Modelling agent societies: co-ordination frameworks and institutions

Virginia Dignum [1, 2], Frank Dignum[2]

[1] Achmea
PO Box 866, 3700 AW Zeist, The Netherlands
virginia.dignum@achmea.nl
[2] University Utrecht
Institute for Information and Computing Sciences
PO Box 80.089, 3508TB Utrecht, The Netherlands
dignum@cs.uu.nl

Abstract. Organisations can be defined as a set of entities regulated by mechanisms of social order and created by more or less autonomous actors to achieve common goals. Multi-agent systems are a natural choice to design organisational systems due to the proactive and autonomous behaviour of agents. However, in business environments it is necessary to consider the behaviour of the global system and the collective aspects of the domain. In this paper, we argue that multi-agent systems should be designed around organisational co-ordination frameworks that reflect the co-ordination structures of the particular organisation. As in human societies, we argue that norms and institutions are a way for agent societies to cope with the challenge of social order. Through institutions, conventions and interaction patterns for the co-ordination of agents can be specified, monitored and managed.

Keywords: Agent societies, co-ordination, institutions, virtual organisations

1. Introduction

In an increasing number of domains, organisations need to work together in transactions, tasks or missions. Work relationships between people and enterprises are also shifting, from the 'job-for-life' paradigm to project-based virtual enterprises in which people and organisations become independent contractors. Furthermore, there is often a decentralised ownership of data, expertise, control and resources involved in business processes. Often, multiple, physically distributed organisations (or parts hereof) are involved in one business process. Each organisation, or part of an organisation, attempts to maximise its own profit within the overall activity. Different groups within organisations are relatively autonomous, in the sense that they control how their resources are created, managed or consumed, and by whom, at what cost, and in what time frame. There is a high degree of natural concurrency (many interrelated tasks and actors are working simultaneously at any given point of the

business process) which makes it imperative to be able to monitor and manage the overall business process (e.g. total time, total budget, etc.). The above considerations show an increasing need for transparency in the representation and implementation of business processes. However, the fact that business processes are highly dynamic and unpredictable makes it difficult to give a complete a priori specification of all the activities that need to be performed, which are their knowledge needs, and how they should be ordered.

An organisation can be seen as a set of entities regulated by mechanisms of social order and created by more or less autonomous actors to achieve common goals. Because of the proactive and autonomous behaviour of agents it is natural to design organisation systems using agent societies that mimic the behaviour and structure of human organisations [22]. Agent societies represent the interactions between agents and are as such the virtual counterpart of real-life societies and organisations. Agents model specific roles in the society and interact with others as a means to accomplish their 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 organisations because they provide mechanisms to allow organisations to advertise their capabilities, negotiate their terms, exchange rich information, and synchronise processes and workflow at a high-level of abstraction [18].

Business environments must consider the behaviour of the global system and be able to incorporate collective characteristics of an organisation such as stability over time, some level of predictability, and clear commitment to aims and strategies. However, typically, agents are assumed to pursue their own individual goals and global behaviour emerges from individual interactions. Existing architectures, behavioural strategies and models for group formation often assume this individualist perspective, which is not suitable for the representation of collective characteristics of an organisation.

In this paper, we argue that multi-agent systems developed to model and support organisations must be based on co-ordination frameworks that mimic the structure of the particular organisation. Methodologies for designing such multi-agent systems have to be able to describe and apply different types of co-ordination models. As in human societies, we argue that norms and institutions are a way for agent societies to cope with the challenge of social order. Agents act autonomously according to their own goals and capabilities. Institutions are needed to enforce the global behaviour of the society and assure that the global goals of the society are met. Different co-ordination models have different needs in terms of how institutions can manage them and consequently which type of roles are present in the institution and which should be the capabilities of the agents fulfilling those roles.

The paper is organised as follows. In section 2 we introduce a model for agent societies that is based on the structural characteristics of an organisation and supported by different co-ordination frameworks. The role of institutions in the engineering of agent societies is described in section 3. In section 4, the characteristics of the different frameworks are described in more detail. Practical applications of this model being developed at Achmea are described in section 5. Finally, in section 6 we present some conclusions and indicate directions for future work.

2. Organisational multi-agent systems

There is a rising awareness that multi-agent systems and cyber-societies can best be understood and developed if they are inspired by human social phenomena [1, 5, 23]. Organisations can be seen as sets of entities regulated by mechanisms of social order and created by more or less autonomous actors to achieve common goals. Multi-agent systems that model and support organisations should therefore be based on co-ordination frameworks that mimic the structure of the particular organisation and be able to dynamically adapt to changes in organisation structure, aims and interactions. The structure of the organisation determines important autonomous activities that must be explicitly organised into autonomous entities and relationships in the conceptual model of the agent society [11].

In a business environment, the behaviour of the global system and the collective aspects of the domain, such as stability over time, predictability and commitment to aims and strategies, must be considered. Organisations are expected to form a coherent, stable system that realises the objectives for which it was designed. When multi-agent systems, or **agent societies**, are considered from an organisational point of view, the concept of desirable social behaviour becomes of utmost importance. That is, from the organisational point of view, the behaviour of individual agents in a society should be understood and described in relation to the social structure and overall objectives of the society. However, until recently, multi agent systems are mainly viewed from an individualistic perspective, that is, as aggregations of agents that interact with each other [13]. In this view looks at the behaviour of multi-agent systems from the perspective of the agent itself, in terms of how an agent can affect the environment or be affected by it.

Open societies assume that participating agents are designed and developed outside the scope and design of the society itself and therefore the society cannot rely on the embedding of organisational and normative elements in the intentions, desires and beliefs of participating agents but must represent these elements explicitly.

The above considerations lead to the following requirements for engineering methodologies for agent societies:

- Agent societies must include formalisms for the description, construction and control of the organisational and normative elements of a society (roles, norms and goals) instead of just agent states [1, 23].
- The methodology must provide mechanisms to describe the environment of the society and the interactions between agents and the society, and to formalise the expected outcome of roles in order to verify the overall animation of the society.
- The organisational and normative elements of a society must be explicitly specified since an open society cannot rely on its embedding in the intentions, desires and beliefs of each agent [7, 17]
- Methods and tools are needed to verify whether the design of an agent society satisfies its design requirements and objectives [15].
- The methodology should provide building directives concerning the communication capability and ability to conform to the expected role behaviour of agents participating in the society.

One last point is that in order to facilitate the development of organisation oriented multi-agent systems it is important to relate to the organisational perception of the domain. That is, a common ground of understanding must be found between agent engineers and organisational practitioners. In our opinion co-ordination is an ideal candidate. In one hand, organisational science and economics have since long researched co-ordination and organisational structures. Relationships between and within organisations are developed for the exchange of goods, resources, information and so on. Depending on transaction costs and interdependent relations, different co-ordination models (market, hierarchy or network) are possible. On the other hand, co-ordination is one of the cornerstones of agent societies and is considered an important problem inherent to the design and implementation of MAS [2]. However, the implications of the co-ordination model for the agent society architecture and design method have usually not been considered. So far, research about co-ordination in MAS has been mainly limited to the study of technical aspects of co-ordination, such as control and planning. In many cases the social organisation is left implicit in the design of the agent society. An agent society model that incorporates co-ordination issues related to the organisational perspective of the domain will thus facilitate the introduction of multi-agent systems in organisations. Co-ordination forms therefore the basis for the model for agent societies introduced in this paper. The following notions are core concepts in our model:

- **Agents** are the inhabitants of the agent society that interact with each other using the communication framework. Agents are designed outside the scope of the society, and may have their own goals and behaviour rules. Every agent within the society must adopt some role(s).
- **Roles** are patterns of behaviour. Roles are described in the society model in terms of externally perceived behaviour
- **Rules** or **constraints** describe the desired behaviour of agents in the society and its consequences in terms of sanctions, rewards and limitations.
- **Communication framework** describes the interaction between agents. It includes the description of the society ontology (vocabulary understood within the society), the communication language (intentions and utterances) and the representation language for domain content.
- **Goals** are the overall objectives of the society

As described before, the design of organisation-oriented multi-agent systems must account for the representation and management of normative aspects of the society and incorporate collective characteristics of an organisation such as stability over time, some level of predictability, and clear commitment to aims and strategies. Human societies have successfully coped with similar issues through the use of institutions that monitor behaviour and enforce social laws. Therefore our agent society model consists of two layers. The institutional layer, or **institution**, provides the social and institutional backbone of the society and are the place where social norms and rules are explicitly specified. Institutional agent roles are designed to enforce the social behaviour of agents in the society and assure the achievement of global goals of the society. The **operational layer** models the overall objectives and intended action of the society and is therefore domain dependent. Interaction between agents in the operational level is not necessarily bound by the institution, and agents are free to act according to their own objectives. However, in order to join the society

agents must commit themselves to the social rules described and enforced by the institution.

3. The role of institutions

Usually human organisations and societies use norms and conventions to cope with the challenge of social order. Norms and conventions specify the behaviour that society members are expected to conform to and are suitable for decentralised control. In most societies, norms are backed by a variety of social institutions that enforce law and order (e.g. courts, police), monitor for and respond to emergencies (e.g. ambulance system), prevent and recover from unanticipated disasters (e.g. coast guard, fire-fighters), etc. In this way civilised societies allow citizens to utilise relatively simple and efficient rules of behaviour, offloading the prevention and recovery of many problem types to social institutions that can handle them efficiently and effectively by virtue of their economies of scale and widely accepted legitimacy. Successful human institutions achieve sustainability of citizens and increase the welfare of the society as a whole. Several researchers have recognised that the design of agent societies can benefit from abstractions analogous to those employed by our robust and relatively successful societies and organisations. There is a growing body of work that touches upon the concepts of norms and institutions in the context of multi-agent systems (cf. [9, 10, 12]).

The benefit of an institution resides in its potential to lend legitimacy and security to its members by establishing norms. The electronic counterpart of the physical institution does a similar task for software agents: it can engender trust through certification of an agent and by the guarantees that it provides to back collaboration. However, the electronic institution can also function as the independent place in which al types of agent independent information about the interaction between the agents within the society is stored. E.g. it defines the message types that can be used by the agents in their interactions, the rules of encounter, etc. In general, institutions enable to:

- Specify the co-ordination structure that is used
- Describe exchange mechanisms of the agent society
- Determine interaction and communication forms within the agent society
- Facilitate the perception of individual agents of the aims and norms of an agent society
- Enforce the organisational aims of the agent society

In our approach we consider that an agent society consists of two layers: one is facilitation-oriented and the other goal-oriented. The institution acts as mediator and animator for the members, who bring various skills and services, and customers (or groups of customers) who bring their problems and requirements. The most important service the institution provides is to regulate the interaction between members. Because the way interaction between agents happens depends on the co-ordination model, institutions will need to be defined differently for each co-ordination model.

We have shown above that co-ordination models provide a setting for agent societies by setting out the goals of the society and the roles (what you can do) need to achieve those goals. Institutions will enforce this model by setting out the scenes

(where you can do it) and protocols (what you can say) for interaction in the society. This defines how agents can interact with the institution or with other agents in the society. The whole point of institutions is for the additional services it can provide and the trust and guarantees that are established through the institution's credibility and norms.

Looking at the structure of organisations we can anticipate the types of interaction involved in interacting in a particular co-ordination model. Thus, an institution defines a performative structure and a dialogical framework, by which we mean, it prescribes the actions members can take and when and where to perform those actions, and determines the form of conversations between members. Therefore, the way norms and conventions are specified and enforced in a society depends on the co-ordination model. In hierarchies, norms and conventions can be embedded in the power relations. These relations determine which agent can demand an action from which other agent or which agent has priority over the resources. The controlling agent is supposed to uphold the norms of the society by managing the sub-ordinate agents according to them. In markets, norms and conventions are for a large part embedded in the market mechanism chosen. E.g. the auction mechanisms try to ensure that all agents get an opportunity to require a resource relative to their private value for that resource. Cheating by over- or underbidding does not lead to any benefit for the agent and thus is prevented by the mechanism itself. In network models explicit roles are defined to 'represent' the institutions that enforce monitoring and trust, and trace the fulfilment of contracts. Some examples of these roles will be given in the next section.

4. Co-ordination models

We identify three basic co-ordination types of agent societies following on the classification of organisations used in organisational theory. Hence, co-ordination of agent societies follows a market, network or hierarchy model. Each co-ordination model determines a different framework for agent societies that describe the institutional layer of the society. The institutional layer must describe institutional roles, the way interactions between roles are organised and the way the interface between the society and the 'outside world' is defined. That is, the co-ordination model determines the institutional roles, social norms and interaction forms in the society.

In **markets**, agents are self-interested (determine and follow their own goals) and value their freedom of association and own judgement above security and trust issues. **Network** organisations are built around general patterns of interaction or contracts. Relationships are dependent on clear communication patterns and social norms. Agents in a network society are still self interested but are willing to trade some of their freedom to obtain secure relations and trust. Finally, in a **hierarchy** interaction lines are well defined and the facilitation level assumes the function of global control of the society and co-ordination of interaction with the outside world. Table 1 gives an overview of the characteristics of different agent societies.

The characteristics and requisites for each role determine the required capabilities of agents fulfilling the role in terms of its communicative and reasoning capabilities.

For example, agents acting in a network are expected to negotiate their interaction procedures and are motivated by mutual interest. This means such agents will be required to be able to reason about other agents and need to possess 'heavy' negotiation algorithms. On the other hand, members of a hierarchical society follow pre-determined communication lines and have limited need for negotiation, thus agents fulfilling hierarchical roles can be much simpler in terms of communication and negotiation capabilities.

Table 1. Characteristics of agent societies

	Market	**Network**	**Hierarchy**
Type of society	Open	Trust	Closed
Members 'values'	Self interest	Mutual interest	Dependency
Society purpose	Exchange	Collaboration	Production
Interaction	Interaction is based on standards; communication concerns exchange only	Both interaction and exchange procedures can be negotiated	Specified on design

In order to be able to assign roles to agents, the society model must be able to make some assumptions on the capabilities of the agent. However, since open societies are based on the principle that participating agents are developed independently from the society, it is not possible to make too many assumptions on the specific architecture of agents. We use a generic agent model as a basis for our assumption on agents. This model is based on the work of [4]. This model makes no demands on the way internal agent components are designed, but assumes that agents will in some way be able to use the indicated capabilities. Agent engineers are free to design their agents' internal components in different ways, and even do without some of the components. The description of roles in the society model refers to this agent model and describes the society expectations on the capabilities of agents that perform the role.

We have developed a methodology (described in more detail in [11]) for the design of agent societies based on co-ordination structures. The aim of the methodology is to provide generic facilitation and interaction frameworks for agent societies that implement the functionality derived from the co-ordination model applicable to the problem domain. We can compare this process to the design a generic enterprise model including roles as accountants, secretaries and managers, as well as their job descriptions and relationships, and then extending it with the functions necessary to achieve the objectives of the given enterprise. These are, for example, designers and carpenters if the firm is going to manufacture chairs, and programmers and system analysts if the enterprise is a software house.

4.1. Roles in the Market co-ordination model

The main goal of a market is to facilitate exchange between agents. In a market model, agents are self-interested (determine and follow their own goals), represent (or provide) services and/or competencies and compete to perform tasks leading to the satisfaction of their own individual objectives. Agents are usually assumed to be

heterogeneous and the negotiation rules are fixed (for example Contact Net or Dutch auction). Interaction in markets occurs through communication and negotiation with the market rules.

Co-ordination through a market mechanism is particularly well suitable for situations in which resources can be described easily or are commoditised, there are several agents offering the same (type) of resources and several agents that need them. Besides obvious e-commerce applications, the market architecture is also a good choice to model product or service allocation problems. Being self-interested, agents will first try to solve their own local problem, and then agents can potentially negotiate with other agents to exchange services or goods in shortage or in excess. Agent societies based on the market model have been used to represent virtual enterprises [19]. Facilitation roles necessary for the organisation of a market model are:

- **Identification**: has the task of registering members of the society. Can also receive requests from matchmakers or bankers
- **Matchmaker**: keeps track of agents in the system, their needs and possibilities and mediates in the matching of demand and supply of goods or services. Depending on the domain, the task of a matchmaker can be a simple unification algorithm or a complex fuzzy matching algorithm. Matchmakers must be able to receive requests from agents and contact possible partners. Depending on the domain, this capabilities can be just a simple message *request(buyer?, product, price)* or *announce(seller, product, price)* or it can involve more general communication determining the requirements on both products and potential partner. Furthermore, matchmakers need to have knowledge of current sellers and requests in the society. I.e. they need to maintain a kind of yellow guide.
- **Banking**: define ways to value the goods to be exchanged and determine profit and fairness of exchanges. A banking service builds confidence for customers as well as offers guarantees to the members of the society. Bankers must be able to receive requests from agents wishing to register themselves (open an account) or wishing to get information on other agents, and need to keep knowledge on their clients

4.2. Roles in the Hierarchy co-ordination model

Hierarchies co-ordinate the flow of resources or information by controlling and directing it at a central point in the managerial hierarchy. Interaction and design are determined by managerial decisions and achievement of global goals is most critical. Demand parties do not select a supplier from a group of potential suppliers: they simply work with a predetermined one. In hierarchical systems, each agent controls a statically defined sub-hierarchy (possibly empty), in many cases an administrative domain of some kind. Environments where the workflow is fixed and cases are repetitive, such as in automated manufacturing are well suited to the hierarchical model. In such systems, reliable control of resources and information flow requires central entities that manage local resources and data but also need quick access to global ones. Hierarchical models of agents have been used to model information agents ([6]) and the management of communication networks ([14]).

In a hierarchical co-ordination model, agents at facilitation level are mainly dedicated to the overall control and optimisation of the system activities. Sometimes, these facilitation activities are concentrated in one agent, typically the 'root' agent of the hierarchy. Facilitation roles necessary to the organisation of a hierarchy are:

- **Controllers**: monitor and orient the overall performance of the system or of a part of the system. Autonomous agents have local perspective and their actions are determined by its local state. Therefore, in a hierarchical co-ordination model it is necessary to have an agent whose role is to control the overall performance of the system.
- **Interface agents:** are responsible for the communication between the system and the 'outside world'. In this architecture communication lines between agents are predefined. Furthermore, agents are usually not free to enter or leave the system. Therefore communication with the outside world must be regulated at the facilitation level.

4.3. Roles in the Network co-ordination model

Networks are coalitions of self-interested agents that agree to collaborate to achieve a mutual goal. Agents in a network society are self-interested but are willing to trade some of their freedom to obtain secure relations and trust. Instead of a direct exchange as in markets, agents in a network model are willing to trade their services in exchange for later or soft rewards (such as a increase of prestige). Network co-ordination models are built around general patterns of interaction or contracts. Relationships are dependent on clear communication patterns and social norms. Co-ordination is achieved by mutual interest, possibly using trusted third parties, and according to well-defined rules and sanctions. These coalitions have been studied in the area of game theory and Distributed Artificial Intelligence (DAI) [20]. Dellarocas introduces the concept of Contractual Agent Societies (CAS) as a model for developing agent societies [7]. Network co-ordination models provide an explicit shared context, describing rules and social norms for interaction and collaboration. The society is responsible to make its rules and norms known to potential members. Agents in a network society enter a social contract with the society in which they commit themselves to act within and according to the norms and rules of the society.

At the facilitation level of a network, agents monitor, register and help others form contracts, introduce (teach) new agents to the rules of the market and keep track of the reputation of agents. Furthermore, they keep and enforce the 'norms' of the agent community and ensure interaction. Roles at facilitation level in networks are:

- **Matchmaker**: keeps track of agents in the system, their needs and possibilities and mediates in the matching of demand and supply of goods or services. In the network co-ordination domain, the matching of supply and demand is usually more complex than in markets, because long-term interests have to be taken into account. Therefore, matchmakers will need to use, for instance, fuzzy matching algorithms, or multi-attribute matching to be able to perform their tasks. As in markets, matchmakers must be able to receive requests from agents and contact possible partners and need to keep knowledge of current offers and requests in the society.

- **Gatekeeper:** is responsible for accepting and introducing new agents to the market. Agents entering the marketplace must be informed about the possibilities and capabilities of the market. Gatekeepers negotiate the terms of a social contract between the applicant and the members of the market.
- **Notary:** register collaboration contracts between agents.
- **Monitoring agents:** are trusted third parties that keep track of the execution of collaboration contracts between agents.

5. Applications

The framework described in this paper can be applied to very distinct problem domains, because it concentrates on the organisational elements of the agent societies. At Achmea, a financial and insurance holding organisation operating mainly in the Netherlands, the ideas described in this paper are being applied to the development of a system for support of knowledge sharing (K-Exchange). This project is further described below. Other plans for application this framework include the development of a mediation system in the area of secondary healthcare co-ordination (CareMarket). Although both projects are still in a initial phase and no results are as yet available, the models developed illustrate the possibilities of the different co-ordination frameworks and the use of institutions

CareMarket

The aim of CareMarket, a community care project is to provide Achmea clients with extra (unskilled) care services, which are not covered by professional organisations, or for which there are long waiting lists. The project is inspired by the LETS concept and based on non-monetary trading concepts. Matching of supply and demand in this kind of situations is not trivial. The fulfilment of a demand usually requires the co-ordination of several suppliers, suppliers are voluntaries and usually of a very limited and constrained range of services. Furthermore, it is desirable to keep a continuity of relationships between suppliers and clients (people tend to develop friendship relations with their care tenders / care takers and do not really appreciate to see a new face every day). This pilot is in a very initial phase of development but there is already a clear realisation that the institutional framework described in this paper will be directly applicable to the development of an agent-based simulation prototype. The evaluation of the system through the simulated institution populated with intelligent agents, representing suppliers and clients, will provide insights and support to the eventual deployment of a real community pilot.

Knowledge Exchange Network

The objective of the Knowledge Exchange Network project is to support non-life insurance experts 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. Current users of the pilot project are project managers, product developers, actuaries in the Non-life group of Achmea but in the future it will be extended to other people (e.g. call centre employees) and groups. Members of the network have lots of knowledge, which is greatly valuable and useful to each other.

So, one of the main tasks of the Knowledge Exchange Network is to support and encourage their contacts. Experience shows that any technological support for knowledge exchange greatly improves if users feel they know and can trust each other. Therefore, the Knowledge Management activities at the Non-life group consist of two parts: face-to-face workshops with the aim of getting people to know each other, share their experiences and extend their knowledge and a virtual network, aiming both at a knowledge repository and at the support of communication and collaboration.

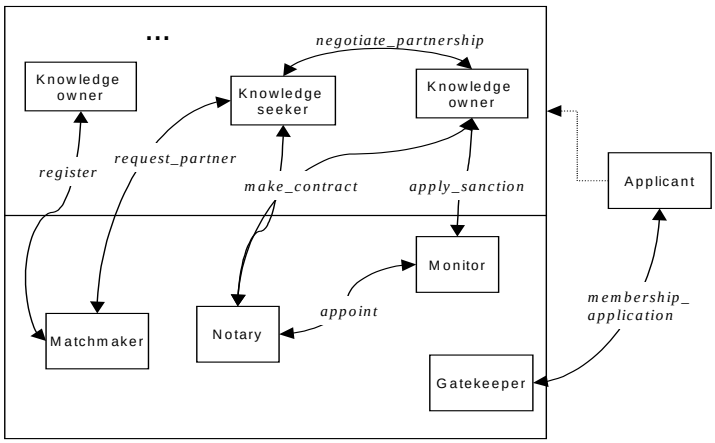
For the share support module, an agent society is being developed using the framework based design method described in this paper. In this society, both knowledge seekers as knowledge owners want to be able to decide on trade partners and conditions. Sharing is not centrally controlled but greatly encouraged by the management. The best-suited partner, according to each participant's own conditions and judgement, will get the 'job'. However, factors such as privacy, secrecy and competitiveness between brands and departments may influence the channels and possibilities of sharing and must thus be considered.

The requirements for the system identify a distributed system where different actors, acting autonomously on behalf of a user, and each pursuing its own goals, need to interact in order to achieve their goals. Communication and negotiation are paramount. Furthermore, the number and behaviour 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. These characteristics indicate a situation for which the agent paradigm is well suited and therefore the methodology we propose can be applied.

Considering the requirements, the network model is the most appropriate for this situation. The aim is to design an exchange society restricted to selected participants with the global goal of supporting collaboration and synergy, and in this way meet the organisation requirements. Participants are aware of and collaborative with this requirement but also have their own objectives and constraints. Participants wish to be free to determine their own exchange rules and to be assured that there is control over who are the other participants in the environment.

Due to space limitations, we cannot describe the complete system in this paper. In the following we will describe some of the roles and interactions. Having decided for a network structure, the roles of matchmaker, notary, monitor, and gatekeeper follow naturally from the application of the framework. From the domain requirements the roles of knowledge owner and knowledge seeker can be deduced. The 'goods' to be exchanged are the contents of the knowledge repository, that is, (XML) documents representing knowledge about reports, people, applications, web sites, projects, questions, etc.[1] Figure 1 shows a fragment of the architecture of the society, indicating roles and possible interaction procedures. These procedures are also determined by the model chosen (network) and are informally described.

[1] This type of goods demands a complex matching mechanism, since matches are not at keyword level but require knowledge about relationships, processes etc. This imposes constraints to the task and communicative components of agents. This will not be discussed here.



`membership_application(X, gatekeeper):`
This is a negotiation between any agent and the gatekeeper of the society resulting in either an acceptance, that is X will become member of the society, or a rejection.
The role the agent will play is also determined in this scene.

`register(M, matchmaker):`
Knowledge owners or seekers can register their requests with the matchmaker, who will use this information in future matches

`request_partner(M, matchmaker):`
Knowledge owners or seekers request possible partners for an exchange.
Results in a possibly empty list of potential partners.

`negotiate_partnership(M, N):`
Owners and seekers check the viability of an exchange and determine conditions

`make_contract(M, N, notary):`
When an agreement is reached, partners register their commitments with the notary.

`appoint(notary, monitor):`
The notary appoints a monitor for a contract. It delegates agreed tasks to the monitor.
The monitor will keep track of contract status and will act when an undesired state is reached.

`apply_sanction(monitor, M):`
when a breech of contract occurs the monitor will contact the faulty party and apply the sanctions agreed upon (either described in the contract or standard in the institution).

Fig. 1. Fragment of the Knowledge Exchange Network architecture

The institution underlying the society also imposes mechanisms for collaboration and certification. For instance, in the knowledge network a special kind of knowledge owner is responsible for the gathering and dissemination of information about a known, fixed list of subjects to knowledge seekers that subscribed to it. The institution must enforce the norm that such agents are required to provide all the information they are aware of. This determines a task for the monitors tracing this type of contracts of checking if information in all subjects in the list is indeed provided.

6. Conclusions and future work

We have presented a framework for the design of agent societies based on the co-ordination structure of the domain that uses institutions to specify and enforce social norms and conventions. The framework takes the organisational perspective as starting point. We believe that one contribution of our research is that it describes the implications of the co-ordination model of the organisation for the architecture and design method of the agent society being developed. Although there are several agent-based software engineering methodologies (see, [8, 3, 16, 21]) these are often either too specific or too formal and not easily used and accepted. Our approach is to provide a generic frame that directly relates to the organisational perception of a problem. If needed, existing methodologies can be used for the development, modelling and formalisation of each step. We believe that our approach will contribute to the acceptance of multi-agent technology by organisations.

We also exposed the need for institutions in systems of autonomous agents that act according to their own goals and capabilities. Institutions enforce the global behaviour of the society and assure that the global goals of the society are met. Institutions play an important role to specify and manage the conventions of the agent society. One of the most important aspects is that they can make organisational goals and norms explicit and warrant their fulfilment by providing explicit facilitation roles and controlled interaction protocols. Different co-ordination models have different needs in terms of how institutions are specified. Feedback from the applications currently under development at Achmea will be used to improve the design methodology and the co-ordination frameworks used.

Important work that is left for the future is the formal description of both the co-ordination framework as well as the institutions. This will provide means for verifying properties of the institution. It will also enable agents that consider joining the society whether they are able and willing to conform to the specified conventions and interaction mechanisms.

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