Moreover, as the knowledge network can undoubtedly influence the culture of the organization, a mutual relationship can be considered between these two classes as well.

6) *How to Inter-connect and Integrate Layers?*

As it is shown in Fig.1 in the proposed architecture, each two consecutive layers are interconnected to each other through a straightforward assessment mechanism. When we are involved in designing the knowledge layer, we may receive/send helpful comments from/to either the business layer or the infrastructure layer. The comments from business layer are mainly related to the gap that may exist in the design of knowledge network in terms of satisfying the business strategy. So, modification feedbacks will be sent to both layers, in response. It is obvious that such incidents may happen very often.

On the other hand, the comments from the infrastructure layer are more concerned with accessibility issues, security problems and so on. For example, knowledge published e.g., in a document management system can be accessed by all members of the organization that have access to this system whereas documented knowledge that is stored on the individual hard disc of a single employee can not be found by interested knowledge seekers. Additionally, it refers to access to experts that hold knowledge about a specific domain. Higher visibility of knowledge, experts, networks and structures increases the risk that important knowledge can be revealed to competitors.

We have claimed that the integration of three distinct layers is a need. For this integration, there are some strong justifications such as time saving and cost reduction (mainly in communication), quality enhancement (using well-known standards), and simplification of development of new services or extensions of existing services and the reduction of the complexity in the development process.

D. *An Example for Development of Organizational Document Management System (DMS) as a Manifestation for Knowledge Network*

As discussed in section III, it is required to structurally and functionally evaluate the proposed framework. For structural assurance of soundness, it has to be notified that the architecture proposed in this paper is based on the idea in [2] which originally disregards 1) assessment components to inter-connect consecutive layers and 2) supportive conditions that integrate three key layers of the proposed multi-aspect architecture. By adding these crucial components and making an interview with domain experts, we have tried to fulfill these structural flaws thus make more coherence and robustness.

To evaluate the functionality of this architecture in an ideal condition, it is necessary to implement the architecture in a number of different organizations, and to ultimately assess the actual pros and cons of it by carefully designing questionnaires. As this complete mode of evaluation is not practical at the current stage, we chose another alternative solution which is assessing the behaviour in different scenarios/contexts as well as proving its usefulness. The selected context here is organizational documents for which we have tried to propose some guidelines for creation of a management system to manage distributed documents around the network. As mentioned in section III, other contexts such as organizational collaboration/experiences are also applicable while not directly considered in this paper.

In order to demonstrate the benefits of the proposed architecture, in this section, an example has been proposed on how to develop one of the most famous subsystems of organizational knowledge management. It has been shown that how the guidelines given by this architecture can guarantee the integration of different knowledge management components as well as networking capabilities in intra and inter-levels.

Document management systems are one of many different types of explicit knowledge management systems in an organization. Organizational documents contains different kinds of documents such as rules, organizational charts, control systems' outputs, documents and certificates, policies, routines, analytical reports, outer certificates referred in processes, plans, programs, maps and many more instances. There are different methodologies in order to develop document management systems. The proposed method in this paper is based on the standard ISO 15489 which guarantees the efficient development of document management systems in different organizations [17]. The hints and guidelines produced by employing the proposed method come below



in Table 2. Please note that in describing the interconnections (Business to Knowledge and vice versa, Knowledge to Infra-structure and vice versa) we used an example just to save the space.

Table 2- An Example on the Development of Organizational DMS based on the Proposed Architecture

Layers / Interconnections	Hints and Guidelines
Business	- Verifying strategic plans and policies of a country (e.g. IT strategic plan) to find the necessity of developing DMS in an organization. - Preparing the strategies of the organization based on the analysis of strategic plans and policies of a country (e.g. IT strategic plan) for developing DMS. - Defining organizational objectives in developing DMS. - Defining evaluation measures to find the effects of DMS development on the efficiency in reaching to organizational objectives. - Providing consistency by setting proper policies in order to facilitate accessing to the outer organization's documents. - Defining outer access policies to organizational DMS. - Preparing the frameworks for promoting personal, group and organizational knowledge based on capabilities of DMS. - Defining the evaluation metrics of knowledge promotion in all levels on the organizational objectives.
Business to Knowledge Interconnection	Assume that the business layer changes to cover this new goal: "Promoting the staff's knowledge". As a result, the organization's knowledge layer should change accordingly to support this goal thus add the proper required learning contents to its DMS.
Knowledge to Business Interconnection	Assume that in an organization, we observe that implementation of DMS has brought outstanding results that were not predictable beforehand (let say "innovation" besides "knowledge promotion"). So, we would revise our business goals to cover this new goal (innovation) as well to make a full support of it in the knowledge layer in future activities.
Knowledge	- Developing proper organizational knowledge structure for employing DMS in explicit knowledge management systems. - Codifying the tacit knowledge of organizational processes for enhancing the functionality of DMS. - Recording the procedures required for keeping or removing of the organizational documents as explicit knowledge of organizations. - Recording the routines of crisis management on organizational documents as explicit source of knowledge in organizations - Codifying the organizational rules and regulations and rules as a part of explicit organizational knowledge.

	- Employing the explicit knowledge recorded in DMS in the process of organizational decision making. - Employing the explicit knowledge recorded in DMS in the process of organizational policy making.
Knowledge to Infra-structure Interconnection	Assume that we have asked the organization's staff to share their documents through the DMS. In return we have to consider some technical issues to guarantee the security as well as accessibility of the shared contents.
Infra-structure to Knowledge Interconnection	As the new technologies come to the market, we have to revise the representation and retrieval mechanisms of the documents in our DMS.
Infrastructure	- Developing the automatic or semi-automatic software systems for creating documents. - Developing the software systems of storage and retrieval of documents. - Developing OCR systems to keep a record of paper resources of organization. - Developing proper meta-data standards for organizational documents. - Preparing approaches for crawling and searching in organizational documents. - Preparing automatic translation systems for organizational documents. - Preparing infrastructures for networking and access to documents. - Preparing intelligent subsystems for document analysis and creation of new explicit knowledge. - Developing web-based services for DMS.

As it has been shown in the above example, activities, tasks and programs that are expressed in different layers have the least amount of correlation and coupling together. This is the main motivation for networking in the level of an organization. It is noticeable that if there exists specific objectives for every layer, each activity and program can be explicitly assessed and enhanced (if it is specified necessary through the built-in assessment mechanism). Moreover, the activities mentioned in the business layer facilitate and support the interaction of this sub-system with those of the other nodes of a knowledge network.

E. Conclusions and Future Works

In this paper, a multi-aspect architecture was proposed to start knowledge networking in any organization with different goals and strategies, different types of knowledge, various technical infrastructure as well as different cultures and human resources. This layered architecture has benefited from unique features such as:



- Decoupling the key layers to bring more independency for each layer for probable modifications
- Considering diverse critical supportive factors in a unified view
- Inter-connecting and integrating layers using a self-assessment mechanism to provide modification feedbacks to all layers

To show the applicability of the proposed architecture, we have shown that, while developing one common KM sub-system to manage the explicit distributed knowledge of the organizational knowledge network –e.g. by designing a Document Management System– one can take advantage from one of the most creditable standards of this domain (ISO 15489). Also by employing the proposed architecture one can support the independencies among layers and utilize the explained self-assessment mechanisms. This capability not only makes consistent the proposed knowledge network architecture, but it also guarantees the extendibility of such network in both inter and intra levels. From the viewpoint of architectural integration, the proposed architecture can be used to extract the guidelines for other required subsystems of knowledge network based on its intrinsic considerations. For example in a Collaboration Management System (CMS), it looks for managing a process in which two or more people or organizations work together to realize their shared goals. The proposed business layer in this paper (for extracting the considerations of developing the CMS) emphasizes on verifying the strategies and policies to find the shared goals as well as preparing the strategies for a better co-working, defining the objectives and the method for evaluation measures and many more related topics.

It is expected that such as approach based on utilizing the multi-aspect architecture be easily extended not only to the other layers of such architecture, but also to other sub-systems used in KN.

To continue the work, an important issue is to practically establish the proposed architecture in inter-organizational level and evaluate its functionality in terms of organizational criterion. Another issue is to investigate the possibility of realizing the proposed multi-aspect architecture through a multi-agent system (MAS) with each agent responsible for its own organizational knowledge tasks.

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