Using Agent Societies to Support Knowledge Sharing

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ABSTRACT

Agent-Mediated Knowledge Management (AMKM) is a new research direction that aims at the cross-fertilization between the KM and the agents research fields. The realization that KM is primarily a *management* science, and not a *computer* science implies a different role for technology in KM, that of supporting and extending human interaction and learning, and therefore a need for intelligence-enhanced, integrated and personalized solutions. That is, AMKM requires the flexible integration of organizational and individual requirements and objectives. We present a agent-based model for organizations that supports individual initiative and collaboration while prescribing a formal model for organizational processes. This model enables the development of people-oriented KM environments that focus on the collaboration between people.

1. INTRODUCTION

Knowledge has widely been acknowledged as one of the determining factors for corporate competitiveness and advantage. In the past years we have witnessed an explosion of approaches to knowledge management (KM). Practitioners and business managers alike agree that issues of technology, process, people, and content must be addressed to achieve success [18]. Moreover, it is becoming increasingly important for organizations to shorten the learning curve (that is, the time to achieve full competence); to rapidly assimilate sophisticated new technologies; and to efficiently fill the gaps in a company's knowledge base—particularly as developments become more complex and operating environments pose increasing demands on people and organizations. Moving forward to be a best-in-class company means transforming everyone in the company into an experienced practitioner in one of more technical or support disciplines.

In our opinion, the basic organizational unit of knowledge management is the *community of practice* (CoP), which is a group of people sharing a common area of expertise and/or who search for solutions to common problems. A CoP is thus not necessarily an authorized or identified group. People in a community of practice can perform the same job, collaborate on a shared task or work together on a product. What holds them together is a common sense of purpose and a real need to know what each other knows. Most organizations will hold several communities of practice and most people belong to at least one of them [2]. Nurturing communities is hard enough when the members are in a single location with good connectivity and increase considerably when the members are spread around different locations, possibly in different areas and with different languages and cultures.

Furthermore, people in organizations tend to develop their own ways of doing things. Processes don' t do work, people do. A close look at how companies really work will show gaps between official work processes - the a priori designed flows of tasks and procedures reflecting the ideal activity of the company - and the real-world practices that actually get things done. These gaps are not problems that need fixing; they' re opportunities that deserve leveraging. That is, the real assets of organizations are the informal, often inspired ways that real people solve real problems in ways that formal processes can' t anticipate. The realization that such gaps exist is of utmost importance for the success of knowledge management initiatives. A KM system that links to the real needs and goals of people on their real-world practices has a much higher chance of success than one than will follow the 'official' workflow processes. Moreover, organizations must keep in mind the limitations of knowledge management and understand that knowledge alone does not guarantee a creative response to decision-making situations. Or, as Einstein has stated: '*imagination is more important than knowledge*'.

The above considerations show a shift in the focus of KM from the management of knowledge assets to the management of collaboration. That is, the aim of KM is no longer just the management of activities related to the creation, preservation and distribution of knowledge assets but the management and nurturing of collaboration between people. The shift is into **collaboration management systems** that meet the following requirements [5]:

1. Assist people generate and apply 'just in time' and 'just enough' knowledge, prevent information overload and stimulate sharing of relevant knowledge in a dynamic, collaborative environment.
2. Preserve individual autonomy and contribute to the creation of a atmosphere of trust between participants.

3. Provide links individual action and company structure such that on one hand, innovative ways of doing things can be effectively integrated into company processes and, on the other hand, it can be verified whether actions are conform to company values and norms.

We have developed an agent-based organizational model that attempts to incorporate formal organizational processes and goals with the different individual perspectives of the actors (people, groups and possibly systems) involved [6]. This model, based on multi-agent systems, is well suitable to describe collaboration support systems that fulfil the requirements above.

The remaining of this paper is organized as follows. In section 2 we will motivate and give examples of the use of agents in KM. Section 3 presents the Agent Society Model (ASM) for organizations. Section 4 introduces KennisNet, a framework for knowledge sharing developed at Achmea[1] that is used as illustration to the ASM model presented in this paper. The application of ASM to the development of a collaboration support component in KennisNet is described in section 5. Finally, in section 6 we present some conclusions and discuss areas for further research.

2. AGENTS IN KNOWLEDGE MANAGEMENT

From the starting days of KM, technology has been recognized as an enabling, and often even a leading, factor for connecting (e.g., people to other people or knowledge) and converting (e.g., data into knowledge) [16]. Comprehensive KM endeavors, however, have always realized that KM is primarily a *management* science, and not a *computer* science. This implies a different role for technology in KM, that of supporting and extending human interaction and learning, and therefore a need for intelligence-enhanced, integrated and personalized solutions.

Agent-Mediated Knowledge Management is a new research direction that aims at the cross-fertilization between the KM and the agents research fields [11]. Applications of agent technology to KM start from the realization that KM and multi-agent systems have several similarities. Agents are mainly used in dynamic environments where activity and reasoning are determined by the interpretation of perceptions about the actual condition of the environment. Like multi-agent systems, KM environments can be seen as distributed systems where different actors, each pursuing its own goals, need to interact in order to achieve their goals and realize organizational objectives. In such environments the ability to communicate and negotiate is paramount. Furthermore, the number and behavior of participants cannot be fixed a priori and the system can be expected to expand and change during operation, both in number of participants as in amount and kind of knowledge shared. The use of multi-agent systems in KM is therefore motivated by the following observations:

- KM domains involve an inherent distribution of sources, problem solving capabilities and responsibilities (applies the autonomy and social ability of agents).
- The integrity of the existing organizational structure and the autonomy of participants need to be maintained (uses autonomous nature of the agents).
- Interactions in KM environments are fairly sophisticated, including negotiation, information sharing, and coordination (requires complex social skills with which agents are endowed).
- KM domains call for a functional separation between knowledge use and knowledge sources as a way to incorporate dynamic behavior into systems design (agents can act as mediators between source and application of knowledge).
- Solutions for KM problems cannot be entirely prescribed from start to finish and therefore problem solvers are required that can respond to changes in the environment, to react to the unpredictability of business process and to proactively take opportunities when they arise (uses reactive and proactive abilities of agents).

Moreover, the use of agents in KM can be seen in two perspectives. In one hand, agents can be used to model the organizational environment where the KM system will operate and, on the other hand, software agents can be used to implement the functionality of KM systems. Most existing KM projects involving agent technology concentrate on the second perspective, that is, use agents as modeling primitives in KM implementation tools. Agents are used to support and extend the activity of (human) users as highlighted in section 2.1. However, more and more interest is arising about the advantages of agent-based modeling of KM environments. Multi-agent models are used a the virtual counterpart of real-life societies and organizations which facilitates the design process since it reduces the conceptual distance between the system and the real-world application it has to model. This perspective is discussed in section 2.2.

2.1 Using Agents to Implement KM Systems

In agent-based implementations of knowledge management systems, software agents are employed as tools to manage loosely coupled information sources, to provide unifying presentation of distributed heterogeneous components and to personalize knowledge presentation and navigation. Agent-based KM services are [14]:

- search for, acquire, analyze, integrate and archive information from multiple heterogeneous sources,
- inform users when new information of special interest becomes available,
- negotiate for, purchase and receive information, goods or services,
- explain the relevance, quality and reliability of that information, and
- learn, adapt and evolve to changing conditions.

Several types of agents have been designed to implement these services. **Personal Assistants** represent the interests of the user and provide the interface between users and the system. They are concerned with user preferences and needs, and will present information in the preferred format, at the right time. A proactive personal assistant agent will not only perform the tasks given to it

[1] Achmea is one of the largest insurance and financial services companies in the Netherlands.

by the user, but will also suggest knowledge sources or other resources that are not explicitly requested if they match the user's interests. **Cooperative Information Agents** (CIAs) focus on accessing multiple, distributed and heterogeneous information sources. A CIA needs to actively maintain its information by communicating with others and reasoning about its own information. **Task analysts** are agents that monitor a certain task in the business process, determine the knowledge needs of the task, and gather that knowledge by communicating with other agents. The agent can also monitor the execution of the task and evaluate the applicability of the knowledge provided. The lessons learned here are used to update its internal state and optimizing task knowledge. **Source keepers** are agents dedicated to maintaining knowledge sources and are responsible for describing the knowledge contained in the source and extract relevant information for a given request. Source keepers can also actively propose uses for its source to other agents based on its own knowledge of other agents' needs. Finally, **mediators** are agents that can provide a number of intermediate information services to other agents. They may suggest collaboration between users with common interests, or provide information about the tools available. Mediators possess knowledge about the domain including where resources can be found.

2.2 Agent-Based Models for KM

Agent-based models for KM see agents as autonomous social entities (like employees in a company) that exhibit flexible, responsive and proactive behavior and the interactions among these entities give rise to complex dynamics. In this context agent is defined as 'one that has the power or authority to act' or 'one that takes action at the instigation of another'. This concept of agent is not new nor restricted to software.

Agent societies represent interactions between agents and are as such the virtual counterpart of real-life societies and organizations. Individual agents model specific roles in the society and interact with others as a means to accomplish the goals specified by those goals. This perspective makes the design of the system less complex since it reduces the conceptual distance between the system and the real-world application it has to model. Therefore, agent societies are an effective platform for virtual organizations because they provide mechanisms to allow organizations to advertise their capabilities, negotiate their terms, exchange rich information, and synchronize processes and workflow at a high-level of abstraction [17]. Agent societies are used both to simulate as to support knowledge management environments. An area of current research is Agent-mediated Knowledge Management, the development of generic knowledge management models that can be used as a basis for the development of customized adaptive solutions for KM. Our approach to agent-mediated knowledge management is described in section 4.

3. THE AGENT SOCIETY MODEL

An organization can be defined as a set of entities and their interactions, which are regulated by mechanisms of social order and created to achieve common goals. While current research on agents often takes the individual agents as starting point and looks at interaction from the perspective of an individual agent, that is, how it affects and influences the goals and beliefs of the agent, agent models for organizations must take the perspective of the organization as a whole. That is, multi-agent systems, or **agent societies**, must therefore be able to define the global aims of an organization, such as stability over time, some level of predictability, and clear commitment to aims and strategies, as well as the objectives and responsibilities of participants.

Agent Societies emerge from the idea that interactions occur not just by accident but aim at achieving some desired global goals. That is, there are goals external to each individual participant (or agent) that must be reached by the interaction of those participants. Desired behavior of a society is therefore often external to the participants. Social structure is determined by organizational design and not dependent on the participants. However, the behavior of individuals is motivated from their own goals and capabilities, that is, people will follow their own goals and motivations and will bring in their own ways of doing things into the society. That is, the actual behavior of the society emerges from the goal-pursuing behavior of the individual agents within the constraints set by the organizational. This creates a need to check conformance of the actual behavior to the desired behavior which has several consequences. Firstly, we need to make explicit the commitments between participants and the society.

The Agent Society Model that we have developed integrates a top-down specification of society objectives and global structure, with a dynamic fulfillment of roles and interactions by participants. The model separates the description of the structure and global behavior of the domain from the specification of the individual entities that populate the domain. This separation provides several advantages to our framework above traditional MAS models. On one hand, coordination and interaction in MAS are usually described in the context of the actions and mental states of individual agents [12]. In open societies such approach is not possible because agents are developed independently from the society and there is therefore no knowledge about the internal architecture of agents nor possibilities to directly control or guide it. Furthermore, conceptual modeling of agent societies (based on the social interactions) requires that interaction between agents be described at a higher, more abstract level, that is, in terms of roles and institutional rules. On the other hand, society models designed from an organizational perspective, reflect the desired behavior of an agent society, as determined by the society 'owners'. However, once 'real' agents populate the society, their own goals and behavior will affect the overall society behavior, that is, such social order as envisioned by the society designer is in reality a conceptual, fictive behavior. From an organizational perspective, the main function of individual agents is the enactment of roles that contribute to the global aims of the society. That is, society goals determine agent roles and interaction norms. Agents are actors that perform role(s) described by the society design. The agent's own capabilities and aims determine the specific way an agent enacts its role(s).

Several authors have advocated such role-oriented approaches to agent society development, especially when it is manifest to take an organizational view on the application scenario [6, 19]. Castelfranchi distinguishes between social order, the non-accidental, non-chaotic pattern of interaction in a given system of interacting agents and social control, agent action aimed at enforcing the conformity of behavior of other agents to some social norm [3]. He argues that due to the autonomous behavior of agents, social control is not enough to deal with the challenge of

social order, but agent societies must be able to cope with unintended, emergent behavior of its members. Figure 1 depicts the interrelation between the different models[2].

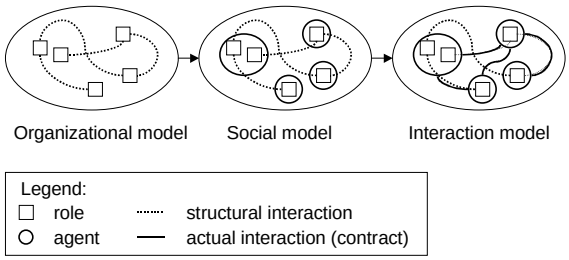

Figure 1. Organizational framework for agent societies

Starting point to the Agent Society Model is the **organizational model** (OM) that describes the structure and global characteristics of a domain from an organizational perspective from the premise that it is the society goals that determine agent roles and interaction norms. The organizational model is based on the analysis of the domain in terms of the coordination and normative elements and describes the expected behavior of the society. The framework does not specify the internal architecture of individual agents. Active entities are described as roles specified in terms of externally perceived actions and behavior. Other components of the model are constraints, interaction rules, and communicative and ontological frameworks.

We assume that individual agents are designed independently from the society to model the goals and capabilities of a given entity. In order to realize their own goals, individual agents will join the society as enactors of role(s) described in the organizational model. This means that several populations are possible for each organizational model. Agent populations of the organizational model are described in the **social model** (SM) in terms of commitments regulating the enactment of roles by individual agents. In the framework, agents are seen as autonomous communicative entities that will perform the society role(s) according to its own internal aims and architecture. Because the society designer does not control agent design and behavior the actual behavior of the society instance might differ from the intended behavior. The only means the society designer has for enforcing the intended behavior is by norms, rules and sanctions. That is, when an agent applies and is accepted for a role, it will commit itself to the realization of the role goals and it will function within the society according to the constraints applicable to its role(s). These commitments are specified as social contracts that can be compared to labor contracts between employees and companies. The society can sanction undesirable (wrong) behavior as a means to control how an agent will do its 'job'.

Finally, interaction between agents populating a society are described in the **interaction model** (IM) by means of interaction contracts. This model accounts for the actual (emergent) behavior of the society at a given moment. Interaction agreements between agents are described in interaction contracts. Usually interaction contracts will 'follow' the intended interaction possibilities specified in the organizational model. However, because of the autonomous behavior of agents, the interaction model must be able to accommodate other interaction contracts describing new, emergent, interaction paths.

A generic methodology to analyze a given domain and determine the type and structure of the agent society that best models that domain is described in [9]. Organization theory shows that organizations with different objectives exhibit different requirements for coordination. Coordination models (market, hierarchy and network) are determined by transaction costs and reflect the balance between organizational objectives and activities. For example, the market model fits well in an exchange situation whereas the hierarchical model is better suited for production environment. The methodology provides generic facilitation and interaction frameworks for agent societies that implement the functionality derived from the co-ordination model applicable to the problem domain. Standard society types as market, hierarchy and network, can be used as starting point for development and can be extended where needed and determine the basic norms and facilitation roles necessary for the society. These coordination models describe the different types of roles can be identified in the society and issues such as communication forms, desired social order and co-operation possibilities between partners. We distinguish between social, or **facilitation** roles, that is roles needed in order to keep the society going, and **operational** roles, which will provide the actual objectives of the society. Facilitation roles are usually played by mutually trusted agents, whereas trust between agents playing operational roles is determined by the type of society organization.

4. A KNOWLEDGE SHARING SCENARIO

The Knowledge Center for Non-Life Insurance at Achmea is responsible for the development and maintenance of non-life insurance knowledge that will give business units across Achmea a leading edge in this area. The center has a need for efficient and goal directed sharing of information and knowledge. Members of the network, insurance product developers and actuaries, are spread around the country at the location of the various brands of Achmea. Their knowledge and expertise are greatly valuable and useful to each other. But, because people are not aware of each other's capabilities, often they will discuss their business problems with a direct colleague just because he/she happens to be conveniently close and not because he/she is the best person to consult with [4]. The objectives of the KennisNet project are to structure, initiate and organize the sharing of knowledge across the non-life development group [8]. Moreover, KennisNet aims at setting up a framework that assures the continuous availability of consistent and up-to-date knowledge.

Experience shows that any technological support for knowledge exchange in such settings will greatly improve if users feel they know and can trust each other. Therefore, a dual approach for the development of KennisNet was chosen that incorporates direct contacts between members of the group with a intranet-based knowledge sharing server. Direct contacts between participants were formalized as quarterly workshops with the participation of all members. The aim of the workshops is twofold. In one hand workshops assure the creation, maintenance and uniformity of domain knowledge (for example, by inviting external authorities in a relevant field and by facilitating structured discussions around a theme). On the other hand, because participants get to

[2] A formalism to provide logical semantics to the model is described in [7].

know and appreciate other colleagues, a feeling of community is developed. In parallel to the workshops, a knowledge sharing server was developed. The development of this framework was inspired by several leading work in Knowledge Management models and systems (for example [10, 13, 15]) and follows the methodology described in section 4.1.

4.1 Developing KM solutions

The development methodology used for KennisNet adapts the usual phases (analysis, design, implementation and evaluation) of system development to the specific case of knowledge management systems. As organizations themselves, the process of developing knowledge management solutions is dynamic, and should be continuously monitored and adapted to the changing goals and structure of the organization. That is, the methodology must be seen as a continuous process, where each level may require changes in the previous levels. Furthermore, users and stakeholders must be involved in each level to assure the realization of a system that meets the needs and wishes of the organization and furthermore to assure that development keeps in pace with organizational and environmental changes.

The first step of this methodology is to identify the strategic goals of the organization or group and the problems that hinder their achievement. Next, problems must be analyzed from a knowledge perspective. The identification of generic solutions and its tailoring to the specific situation makes the design phase. The usability and evaluation phase takes care of the testing and applicability studies of the solution. Finally, in the implementation phase the chosen solutions are developed and built. The main methodological steps in the development of KennisNet are as follows:

Analysis: Knowledge problems arise in the conservation and sharing of knowledge and information across the organization. Existing knowledge is dispersed across the organization, knowledge gathering activities are often duplicated at different locations and employees are not aware of expertise and possibilities of each other. Moreover, employees do not have a clear motivation and reward for sharing their own knowledge and experience across the organization and different locations use different procedures and methods for development of insurance products.

Design: The objectives and the format of the project were analyzed, discussed and decided upon during several meetings in which all members of the group participated. It was chosen for a dual approach incorporating direct contacts between members of the group and a virtual meeting place and knowledge repository as described above. Users and stakeholders have indicated the most important requirements for the knowledge repository: task-oriented search of knowledge sources, knowledge creation support, availability of up to date, trusted sources, easy to use publishing functionality, communication support, possibility for control distribution conditions.

Implementation: Following the principle that gradual change is more favorable to the acceptance of the system, the implementation of the KennisNet was split in several phases each followed by an evaluation process. In the first phase, the existing technical infrastructure at Achmea (a Lotus Notes network) was used for the implementation of the repository. Available functionality of Lotus Notes was used to support direct access to contents, publishing and browsing of knowledge items and the implementation of facilities for discussion and broadcast of requests.

Evaluation: The first implementation phase is now completed. We have conducted a user satisfaction survey after the system was running for one year. The two main conclusions from this survey are that the workshop structure is greatly appreciated and found of great value but the added value and potential of the knowledge server is not clear to the users and the server is hardly used. The organization of the workshops is now for a large part in the hands of the different business units involved. Participants share the feeling that the potential of the repository as a virtual system to support knowledge sharing is large, but somehow its implementation lacks appeal and user attractiveness. The main reason for the lack of use of the repository, as pointed in the survey, is that users need a more personal means of interaction to make them comfortable exchanging knowledge. The survey also indicates that knowledge owners prefer to share their expertise within a controllable, trusted group under conditions negotiated for the specific situation and partners. This issue of trust, that emerges as one of the most relevant aspects of this evaluation, is further discussed in next section.

4.2 Trust and Knowledge Sharing

The community of users supported by the KennisNet operates across business unit boundaries, independently of the holding organizational structure. Sharing knowledge therefore implies that knowledge seeker and knowledge owner must be able to find each other and agree on the terms of the exchange. Several studies show that success of knowledge sharing is dependent on the level of trust and dependency between community members and on the kind of culture holding in the society [1]. In a individualistic culture, characteristic of Western societies, there is a strong feeling of autonomy and independence. Own knowledge is considered part of one's property and identity. Furthermore, self-inventing knowledge is considered more valuable that working with acquired knowledge. This explains the reluctance of users to make their knowledge and expertise available through a knowledge repository such as KennisNet where knowledge is decoupled from the knowledge owner. Knowledge owners prefer to share it within a controllable, trusted group under conditions negotiated for the specific situation and partners.

In order to encourage publisher participation, repository systems often use reward and sanction methods that provide an external 'objective' valuation for knowledge. That is, people that submit items to the repository are rewarded either by evaluation factors (contributing to career development), monetarily, by a point system or by explicit acknowledgement (highlight top contributors). Conversely, organizations can choose to 'punish' people who don't contribute enough to the repository.

Despite all reward and sanction schemas, people still rather keep the decision about sharing knowledge on their own hands, and want to be able to decide on a case by case basis whether an exchange is interesting to them or not. Furthermore, the value of a knowledge item cannot be fixed a priori but depends on many factors that are not always caught in a reward system. Finally, often knowledge and information requests are not a mere exchange of a finished 'product' but imply a work process during which the knowledge owner will develop the answer sought by the requester.

Experience with KennisNet shows that collaboration and direct exchange between people are the crucial aspects to realize. The next phase of development of KennisNet concentrates on the collaboration aspects of the system and provides mechanisms for knowledge exchange and collaboration that keep ownership links between knowledge and people and that support the search and negotiation process. Furthermore, the process of negotiation and valuation of knowledge[3] is supported. The result is an agent-mediated knowledge market based on the Agent Society Model described in the next section, that adds the following functionality to KennisNet:

- Possibility to share knowledge that is not available in the knowledge repository
- Support for coalition formation (in order to develop new solutions when knowledge is not available)
- Support for direct exchange between parties where the negotiation of exchange conditions happens in a case to case basis

However effective, such solution will only be effective when sharing is anchored into organizational culture and processes. Change management initiatives to enforce such culture are still crucial for the success of any collaboration support project.

5. USING ASM TO IMPROVE KENNISNET

Based on the Agent Society Model, we are developing a Knowledge Market to support KennisNet members to exchange knowledge with each other, in a way that preserves the knowledge, rewards the knowledge owner and reaches the knowledge seeker in a just-in-time, just-enough basis. This model enables for the incorporation of individual initiative (embodied in personal agents) within organizational processes (described by organizational model of the society).

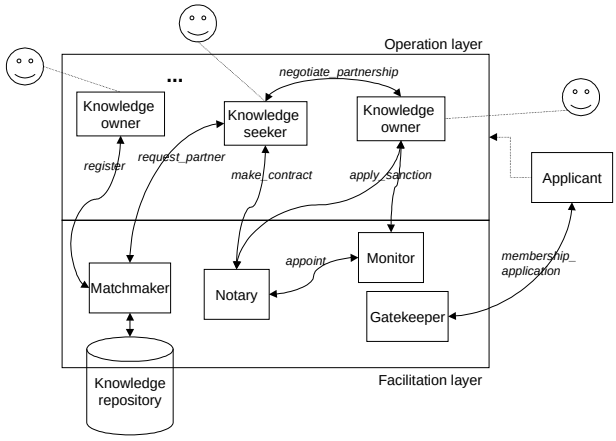

Figure 2. Knowledge Market architecture

The architecture of the Knowledge Market is illustrated in figure 2 and consists of two layers **operation** and **facilitation.** The 'goods' to be exchanged in this market are descriptions of knowledge needs and assets, similar to items in the knowledge repository developed in the first phase.

The Knowledge Market must be able of describing its rules of interaction, regulations, facilities and legal guarantees to applying members. Furthermore, the marketplace must be able to enforce the interaction contracts agreed between participants and punish potential violators (for example, through loss of reputation or eventually banishment).

5.1 Organizational Model

The social activity of agents is coordinated at the facilitation level. That is, at facilitation level, the 'norms' of the society are kept and enforced and interaction is ensured. Furthermore, facilitation agents ensure interaction by monitoring and supporting contract formation, take care of introducing new agents to the rules of the society and keep track of the reputation of trading agents. Typical facilitation agent roles are matchmakers, gatekeepers and reputation agents. **Gatekeepers** are responsible for accepting and introducing new agents to the knowledge market. **Matchmakers** keep track of agents in the system, their needs and possibilities and mediate in the matching of demand and supply of knowledge. **Notaries** register and keep track of collaboration contracts between agents. Finally, **monitoring agents** are trusted third parties that keep track of the execution of collaboration contracts between agents.

The operational roles identified from the requirements and domain characteristics are knowledge seeker and knowledge owner, which are both specific aspects of personal assistants. The **seeker agent** provides the interface between the user seeking collaboration and the market and reflects the personal preferences, learning style and work process of the user. **Owner agents** are responsible to 'advertise' the capabilities of a knowledge worker and vindicate the interests of the knowledge owner. The owner agent can also actively offer the services and skills of its user propose uses for its source to other agents based on its own knowledge of other agents needs or indicated by the matchmaker.

Furthermore, the organization must describe how its objectives are to be achieved by the interaction between roles. In ASM roles interact following interaction scene scripts which are composed into an interaction structure to describe more complex activity. An interaction **scene script** describes a scenario of activity, that is, how roles interact and evolve in the context of a scene. Interaction structures are depicted as directed graphs where the boxes represent scenes and the arcs possible transitions between scenes. Facilitation roles active in a scene are represented by an oval linked to the scene box.

The interaction structure displayed in figure 3 describes the activity of the user roles (knowledge owner and seeker) in the Knowledge Market. Knowledge seekers and knowledge owners apply to enter the society through the 'Member registration' scene. If the application is successful, the agent proceeds to the 'observing' scene. In this scene the agent is not active in a knowledge exchange but can access the repository, follow newsgroups, etc. Both seeker or owner agents can initiate an exchange by respectively announcing a need or a skill. In the 'negotiate partnership' scene, seeker and owner discuss the conditions of an exchange. The result is a interaction contract that describes an instance of the 'exchange' scene. Interaction scripts

[3] That is, how much is a specific piece of knowledge worth, at a specific moment, under the specific circumstances holding and to the specific partners involved in the exchange.

serve as a blueprint for the actual interactions between agents enacting roles.

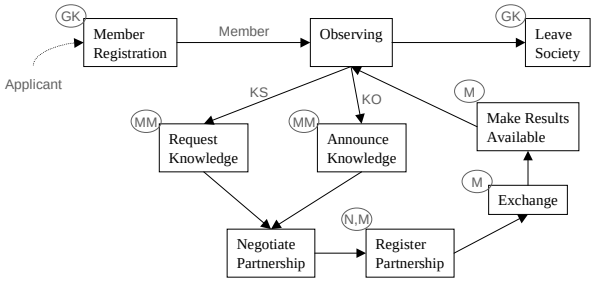

Figure 3: Interaction structure of Knowledge Market

5.2 Social Model

Social contracts describe the agreements between participating agents and the Knowledge Market society. People seeking collaboration can initiate through the user interface of the Knowledge Market a personal agent that will act as their avatar in the system. This agent will use the preferences and conditions specified by the user to find appropriate partners and negotiate exchange terms. Furthermore, factors such as privacy, secrecy and competitiveness between brands and departments may influence the channels and possibilities of sharing and must thus be considered. Matching of supply and demand of knowledge is very complex and requires techniques such as fuzzy matching algorithms, or multi-attribute matching. Due to space restrictions we will not further discuss this here.

Negotiation of social contracts is done between the applicant agent and the Gatekeeper agent, which will watch over the interests of the society itself. For example, imagine that Anne is a member of the KennisNet group that is seeking knowledge on price policies from the competition. Anne will initiate an agent enacting the knowledge seeker role in the Knowledge Market. During the Member admittance scene, the conditions for Anne's agent will be negotiated and fixed in a social contract that specifies, for instance, which parts of the repository Anne is allowed to access, which are the obligations of Anne concerning the publication of knowledge items received as result of an interaction, and whether Anne allows for items that she provides to be published or not.

5.3 Interaction Model

The **Interaction Model (IM**), specifies the activity of an Agent Society in terms of agreements between role enacting agents (specified in the SM) concerning the enactment of interaction scenes (specified in the OM). The scene scripts specified in the OM describe possible interactions as desired by organizational design. In fact, scripts are abstract, generic patterns for interaction which can be fulfilled in many ways.

When role enacting agents come together in an interaction scene, the actual interpretation of the scene script, that is the interaction protocol to be used must be agreed upon. In ASM, role enacting agents will, for each scene, negotiate an **interaction contract** that defines their partnership, and fixes the way a specific interaction scene is to be played. Interaction contracts describe instances of scene scripts which inherit the organizational norms and objectives described in the interaction script and possibly extend or restrain it to accommodate the specific needs and desires of the participating agents.

The following example describes a contract between two members. In this example, fictive but typically possible in the domain of non-life insurance, Anne will provide Bob with a report about competition prices, on the condition that Bob will give her comments on the report (that she will have to present to her Unit directors) and eventually share with her his new pricing concept for car insurance. This contract is generated during the 'Negotiate partnership' scene and registered in the 'Register partnership' scene. In this scene, the notary agent will assign a monitor agent to check the fulfillment of the contract between Anne and Bob.

6. CONCLUSIONS AND FUTURE WORK

Current developments in KM show a shift in the focus of KM from knowledge to collaboration. The aim of KM is no longer just the management of activities related to the creation, preservation and distribution of knowledge assets but the management and nurturing of collaboration between people. Such **collaboration management systems** call for approaches that are reactive and proactive in relation to the needs and expectations of its users. Agent concepts, which originated in artificial intelligence but which have further developed and evolved in many areas of computing, hold great promise for responding to the new realities of knowledge and collaboration management. In this paper, we have presented an agent-based model for organizations that fulfills the specification requirements of collaboration management systems. The model is being applied to the development of a knowledge market at Achmea.

Agent concepts can fundamentally alter the nature of knowledge management both in the way KM systems are build as well as the way organizations are analyzed and modeled. On the one hand, the technical embodiment of these concepts can lead to advanced functionality of KM systems, e.g. personalization of knowledge presentation and matching supply and demand of knowledge. On the other, the rich representational capabilities of agents as modeling entities allow more faithful and effective treatments of complex organizational processes. In our opinion, one of the main contributions of agent-based modeling of KM environments is that provides a basis for the incorporation of individual initiative and collaboration into formal organizational processes. Future research in agent-oriented approaches to knowledge management and collaborative systems must therefore include:

- Methodologies are needed that support the analysis of knowledge management needs of organizations and its specification using software agents and agent societies
- Reusable agent-oriented knowledge management frameworks, including the description of agent roles, interaction forms and knowledge description
- Agent-based tools for organizational modeling and simulation that help determine the knowledge processes of the organization
- The role of learning in agent-based knowledge management systems, namely, how to use agent learning to support and extend knowledge sharing

7. REFERENCES

[1] Ali, I., Pascoe, C., Warne, L.: Interactions of organizational culture and collaboration in working and learning. IEEE Journal Educational Technology & Society. 5(2), April 2002.

[2] J.S. Brown and E.S. Gray: The People are the Company. *Fast Company*, 1:78-82, 1995. URL: http://www.fastcompany.com/online/01/people.html

[3] Castelfranchi, C.: Engineering Social Order. In: Omicini, A. Tolksdorf, and Zambonelli, F. (Eds.): Engineering Societies in the Agent World, LNAI 1972, Springer-Verlag, 2000.

[4] Davenport, T. and Pruzak L.: Working Knowledge: How organisations manage what they know, Harvard Business School Press, 1998.

[5] Dignum, V., Dignum, F.: The Knowledge Market: Agent Mediated Knowledge Sharing. Marik, V., Muller, J., Pechoucek, M. (Eds.): Proceedings of CEEMAS'03, Prague, June 16 – 18. LNAI, Springer-Verlag, 2003.

[6] Dignum, V., Meyer, J-J., Weigand, H., Dignum, F.: An Organizational-oriented Model for Agent Societies. In: Proc. Int. Workshop on Regulated Agent-Based Social Systems: Theories and Applications (RASTA' 02), at AAMAS, Bologna, Italy, July, 2002.

[7] Dignum, V., Meyer, J.-J., Dignum, F., Weigand, H.: Formal Specification of Interaction in Agent Societies. 2nd Goddard Workshop on Formal Approaches to Agent-Based Systems (FAABS), Maryland, Oct, (2002)

[8] Dignum, V.: A Knowledge Sharing Model for Peer Collaboration in the Non-Life Insurance Domain. In: Proc. German Workshop on Experience Management, Lecture Notes in Informatics, German Society for Informatics, Berlin, 2002.

[9] Dignum, V., Weigand, H., Xu L.: Agent Societies: Towards framework-based design. In: Wooldridge, M., Ciancarini P., Weiss, G. (Eds.): Agent-Oriented Software Engineering II, LNCS 2222, Springer-Verlag, pp. 33 – 49, 2002.

[10] Domingue, J. B. and Motta, E.: A Knowledge-Based News Server Supporting Ontology-Driven Story Enrichment and Knowledge Retrieval. Proc. EKAW' 99, 1999, URL: http://kmi.open.ac.uk/people/motta/papers/planet_onto.pdf.

[11] L. van Elst, V. Dignum, A. Abecker: Agent-Mediated Knowledge Management. Agent-Mediated Knowledge Management: Papers from 2003 AAAI Spring Symposium. Technical Report SS-03-01. AAAI Press, 2003.

[12] Ferber, J., Gutknecht, O.: A meta-model for the analysis and design of organizations in multi-agent systems. Proc. of ICMAS'98, IEEE Press, 1998.

[13] Gandon, F., Dieng, R., Corby, O. & Giboin, A.: A Multi-Agent System to Support Exploiting an XML-based Corporate Memory. Proceedings PAKM' 00Basel, (2000).

[14] Klusch, M. (Ed.): Intelligent Information Agents: Agent-based Information Discovery and Management in the Internet. Springer-Verlag, 1999.

[15] Mentzas, G., Apostolou, D., Young, R., Abecker, A.: Knowledge networking: a holistic solution for leveraging corporate knowledge. Journal of KM, MCB, 5(1), 2001.

[16] O'Leary, D.: Knowledge Management Systems: Converting and Connecting. IEEE Intelligent Systems, May-June 1998, pp. 30-33.

[17] Preece, A., Hui, K.-Y., Gray, W., Marti, P., Bench-Capon, T. Jones D. & Cui Z.: The KRAFT Architecture for Knowledge Fusion and Transformation. Proc. 19th SGES Int. Conference on Knowledge-based Systems and Applied Artificial Intelligence, 1999.

[18] Reid G. Smith and Adam Farquhar: The Road Ahead for Knowledge Management: An AI Perspective, *AI Magazine*, AAAI, 21(4):17-40, Winter 2000.

[19] Zambonelli F., Jennings, N., Wooldridge, M.: Organisational Abstractions for the Analysis and Design of Multi-Agent Systems. In: Ciancarini P., Wooldridge, M. (eds.): Agent-Oriented Software Engineering, LNCS 1957, Springer-Verlag, 2001.