The *E-Decisional Community*: An Integrated Knowledge Sharing Platform

Leonardo Mancilla-Amaya[1], Cesar Sanín[2], Edward Szczerbicki[2]
School of Engineering, Faculty of Engineering and Built Environment
The University of Newcastle, Australia
University Drive, Callaghan, 2308, NSW

[1]leonardo.mancilla@studentmail.newcastle.edu.au

[2]{Cesar.Sanin, Edward.Szczerbicki}@newcastle.edu.au

Abstract

Knowledge Management (*KM*) has become a key success factor in diverse fields, given the importance of knowledge as a significant organizational asset. In order to solve problems and support complex decision-making processes, knowledge and experience have to be transmitted across individuals, business units and organizations. Thus, *Knowledge Sharing* (*KS*) can be considered as the basic element of any knowledge-oriented process: *KS* fosters collaboration in complex environments, and facilitates experiential knowledge discovery, distribution and use. This paper presents a proposal for the development of a *Community of Practice* (*CoP*) called the *E-Decisional Community*. This community uses a domain-independent knowledge representation called *Set of Experience Knowledge Structure* (*SOEKS*), and captures the decisional fingerprint inside organizations using *Decisional DNA*. It is based on principles from different technologies namely *Software Agents*, *Grid* and *Cloud* computing, in order to provide an autonomous, intelligent and coordinated large-scale *KS* environment. The *E-Decisional Community* biggest concern is to promote experiential knowledge evolution and sharing through generations of decision-makers, aiming at the creation of a marketplace where knowledge is provided as a service.

Keywords: Knowledge Management, Software Agents, Grid Computing, Cloud Computing, Knowledge Engineering, Smart Knowledge Management System, Decisional DNA, Set of Experience Knowledge Structure.

1 Introduction

Acquiring knowledge, representing it in an explicit and formal way, and supplying suitable mechanisms to re-use it and improve it inside organizations is a complex task. The *Smart Knowledge Management System* (*SKMS*) defines the processes and components required to capture, store, improve, re-use, and transmit experience through generations of decision makers.

Nowadays, organizations need to share their knowledge with others when pursuing a common objective. As a result *KM* has become a critical element for organizations, given the importance of knowledge as a major asset that guarantees competitive advantage in a rapidly changing, economic-driven environment (Zhang et al., 2008a).

Several theories and proposals on *Knowledge Sharing* (*KS*) can be found in literature, and all of them are a valuable contribution to the area of *Knowledge Engineering*. They are concerned with providing technical support for *KS* between entities in various ways and using different approaches such as *software agents*, folksonomies, social networks and many more.

However, there is not a *KS* approach that captures the experience from multiple formal decision events, and transmits it across different generations of workers, using the vision of the *Set of Experience Knowledge Structure* and *Decisional DNA* (Maldonado Sanín, 2007). To achieve this, *SKMS* proposes a *Community of Practice* (*CoP*). In this *CoP*, similar systems interact with each other creating new knowledge, and thus, new experience.

This paper describes the *E-Decisional Community*, our proposal for *KS* among individuals and organizations. This is a work currently developed by the *Knowledge Engineering Research Team* (*KERT*), at The University of Newcastle, Australia.

The following sections are structured as follows: section two presents a theoretical background on basic concepts around our work; section three describes the vision, features and design for the *E-Decisional Community*. Finally, section four presents some conclusions and future work.

2 Background

This section presents the conceptual elements constituting the foundations on which our proposal is based. We will briefly describe topics in *Knowledge Management* (*KM*), *software agents*, *Grid* and *Cloud* computing

2.1 Knowledge Sharing

These days, economy and competition are based on knowledge. The ability to learn from past experiences and adapt to rapidly changing conditions determines which organizations will prevail. Consequently, managers are more conscious about the importance of knowledge in their enterprises; thus, giving a higher priority to *KM* related activities.

One of those activities is *Knowledge Sharing* (*KS*) and dissemination. *KS* is a key factor, because knowledge is only useful if it is accessible to all users and can be used to solve problems and make decisions (Lao et al., 2008)

According to Hustad (2004), *KS* can be performed at different levels: between individuals, from individuals to groups, between groups and from groups to organizations. In fact, Vidou et al. (2006) state that an organization is comprised of many interconnected groups of interest, called *Communities of Practice* (*CoPs*). *CoPs* are: "*groups of people who share a passion for something that they know how to do, and who interact regularly in order to learn how to do it better*" (Wenger, 2004: p. 2).

Nowadays, such groups can perform their activities using the latest advances in technology. Many tools and proposals have been developed in order to support collaboration and knowledge sharing using different approaches: ontologies, folksonomies, wikis and social networks are some models that support *KS* (Kings et al., 2007). Research projects like SQUIDZ (Kings et al., 2007), Knowledge Spaces (Zhang et al., 2008b), Palette (Vidou et al., 2006), Jasper (Davies et al., 1998) or Wikipedia (Wikimedia-Foundation, 2009) are just a few clear examples of *KS* technologies of everyday use.

Improving *KS* by means of automated distribution mechanisms, and using a single and domain independent knowledge representation still remains as a research area to be explored.

2.2 Smart Knowledge Management System, SOEKS and Decisional DNA

Managers, and decision-makers in general, base their current decisions on lessons learned from previous similar situations (Sanin and Szczerbicki, 2005a). However, much of an organization's experience is not properly capitalized because of inappropriate knowledge administration; this leads to high-response times and lack of flexibility to adapt in dynamic environments.

The *Smart Knowledge Management System* (*SKMS*) is a platform that defines a set of four macro-processes and components with the objective of supporting experiential knowledge creation, store, re-use, improvement and distribution inside organizations (Maldonado Sanín, 2007). The *SKMS* dynamically transforms large amounts of data and information from diverse sources into knowledge, supporting decision making processes at any level of the organizational hierarchy.

This platform uses a standard, flexible and domain-independent knowledge representation called *Set of Experience Knowledge Structure* (*SOEKS* or shortly *SOE*). Each *SOE* represents a single formal decision event, and after being transformed by the *SKMS* macro-processes, many *SOEKS* comprise a *Decisional DNA* strand of an organization. Consequently, *Decisional DNA* captures the inference strategies of enterprises (Sanin and Szczerbicki, 2008).

Given that formal decision events are meant to be kept in an explicit way inside the *SKMS* standard representation means, for instance *Ontology Web Language* (*OWL*) and *XML,* are used for such matter. These representation mechanisms facilitate knowledge sharing and transportation, mainly because they describe human-cognition with a high level of abstraction and are broadly accepted standards (Sanin and Szczerbicki, 2005b;Sanin et al., 2007).

The *SOE* has been successfully applied in industrial environments, specifically for maintenance purposes, in conjunction with *Augmented Reality* (*AR*) techniques (Toro et al., 2007). Additionally, implementations in the fields of finances and energy research have evaluated the performance of the *SOE* and demonstrated that it is an optimal multi-domain knowledge representation (Sanin et al., 2009).

2.3 Software Agents

Software Agents (or simply *agents*) represent an active research area where many efforts have been made to develop human-like behavior in computer systems. Basically, an *agent* is a software or hardware component that acts without external intervention to achieve a set of well-defined goals on behalf of its user (Nwana, 1996). According to Wooldridge and Jennings (1995), this technology possesses some features that have made it a suitable approach for modeling complex systems; these characteristics are: (i) Autonomy, (ii) Social ability, (iii) Reactivity, (iv) Pro-activeness, (v) Mobility, (vi) Veracity, (vii) Benevolence and (viii) Rationality. As a consequence, *agents* are used in many *KM* approaches because they provide an appropriate way for modeling organizational knowledge. As mentioned by Van Elst et al. (2004), knowledge distribution, low-priority *KM* goals, complex interactions and dynamic environments are some characteristics that justify the use of *agents* in knowledge management solutions.

Previous work on *KM* based on *agents* was concerned with text mining, automated suggestions and smart document access (De Rezende et al., 2007;Kim et al., 2007), Distributed Organizational Memories (Abecker et al., 2003;Gandon and Dieng-Kuntz, 2002), *agent*-based architectures (Vizcaino et al., 2007), and use of ontologies in *Multi-Agent Systems* (*MAS*) among others.

However, to the best of our knowledge, existing proposals do not address experiential knowledge representation, management, evolution and distribution in the way the *SKMS* does using *SOEKS* and *Decisional DNA*.

2.4 Grid Computing

Grids provide a robust and highly scalable infrastructure for multi-purpose problem solving tasks. This is achieved by sharing resources and coordinating efforts in *Virtual Organizations* (*VO*s) (Foster, 2002).

As the complexity of problems undertaken by users everyday increases, the requirements surrounding the *Grid* have become more complex and demanding. Efforts like the *Semantic Grid* provide new capabilities to users, and also, as mentioned by De Roure et al. (2005), new research opportunities: semantic service description, smart interaction, autonomous behavior, knowledge technologies, among others, are topics that should be addressed by future efforts.

In fact, knowledge technologies for *Grid* environments are getting more attention from the scientific community. Approaches like the *Knowledge Grid* presented by Zhuge

(2008) propose a highly distributed collaborative environment, where explicit knowledge resources are managed to support decision-making processes and cooperative work.

Regardless of its powerful attributes, *Grid* technology concepts need to be improved with ideas from other areas in order to fulfill the elements proposed by De Roure et al. (2005). *Software agents*, as described in the previous section, possess some unique attributes which are common to the research topics defined for the *Grid* (Foster et al., 2004). Elements like autonomous behavior, community management and advanced coordination and negotiation techniques are being be used in the *Grid* to make it more resilient and efficient; two examples of this are presented by Gil (2006) and Norman et al. (2004), who described new ways to make *Grid* environments more robust and to dynamically manage *VOs* in electronic commerce scenarios, both based on *agents*.

In conclusion, *Grids* have the potential to provide large-scale knowledge oriented services, to support critical decision-making processes. This may be achieved by developing advanced mechanisms based on other technologies.

2.5 Cloud Computing

There are many definitions about *Cloud Computing* (*CC*), but until now, there is no consensus on what *CC* is (Foster et al., 2008;Mc Evoy and Schulze, 2008;Youseff et al., 2008).

CC is closely related to *Grids*, and according to Foster et al. (2008), *Clouds* are an evolution of *Grid* technology, but with different requirements in areas such as business model, applications and abstractions. *CC* is a service oriented approach that takes full advantage of current developments in virtualization, Semantic Web and *Grid* computing to provide different services on-demand. These services most frequently are: applications (i.e. *SaaS: Software as a Service*), platforms (i.e. *PaaS: Platform as a Service*), and hardware/software infrastructures (i.e. *IaaS: Infrastructure as a Service*).

There is an increasing interest in the scientific community regarding *CC*. Some proposals for the implementation of *Cloud* based environments have been developed, for example Zhan et al. (2009) presented a cloud computing system software to consolidate heterogeneous workloads in organizations. Others propose the use of human organizational principles to develop client *CC* environments, which facilitate knowledge and experience transfer between people (Hewitt, 2008).

Moreover, *KM* systems based on the *Cloud* vision have been envisaged by Delic and Riley (2009); knowledge *Clouds* will interconnect users across several organizations and data centers, thus supporting the "*Intelligent Enterprise*". This *Intelligent Enterprise* is an entity (*agent*) that behaves intelligently and used the Internet as its base for providing services and performing operations.

In spite of the existing work, more research needs to be done on *CC* and the way it supports knowledge based tasks inside organizations.

3 The E-Decisional Community Proposal

Due to the increasing need of many organizations to share knowledge, not only among them, but inside their different business units, the *SKMS* proposes a *Community of Practice* (*CoP*) called *E-Decisional Community*. In this *CoP* similar systems interact with each other creating new knowledge and experience, and thus, extend the limits of the *SKMS*. This section presents different aspects and features of the *E-Decisional Community* proposal, such as its global vision and suggested design.

3.1 Vision

The *E-Decisional Community* is concerned with experiential knowledge represented as *Decisional DNA* and *SOEKS*, and the way this novel knowledge representation is passed on and evolves through generations of decision makers.

Extending the limits of the *SKMS*, autonomous and smart knowledge sharing mechanisms must be developed. This will make the *SKMS* capable of discovering knowledge based on real-world data and information provided by users. However, the *E-Decisional Community* is not a data/text-mining tool, or just a smart document-repository. It is meant to be a dynamic and scalable platform for problem solving activities among individuals and organizations.

Our proposal is based on concepts from *software agents, Grid* and *Cloud* computing. Modeling of complex human interactions, coordinated knowledge sharing, team formation, autonomous actions and on-demand services, are just some of the concepts surrounding the *E-Decisional Community*.

Figure 1 illustrates the global vision for the *E-Decisional community*. Our proposal for a *CoP* allows individual agents (i.e. workers), as well as groups (i.e. business units), to contribute with their experience to the construction of collective knowledge. To achieve this, the entities involved must share knowledge and interact in a coordinated fashion. Continuous participation in the *CoP* to solve problems promotes experience transmission, and knowledge discovery and re-use.

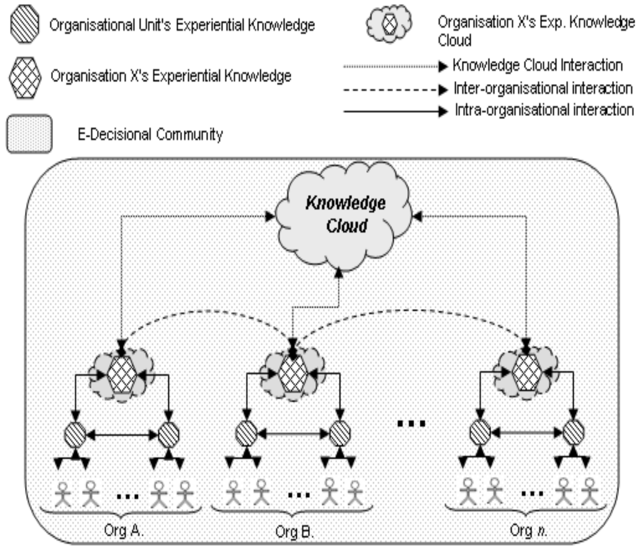

Figure 1: The E-Decisional Community Vision

In our approach, organizations may create their own *clouds*, interacting with other and providing knowledge-based on-demand services. These interactions are motivated by economic principles for instance alliances, and producer-consumer relationships. In fact, the interconnection of different business partners will generate a much larger *Knowledge* C*loud*, stimulating the creation of a large-scale marketplace, in which knowledge is the main asset, and it is sold or exchanged as part of collective strategies.

3.2 Features

In order to support decision-making processes in organizations, the *E-Decisional Community* provides the following features:

–*People-oriented*: the platform is a tool that provides knowledge-oriented problem solving, in which people can take advantage of today's computational improvements to support complex decision-making processes in organizations.

–*Agent-based capabilities*: characteristics from software agents are provided to model complex human interactions and support intelligent *KM* processes, in highly distributed and complex environments.

–*Constant Evolution*: knowledge evolution and refinement is an intrinsic characteristic of *SKMS*, and is achieved by constantly updating existing experiences with data from the real world which is fed by the users.

–*Community formation*: there are tasks that cannot be executed successfully in an individual fashion; therefore, grouping, based on objectives and knowledge, is supported, both in a static and dynamic manner.

–*Well-defined interactions*: agents and services participating interact in an orderly fashion. Therefore, protocols and interaction schemes are defined to establish proper communication, role assignment and permission policies.

–*Conflict resolution*: negotiation techniques and conflict resolutions mechanisms are provided to solve disputes caused by accessing scarce resources or by conflicting beliefs and experiences.

–*Multimedia information*: multimedia information should be a source for experiential knowledge extraction in today's organizations. The *E-Decisional Community* aims at including multimedia resources as part of the decisional fingerprint of organizations.

–*Security, trust and provenance*: it is clear that a secure environment is a key requirement for any distributed system these days; moreover when Internet is used as the primary communication channel. Also, knowledge collected must be reliable to make the right decisions; that is why the concept of *Decisional Trust* (Sanin and Szczerbicki, 2008) is extended to include more features that reflect human-like behavior. Finally, as knowledge is transformed, it might be useful to have a way to trace the derivation history of it, which can be used to generate performance measures for the system, or for possible auditing and/or legal purposes.

3.3 Design

3.3.1 Conceptual Model

The proposed model for the *E-Decisional Community* is comprised by four layers: Knowledge-based Application Layer, Collective and Individual Management Layers, and Knowledge-Oriented Services Layer. The platform is built on top of the *SKMS*, extending its limits always using *Decisional DNA* and *SOEKS* for knowledge transmission and representation Figure 2 depicts the conceptual model for the *KS* platform.

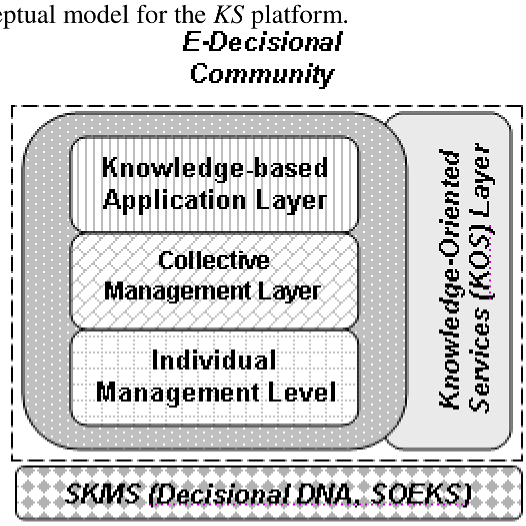

Figure 2: E-Decisional Community Conceptual Model

All the comprising layers make extensive use of *Knowledge Oriented Services* (*KOS*) to provide appropriate *KS* capabilities. Each layer has a set of responsibilities and characteristics as follows:

–*Knowledge-based Application Layer (KAL)*: this layer provides end-user access to the platform functionality. At this level, Web 2.0 or mobile applications may be used by workers to interact with other individuals or groups in order to solve problems and make decisions, as well as to feed the system with data based on their daily activities. Knowledge-based applications can use complementing technologies such as software agent or *Augmented Reality* (*AR*), to promote interaction with the environment and capture experiential data from different sources.

–*Collective Management Layer (CML)*: dynamic teamwork management, inter and intra-organizational interactions, cooperation and global policies, among other mechanisms, are provided by this layer to support collaborative work. Groups and organizations are represented as heterogeneous *MAS*, thus, multiple *MAS* can interact between each other using well-defined protocols and policies provided by the *CML*. During the interaction process, new collective experiential knowledge is created or inferred, increasing the expertise level of the entire enterprise. *VO* formation and management based on knowledge objectives is also supported at this level.

–*Individual Management Layer (IML)*: individuals in an organization are represented by *software agents*. As a consequence, knowledge exchange, collaboration and dynamic teamwork formation can be performed in an autonomous fashion, resembling human behavior.

Moreover, *agents* can remember users' behavior in order to proactively initiate knowledge-based tasks. In this layer, *agents* are an entry point to the knowledge-oriented services provided by the platform, and are able to create an individual's decisional fingerprint, that can be used, for example, as a performance or reputation indicator. This layer provides all the required mechanisms to support the aforementioned functionality.

–*Knowledge-Oriented Services Layer (KOS)*: knowledge-oriented services deliver a wide range of features oriented to promote proper *KS* inside organizations. Access to *Decisional DNA* and *SOEKS* repositories, yellow and white pages directories, role definitions, trust and reputation services, among others, are provided by the *KOS* layer. Additionally, this layer defines the interoperability elements required to perform inter-cloud communication in order to provide on-demand access to users across different organizations. Coordinated execution of *KOS* is defined by the interaction protocols of the *CML* and *IML*.

-*SKMS, Decisional DNA and SOEKS*: this is not a layer of the *E-Decisional Community*; however the four macro processes defined by the *SKMS* (diagnosis, prognosis, solution and knowledge), along with its knowledge capturing and representation mechanisms, constitute the foundation on which the *KS* will be constructed. More details about the *SKMS* proposal can be found in (Maldonado Sanín, 2007;Sanin and Szczerbicki, 2005a;Sanin and Szczerbicki, 2005b;Sanin and Szczerbicki, 2008;Sanin et al., 2007)

3.3.2 Conceptual Architecture

Figure 3 illustrates the proposed conceptual architecture, based on the model previously described. The objective of the conceptual architecture is to identify the elements and global relationships that might be present in the *SKMS* knowledge sharing environment.

In the *E-Decisional Community*, users access the *KS* platform by means of knowledge-based applications. As mentioned in the *KAL* description, Web 2.0 applications are used for this purpose, as a consequence, protocols like HTTP or SOAP, and architectural approaches such as REST (Representational State Transfer) must be employed.

Applications in the *E-Decisional Community* make use of *software agents*; each user is represented by a *Personal Agent* (*PA*) which acts in his/her behalf inside the community, and provides access to *KOS*. *PA*s know about their roles, interaction restrictions, trust relationships and reputation of other entities by means of specialized *KOS*.

Numerous *PA*s may share a temporary, or permanent, interest for a specific topic which leads to a dynamic group formation. When various *agents* form a coalition (i.e. a *MAS*), they are represented by a *Group Agent* (*GA*). Consequently, multiple *MAS* are viewed as complex agents that interact similarly to how individual *PA*s do, but with higher-level goals and interests. Also, *GA*s are able to solve more complex problems or take critical decisions, because they count on the experience from many individuals. Dynamic teamwork formation and life-cycle management is also supported by *KOS*.

Interaction between enterprises is also carried out using *GA*s that represent each individual organization. At this level, the strategic experience of each organization may be shared or sold using a *Cloud* scheme for on-demand usage.

The architecture defines six *KOS* categories oriented to facilitate experience diffusion. Services may be provided on-demand for external or internal entities, and an organization can provide one specific type of *KOS* over the *Cloud* as a profit opportunity. The service categories are:

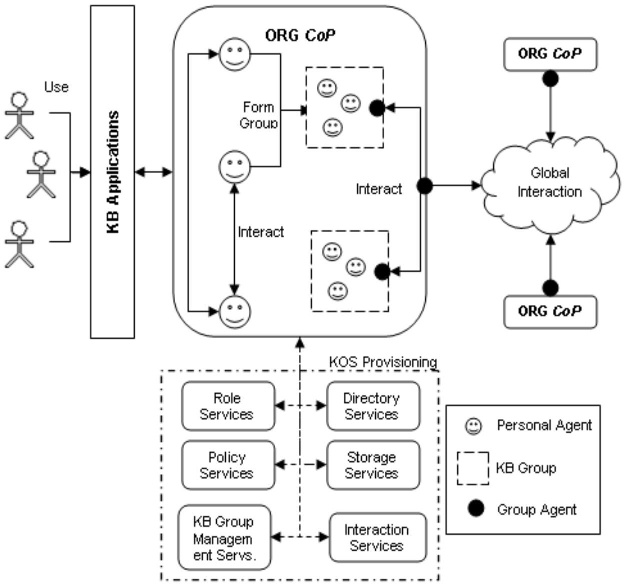

Figure 3: E-Decisional Community Conceptual Architecture

–*Role Services*: this service category acts as a repository where organizational roles are mapped, defining the corresponding behaviors, responsibilities, capacities, goals and permissions. Roles can be dynamically queried and executed by any entity.

–*Directory Services*: provides white and yellow pages services, in order to query for individuals or knowledge resources/services, respectively.

–*Policy Services*: stores the organizational policies for dealing with different issues. For example, policies for uncertainty management, service distribution, rewards/punishment, and others, are stored for dynamic querying.

–*Knowledge Storage Services*: these services provide storage and retrieval capabilities for individual, collective knowledge and organizational experiential knowledge. Providing secure, reliable, location-independent and fast access to *SOEKS* and *Decisional DNA* structures is the main concern of this service category.

–*Knowledge-based Group Management Services*: dynamic formation of groups based on knowledge objectives is a key feature of the *E-Decisional Community*. As a consequence, a specific category of services is devoted to support this aspect. Trust, negotiation, reputation, quality of service and service level agreements constitute the key elements that are provided to support cooperative problem-resolution and decision-making.

–*Interaction Services*: these set of services contains the definition of all the protocols that are used inside the *CoP*, to guarantee orderly interaction. These protocols are employed to coordinate the communication flow between organizational units, organizational units and the enterprise, and among enterprises.

4 Conclusions and Future Work

We presented a design proposal for a *CoP* that allows sharing experiential knowledge across different organizational levels. It uses a standard knowledge representation called SOEKS, which in turn, comprises Decisional DNA (i.e. a collection of multiple SOEKS).

This proposal, called *E-Decisional Community*, is based upon the principles of different computing technologies, namely: *software agents*, *Grid* and *Cloud* computing. Modeling of complex human interactions, autonomous and intelligent behavior, coordinated knowledge sharing, and on-demand service provisioning are some of the concepts behind the *CoP*. As a consequence of this approach, eight global features have been presented as the main concerns in our work.

Since the *E-Decisional Community* proposal is at its early development stages, further research and refinement of the elements presented in this paper remains to be done. Some future tasks are:

–Evaluation of different *agent* architectures to determine which approach is more appropriate for smart *SOEKS* and *Decisional DNA* sharing. Also, validation of the candidate architectures with a case study implemented using a Java-based *agent* framework is required. Java is preferred because the first version of the *SOEKS* API was developed using this language, and it allows for OS independency.

–Comparison and evaluation of the different interaction, negotiation, coordination and conflict resolution protocols for *agents* that might be used inside the *E-Decisional Community*. If new protocols are required for knowledge-based collaboration, then a proposal will be formalized.

–Refinement of the requirements for dynamic knowledge-based teamwork formation. Requirements like protocols, policies and life cycle management need to be described in detail.

–Establish appropriate human-machine interaction mechanisms to capture experience from different sources other than data warehouses or files. Currently, *ARTag* (Fiala, 2009) is being evaluated by the *KERT* as an *Augmented Reality* tool for this purpose.

–Technical review of *Cloud* and *Grid* tools and middleware and design principles to determine their viability for a future implementation of the *CoP*, both at a conceptual and technical level.

–Research on experience extraction and inference from multimedia files.

– Complement the work around *Decisional Trust*, to include elements that allow entities to trust others, but not only in the virtual world. People-system trust relationships should be bidirectional, based on reputation and other measures that can be applied to human and virtual workers alike, and that can be used by either one of them to asses critical decisions.

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