KNOWLEDGE SHARING AND ORGANIZATIONAL PERFORMANCE
An Agent-mediated Approach

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Abstract: Organizational effectiveness depends on many factors, including excellence, effective planning and capability to understand and match context requirements. Moreover, organizational performance cannot be just evaluated in economic or other global terms, but it must consider values of the participating agents (people or groups), such as individual satisfaction. Different organizational structures are clearly better matched to certain problems and context requirements than others, but evaluation methods are mostly lacking. In this paper, we will present ongoing work on tools and formalisms to model organizations and evaluate their performance according to global and individual values, under different circumstances.

1 INTRODUCTION

Today, collaboration is the common place for organizational activity. Both within as across organizations, collaborative work happens for product development, marketing, sales, R&D, etc. For instance, in the field of product development several companies collaborate nowadays to develop new products, e.g., cars, aircrafts or machinery, resulting in what is referred to as a collaborative supply chain. Collaborative development efforts are usually conducted on a project basis, i.e., centered around a new product or service. The duration of such collaborative development projects can vary from some months to several years.

Several challenges arise in such collaborative projects. On the one hand, efficient organization structures need be implemented that facilitate the performance of project teams. Typically, such teams consist of employees from the different groups involved in the collaboration, possibly augmented with external consultants. This means that members of the team fulfil a specific role on the project, but are also part, and must answer to, the original organizational structures of their own companies and groups. Furthermore, from a knowledge management perspective, these collaborative teams depend on knowledge that is spread over different companies that are part of the chain. That is, the team will need to tap in to knowledge from other people in the different partner organizations. Managing this knowledge effectively contributes to the performance of the supply chain as well as the individual companies.

Effectiveness of organizations and teams depends on many factors, including excellence, effective planning and capability to understand and match context requirements. Despite a large number of studies, the effect of organizational structure on the performance and the knowledge sharing capabilities of a group is still not well understood. Different organizational structures are clearly better matched to certain problems and context requirements than others, but evaluation methods are mostly lacking.Furthermore, environments are not static, which implies that structuring decisions must be adaptable to change and therefore the process of determine congruence between structure and environment is cyclic.

Moreover, organizational performance cannot be just evaluated in economic or other global terms, but it must consider values of the participating agents (people or groups), such as individual satisfaction. Intelligent agents have been defined as autonomous, reactive, proactive entities capable of social interactions in dynamic environments. As such, the agent paradigm is particularly suitable to model project teams. In order to cope with the inherent complexity of knowledge sharing in teams, the concept of Agent-mediated Knowledge Management (AMKM) proposes agent-based approaches to deal with collective aspects of the domain in an attempt to cope with the conflict between desired order and actual behavior in dynamic

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environments (van Elst et al., 2004).

In this paper, we will present ongoing work on tools and formalisms to model organizations and evaluate their performance under different circumstances. The aims of this project are to generate tools and methods to understand and model the relation between organizational design, agent behavior and team performance. Results will be applied to the design of more effective agent systems that support the activity of virtual groups. The paper is organized as follows: in section 2 describes our work on organizational models, section 3 discusses the factors that influence performance and how to dynamically adapt these factors in order to improve performance. In section 4 we introduce our current work on the development of simulations that enable to study the performance model proposed. Finally, section 5 presents our conclusions and directions for future work.

2 AGENT ORGANIZATIONS

The agent paradigm offers an effective way to model and analyze complex systems composed of multiple and distinct components. In this sense, an organization can be seen as a set of agents whose interactions are regulated by mechanisms of social order and are created to achieve common goals. Furthermore, virtual teams as described in the previous section, operate in open environments, where autonomous participants and stakeholders are not centrally organized and follow heterogeneous models and motivations, and act according to their own plans and norms. Such open environments demand organizational models that integrate the realization of organizational requirements and objectives, and at the same time allow participants to have the freedom to act according to their own agendas and goals. This means that we should take a distributed view on Knowledge Management (KM): knowledge is autonomously managed where it is created and used, namely within each community or project team. Moreover, autonomy without coordination is almost useless for knowledge sharing in complex organizations, yet coordination should be reached through interoperation rather than centralization (Bonifacio et al., 2001). Recently, several agent-oriented analysis methodologies for Knowledge Management have been proposed (van Elst et al., 2004; Dignum et al., 2004).

Our approach prescribes such an agent-oriented framework, which considers individual and social goals in order to determine which structure is the best applicable for a project team, given the task environment, the knowledge needs, and the organizational constraints of its members. The framework is described in more detail in the remainder of this section

2.1 Organizational Structure

The OperA model for agent organizations, (Dignum et al., 2004), enables the specification of organizational requirements and objectives, and at the same time allows participants to have the freedom to act according to their own capabilities and demands. OperA considers agent organization models as having at least two description levels. At the *abstract* level, which can be seen as a receipt for collective activity, organizations are described in terms of roles, their dependencies and groups, interactions and global norms and communication requirements. The *concrete* level is a possible instantiation of the abstract organization, by populating it with real agents that play the roles and realize interactions (Vazquez-Salceda et al., 2005), (Sichman et al., 2005). Organizational design starts from the identification of business strategy, stakeholders, their relationships, goals and requirements and results in a comprehensive (agent) organization model including organizational roles, interactions and planning rules, that fulfil the requirements set by the business strategy. Organizational instantiation is the process that accepts an abstract organization model and a set of agents, and resources and generates a concrete organization by assigning responsibilities and organizational goals to each agent.

The OperA framework consists of three interrelated models. The organizational structure of the society, as intended by the organizational stakeholders, is described in the **Organizational Model** (OM). The OM specifies an agent organization in terms of four structures: social, interaction, normative and communicative. The *social structure* specifies objectives of the system, its roles and the model that governs coordination. The *interaction structure* gives a partial order of the scene scripts that specify the intended interactions between roles. Interaction scene scripts are flexible constructs that describe *how* a result should be achieved, instead of using procedures to describe *what* are the steps to follow. Society norms and regulations are specified in the *normative structure*, expressed in terms of role and interaction norms. Finally, the *communicative structure* specifies the ontologies for description of domain concepts and communication illocutions. The way interaction occurs in an organization depends on the aims and characteristics of the application, and determines the way roles are related to each other, and how role goals and norms are 'passed' between related roles. For example, in a hierarchical organization, goals of a parent

role are shared with its children by delegation, while in a market organization, different participants bid to the realization of a goal of another role.

The **Social Model** (SM) describe how agents can enact roles in the organizations. That is, the SM specifies the interaction scenes that describe the possibilities for negotiation of role enactment by agents joining the organization. These scenes generate social contracts for the participating agents that describe the capabilities and responsibilities of an agent within the organization, that is the desired way that an agent will fulfil its role(s). The use of contracts to describe the activity of the system allows on the one hand for flexibility in the balance between organizational aims and agent desires and on the other hand for verification of the outcome of the system. Finally, given an agent population for an organization, the **Interaction Model** (IM) specifies possible interaction protocols between agents that implement the functionalities described in scene scripts in the OM.

A generic methodology to analyze a given domain and determine the type and structure of an application domain resulting in a OperA agent organization model is described in (Dignum et al., 2004). 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 organization types such 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. A brief summary of the methodology is given in table 1.

In order to design and analyze OperA models for organizations, we are currently developing an graphical tool, OperettA. The tool enables the verification of the OM, but it also generates simulations of the organization, to be populated with agents so that its activity can be animated.

2.2 Agents in Organizations

Section 2.1 described the modelling of organizations from the perspective of the organization's designer. As such, organizational models describe the goals, requirements and expectations of the organization itself. Obviously, individual agents will have their own motivations and expectations when joining a certain organization. This implies than more than a need for frameworks that specify the organization's structure and goals, we need to specify mechanisms through which prospective participants can evaluate the characteristics and objectives of society and role goals, in order to decide about participation. Furthermore, tools for individual agents to adapt their architecture and functionality to the requirements of an assumed role must be provided (Dastani et al., 2003).

In the context of project teams, organizational roles indicate the capabilities of agents that are to fulfil the role, typically describing the minimum expectations on the enactment of participating agents. The success, that is, improved performance, of the team is dependent on the effort agents will put into their role performance. As in human organizations, the idea here is that a job description only describes part of one's input into the organization (as well as one's reward). What distinguishes employees is how well they put themselves to their job. That is, an agent, representing a member of one of the companies participating in the project, is faced with a decision about how to best enact its teams role in a way that ideally benefits both the project team as its original company. Many issues influence this decision, including trust, strategic reasoning and cultural characteristics.

The considerations above indicate the need to match agent and role objectives and functionality. At the moment most approaches to this problem simply design agents from scratch so that its behavior complies with the behavior described by the role(s) it will take up in the society. This applies especially to closed MAS where all agents are designed centrally and with a pre-intended purpose. In this case the design of the agent follows from the requirements specified for the role(s) the agent is fulfilling. Comprehensive solutions for this problem require complex agents that are able to reason about their own objectives and desires and thus decide and negotiate their participation in a society. A first step on the road to this solution (taken in (Dastani et al., 2003)) is to have a formalism to compare the specifications of agents and roles and determine whether an agent can enact a role. In the future, agents themselves should be able to use this mechanism to automatically evaluate their participation on a society.

Furthermore, once a decision has been reached that an agent will indeed enact a role, there must be ways to modify that agent in order to include the characteristics of the assumed role. A possible solution for this point has been proposed in (Esteva et al., 2001) in which agents are extended with an interface to the society. This interface prevents any action not allowed by the role definition. However, it does not facilitate proactive behavior expected from the agents while playing the role. Therefore, our proposal allows for different approaches to such modification of an agent which result in different role performances, by providing the for negotiation of role enactment for spe-

Table 1: *Overview of OperA methodology.*

	Step	Description	Result
OM	Coordination Level	Identifies organization's main characteristics: purpose, relation forms	Stakeholders, facilitation roles, coordination requirements
	Environment Level	Analysis of expected external behavior of system	operational roles, use cases, normative requirements
	Behavior Level	Design of internal behavior of system	Role structure, interaction structure, norms, roles, scripts
SM	Population Level	Design of enactment negotiation protocols	Agent entrance scripts, Role enactment contracts
IM	Interaction Level	Design of interaction negotiation protocols	Scene script protocols, Interaction contracts

cific agents in the SM. For instance, some agents will uniquely attempt to achieve the goals of its adopted role and forget its own private goals, while others will only attempt to achieve the goals from the role after its own goals have been satisfied.

2.3 Organizational Environment

Organizations do not exist in a vacuum. Each organization is set in a particular environment to which it is inextricably linked. This environment provides multiple contexts that affect the organization and its performance, what it produces, and how it operates. The "rules of the game" of a society are one of the most important ingredients of the enabling environment. All societies require appropriate rules, as well as fair and efficient mechanisms by which they can be enforced. Organizations must pursue their goals within a normative structure that facilitates or inhibits their work. North defines rules as "... the formal laws and codes that positively or negatively influence the behavior of organizations through the incentives and constraints they provide or impose." (North, 1990). There are rules for all dimensions of the environment be it at administrative, technological, political, economic, socio-cultural, or stakeholder's level. Rules can be formal or informal, explicit or implicit. In addition to norms, teams and organizations possess a certain combination of resources that influences the type and scale of activities undertaken by the group, as well as how successful their efforts are likely to be. Capabilities of a group include natural resources, human resources, financial resources, infrastructure and technology. Together with norms, these capabilities create an enabling or inhibiting environment for organizations (Lusthaus, 2002).

Furthermore, given dynamic environments, teams, and therefore, their members, should have a range of capabilities and the ability to decide how best to apply those capabilities to changing situations. This implies that,ideally, team members should have a sense of responsibility towards the global objectives of the team (which in our model we represent as social contracts to role enactment), and the ability to assess a situation and modify its behavior to maintain or improve overall team performance.

Compelling as this aim may be, such agents are usually quite expensive and not always available for any project team[1]. Therefore, it is important to design the structure of teams in a way that adaptation is possible without requiring all participants to have this type of functionality and ability.

3 UNDERSTANDING PERFORMANCE

Efficiency of organizations is usually measured in terms of performance, or the degree to which goals are achieved. Contingency theory shows that: (a) there are no one optimal organizational design, and (b) structural constraints, task constraints, cognitive constraints and other environment conditions influence organizational outcomes. In human settings, organizational performance has been demonstrated empirically to be associated with the degree of congruence (or 'fit') between organizational structure and properties of the task or environment (Donaldson, 2001). Accordingly, it is to an organizations advantage to monitor the fit between its structure and mis-

[1]Note that this observation applies both to human agents in project teams as to artificial agents in multi-agent systems. People with wide capabilities and ability to quickly assess a situation and determine the best course of action to take are often high educated, have a wide and long experience and therefore are expensive. Software agents with similar possibilities are, if at all existing extremely complex, and therefore computationally expensive.

sion, and to alter its structure when a misfit is identified. There is empirical evidence that high performing organizations can discern when environmental forces have changed the state of congruence (i.e., the goodness of fit), thus driving changes in the strategies (e.g., communication patterns, back-up behaviors) that they employ (Entin and Serfaty, 1999). In the next section, we will discuss in more detail the factors that influence performance.

From the discussion in the previous sections, it becomes evident that organizational performance is a complex issue that depends on many different factors. Performance, or efficiency, is affected by the organization's design, the cognitive, by information processing capabilities of the agents, the operating conditions, the task and the task environment faced by the organization (Carley and Svoboda, 1996). Reorganization can then be seen as a means to achieve better performance, or creating a more efficient organization, by changing one or more of the factors that affect performance. From the analysis of many organizational simulation projects, some of which will be discussed in the next sections, and inspired by So and Durfee (So and Durfee, 1998), we classify the factors that determine performance into three broad classes. The first are the *structural factors*, which are the components and features of the organization (such as roles, dependencies, constraints, norms and regulations). The second are *task environmental factors*, which are the components and features of the task (such as size, time constraints, uncertainty). The third class of factors are *agent factors*, which are the characteristics of the individual agents concerning task capability, knowledge (including decision making and reasoning capabilities), social awareness, etc. These three classes of factors jointly determine the performance of the organization.

This suggests a 3d-space in which the results of different organizational simulations can be placed and eventually compared. Axes in this 3-space correspond to the groups of factors listed above. Each point in the space represents a specific organization instance (that is, with a given structure, task, agent capabilities and operating conditions). For each point, the performance can be calculated. In this perspective, reorganization means a move into another point in the space which has a better performance. In order to cope with complexity, we are developing simulations that based on two dimensional projections of the overall space, which means that one set of factors is kept fixed in that particular simulation. In the following we introduce our work on organizational simulations along these lines.

4 AGENT ORGANIZATION SIMULATION

Both in social sciences as in computer science many simulation studies have been realized that aim to increase the understanding of reorganization in human and agent organizations respectively. Different organizational simulation projects have studied the influence of different factors on the organizational efficiency, using different techniques and aiming at proving different hypothesis.

So far, we have discussed models for the specification of organizations that enable the representation of organizational requirements, in terms of structures and objectives, independently from the specification of the individual agents. Such models enable the analyze of sharing and interaction in organizational settings. The novelty of the approach is that the same model enables analyze at both the level of organizational performance as well as at the level of the individual expectations. In this section, we will discuss our current research towards simulation frameworks for such models.

Currently, several agent-based simulation languages and platforms are available (e.g. Repast[2]). By following an agent-oriented approach, these platforms enable the observation and analysis of (complex) social processes between the entities. However, most of these simulations are based on very simple models of agency, that hardly enable the specification of the cognitive aspects of the agents. On the other hand, languages and tools for agent development, such as 3APL, Jason or Jack, that are based on a cognitive notion of agency (typically the BDI model) often lack the constructs to represent high level social aspects, such as roles, norms or organizational structures. Moreover, from a computational point of view, these agent platforms do not provide the scheduling and timing mechanisms required to run simulations. A few languages attempt to counter these problems. A good example is Brahms (Sierhuis et al., 2003), or the MAS-SOC platform (Bordini et al., 2005).

Simulation of organizational or group behavior requires more than the organizational model and its members, as developed in the OperA model. The simulation must be able to incorporate the environment conditions under which activity will take place. Simulation tools are well suitable to describe and modify environment conditions by enabling for instance to vary task complexity and frequency, or the harshness or the environment. Our approach is use an existing simulation platform (Repast) and create a plugin to

[2]http://repast.sourceforge.net/

cognitive agents developed in an agent-oriented language (for the moment we are using 3APL[3]. The aim is to eventually be able to integrate in one platform agents developed using different languages so that different approaches to cognition can be integrated.

Our current research on the development of a simulation tool for reorganization experimentation aims at the identification of conditions and requirements for change, ways to dynamically incorporate changes in systems, how to determine when and what change is needed, and how to communicate about changes. In (Dignum et al., 2006) we presented a simulation scenario, VILLA, to evaluate different reorganization forms and understand triggers for reorganization.We are currently working on a simulation that analyzes the relation between agent capabilities and organizational structure, when the objective is to share knowledge on a particular task.

5 CONCLUSIONS

In this paper, we argued that effectiveness of project teams is dependent on the structure and norms of the team, on the capabilities and values of participants, on the way the team is able to consider and relate to the external links of its members, and on the overall characteristics of the environment where the team exists. This means that team performance cannot be evaluated just on economic terms but must consider the values and expectations of participants. We have presented a model for organization design that describes requirements concerning the overall goals and norms of the organization or team, but also takes in account the autonomy of individual participants. In order to understand relation between structure and performance of teams we are developing simulations tools that enable the controlled variation of factors and their effects. Our current and future work is centered around the further development of simulation and evaluation tools.

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[3]http://www.cs.uu.nl/3apl/

REFERENCES

Bonifacio, M., Bouquet, P., and Traverso, P. (2001). Enabling distributed knowledge management: Managerial and technological implications. *Upgrade*, III(1).

Bordini, R. H., Costa, A. C. d. R., Hübner, J. F., Moreira, l. F., Okuyama, F. Y., and Vieira, R. (2005). MASSOC: a social simulation platform based on agent-oriented programming. *Journal of Artificial Societies and Social Simulation*, 8(3).

Carley, K. and Svoboda, D. (1996). Modeling organizational adaptation as a simulated annealing process. *Sociological Methods & Research*, 25(1):138–168.

Dastani, M., Dignum, V., and Dignum, F. (2003). Role assignment in open agent societies. In *AAMAS03*. ACM Press.

Dignum, V., Dignum, F., and Meyer, J. (2004). An agent-mediated approach to the support of knowledge sharing in organizations. *Knowledge Engineering Review*, 19(2):147–174.

Dignum, V., Dignum, F., and Sonenberg, L. (2006). Exploring congruence between organizational structure and task performance: A simulation approach. In *Coordination, Organization, Institutions and Norms in Agent Systems I*, volume 3913 of *LNAI*, pages 213–230. Springer.

Donaldson, L. (2001). *The Contingency Theory of Organizations*. Sage.

Entin, E. E. and Serfaty, D. (1999). Adaptive team coordination. *Journal of Human Factors*, 41:321–325.

Esteva, M., Padget, J., and Sierra, C. (2001). Formalizing a language for institutions and norms. In *ATAL-2001*, LNAI 2333, pages 348–366. Springer.

Lusthaus, C. (2002). *Organizational Assessment: A Framework for Improving Performance*. IDRC.

North, D. (1990). *Institutions, Institutional Change and Economic Performance*. Cambridge University Press.

Sichman, J., Dignum, V., and Castelfranchi, C. (2005). Agent organizations. *JBCS*, 11(3).

Sierhuis, M., Clancey, W., and van Hoof, R. (2003). Brahms: a multiagent modeling environment for simulating social phenomena. In *SIMSOC VI*.

So, Y. and Durfee, E. (1998). Designing organizations for computational agents. In *Simulating Organizations*, pages 47–64.

van Elst, L., Dignum, V., and Abecker, A., editors (2004). *Agent-Mediated Knowledge Management: Selected Papers*, volume 2926 of *LNAI*. Springer.

Vazquez-Salceda, J., Dignum, V., and Dignum, F. (2005). Organizing multiagent systems. *JAAMAS*, 11(3):307–360.