Towards Dynamic Reorganization of Agent Societies

Virginia Dignum [1] and **Frank Dignum** [2] and **Liz Sonenberg** [3]

Abstract. In this paper, which is exploratory in nature, we discuss reorganization issues in agent societies. We are interested in how and why organizations change, and how can reorganization be done dynamically, with minimal interference from the system designer. It is evident that changes in the environment trigger reorganization, but in which situations do agents decide to modify their behavior, and when is a complete change of the organization structure needed? We present a classification of reorganization situations, based on the focus of the reorganization, the authority to modify the organization, and how reorganization decisions are taken. We will also discuss the requirements for agent models necessary to allow for dynamic, automatic adaptation to the reorganized system.

1 INTRODUCTION

Multi-Agent Systems (MAS) are often cited as one of the most promising approaches to create open systems. However, these open MAS themselves and their environments are not static. They change, disappear or grow. Agents can migrate, organizational objectives can change, or operational behavior can evolve. Models for MAS must therefore not only cater for adaptive agents [14] but also be able to describe dynamically adapting organizations to changes in the environment.

Establishing an organizational structure that specifies how agents in a system should work together helps the achievement of effective coordination in MAS [1]. An organization-oriented MAS is described in terms of the capabilities and constraints of organizational concepts such as roles (or function, or position), groups (or communities), tasks (or activities) and interaction protocols (or dialogue structure), thus on what relates the structure of an organization to the externally observable behavior of its agents.

Depending on the type of organization and on the perceived impact of the changes in the environment, adaptation is achieved by behavioral changes at agent level, modification of interaction agreements, or the adoption of a new social structure. Even though most reorganizations are realized by re-engineering the system (i.e. external assessment and modification of a system), for MAS to be truly autonomous, mechanisms for dynamic reorganization must be available. The concept of *dynamic adaptation* refers to modifications in structure and behavior of a MAS, such as adding, removing or substituting components, done while the system is running and without bringing it down [29]. Dynamic adaptation demands that systems can evaluate their own health (i.e. success and other utility parameters) and take action to preserve or recover it, by performing suitable integration and reconfiguration actions. Reorganization of organizations should therefore describe both situations in which the operational behavior of the organization changes, due to admission or departure of agents, as well as situations in which the social structure of the society changes, that is, roles, relationships, norms or interactions change.

Most existing approaches to reorganization consider only the behavioral aspects, that is reorganization only affects the current population of agents in the system, both at the social (i.e. interactions and relationships) [2], as well as individual level [12]. Our contribution is that we discuss a number of aspects that are important for structural reorganization, that is, permanent changes to the organizational structure of the system.

First of all we will look at reasons for actually changing the structure of the organization. Not every change in the environment or an agent will lead to an organizational change. But when and who will actually decide upon such a structural change?

When a decision is made to change the organization it should also be decided what and how the organization is changed. Are interaction patterns changed, do we change some roles, some constraints,...?

Organizational success is brought about by the organization's ability to bring all its information and assets to bear, and the ability to recognize and take advantage of fleeting opportunities. In this sense, successful reorganization should lead to an increased utility of the system. That is, the reorganized instance should perform better in some sense than the original situation. From the perspective of the individual agents, their participation in an organization also depends on utility factors. Utility is however appreciated differently from the perspectives of the society and of the agents. On the one hand, the organization will only admit an agent, if the overall utility of the society increases [11]. On the other hand, assuming rational agents, the agent will only join an organization if its own utility increases. We will indicate a number of aspects that can be used to measure the utility of an organization and how they can be used to measure the gains of a reorganization.

Finally, dynamic reorganization of an agent society imposes certain requirements on the architectures of the participating agents. Agents that are required to reason about change in the environment, its consequence for the organizational structure of the system, and determine how the system as a whole should adapt to change, are obviously more complex than agents that are only required to adapt their own individual behavior, or that just follow orders.

In this paper, we discuss different types and motivations for reorganization and the consequences for MAS models of enabling dynamic reorganization at different complexity levels. In section 2, we introduce different types of organization for agent systems. In section 3, we present reorganization aspects such as motivation, types of reorganization and decision authority. In section 4 reorganization

[1] Institute of Information and Computing Sciences, Utrecht University, 3508 TB Utrecht, The Netherlands; email: virginia@cs.uu.nl
[2] Institute of Information and Computing Sciences, Utrecht University, 3508 TB Utrecht, The Netherlands; email: dignum@cs.uu.nl
[3] Department of Information Systems, University of Melbourne, Parkville 3010, Australia; email: l.sonenberg@dis.unimelb.edu.au

challenges for agent and their capabilities are discussed. We present preliminary conclusions and point directions for further research in section 5.

2 SOCIAL ORGANIZATION

Organizational structure can be defined as that "what persists when components or individuals enter or leave an organization, i.e. the relationships that makes an aggregate of elements a whole" [9]. A concrete organization is one possible instantiation of an organizational structure. Social structure is thus an independent construct that enables interaction between, or that describes the organization of, two or more agents in the same system. A social structure may be explicitly implemented in the form of a social artifact existing independently of the implementations of the agents, may be realized as part of the implementations of the agents, or may exist only intangibly, in the form of the policies or organizational rules followed by the agents during interaction [16]. Two types of MAS structures can be distinguished:

1. *Emergent MAS*: global behavior cannot be specified in advance, but emerges from the interaction of local behaviors [19].
2. *Designed MAS*: have an explicit interaction structure that determines the coordination of the agents participating.

Emergent systems can be seen as conglomerations of single agents with hardly any fixed interaction or explicit social structure. There is no notion of common goals or plans, and agents are free to enter or not in interaction with others. That is, emergent organizational behavior is primarily a bottom-up process in which agents look for interaction and local control decisions that have been effective in the past and give similar decisions preference in the future. By aggregating these preferences together, an emergent organizational structure can be created. Individual agents may not be aware of the emergent global behavior, which is only perceivable by an external observer. An agent behaves following its own local laws under the influence of the other agents and of an external environment. Individual agents may compete for resources, yet produce a common effect. Structure has a temporal determination: it is cumulative over time in a single direction, non-reversibly, and determines the action of agents differently as it evolves. Structure is implicit in the activity of the agents. New agents cannot use that structure, but must learn from scratch and adapt as they go along. The emergent paradigm can be applied to both open and closed domains.

In contrast, *designed systems* are created using organization-design knowledge and task-environment information to develop an explicit organizational structure that is then elaborated by the individual agents into appropriate behaviors. Society structure is determined by organizational design, which is independent of the agents themselves. Such structures implement the idea that agent interactions occur not just by accident but aim at achieving some desired global goals [30]. That is, there are goals external to each individual agent that must be reached by the interaction of those agents. Desired behavior of a society is therefore external to the agents. Organizational hierarchies, teams, shared blackboards, global plans, and auction systems are all social structures. In closed domains, designed structures completely determine the communication primitives available and possibly describe the resources available in the environment. Furthermore, it may organize agents into groups or teams and specify joint action. A special case of designed systems are *agent societies* which include social concepts such as norms and ontologies. Besides the specification of action-oriented behavior as in designed MAS, agent societies enable the specification of normative behavior and as such provide agents with the possibility to reason about their own behavior, plans and goals. Agent societies are norm-oriented structures, appropriate to model open domains, also due to the explicit specification of ontological aspects.

2.1 Organization and autonomy

Many applications require a set of agents that are individually autonomous (in the sense that each agent determines its actions based on its own state and the state of the environment, without explicit external command), but corporately structured. As such, there is a growing recognition a combination of structure and autonomy is often necessary. Selznick states that *"all formal organizations [follow] ordered structures and stated goals ... and will develop an informal structure within the organization which will reflect the spontaneous efforts of individuals and subgroups to control ... the [organizational] environment... Informal structures are indispensable to ... the process of organizational control ... and stability"* [25].

Effective multi-agent systems must therefore yield coordinated behavior from individually autonomous actions [23]. That is, on the one hand, "pure individualism", as reflected by the principle of individual rationality assumed by emergent models, is often not a good choice as a guideline for decision-making of autonomous agents that participate in MAS [13]. Individual rationality is for instance insufficient for describing a range of desirable social behavior such as being helpful or doing things for the greater good. On the other hand, models that limit the action of its agents to the strict realization of pre-determined protocols, are not agile enough, and furthermore do not take full advantage of the potential of participating agents. Already in 1993, Wellman noted that *"combining individual rationality with laws of social interaction provides perhaps the most natural approach to generalizing the Knowledge Level analysis idea to distributed computations"* [31]. In [30], we have introduced two requirements for MAS models that reconciliate organization and autonomy:

- The *internal autonomy requirement* enables the design of open societies, with heterogeneous participants, by imposing that social structure is represented independently from the internal architecture of agents.
- The *collaboration autonomy requirement*, enables the design of evolving societies, by indicating that social activity is specified without fixing a priori all interaction structures and protocols.

These requirements reflect an organizational design perspective. That is, should be taken as guidelines for the design of MAS models. From an agent perspective, it is also necessary to consider the influence of social interaction on the behavior of independent agents. [22] proposes *structural functionalism* as a model of how society, or social structure, 'molds' individual behavior so as to achieve globally functional behavior. In structural functionalism theory, social structure is seen as *"an arrangement of persons in institutionally controlled or defined relationships"* [24]. Social relations arise either from person to person or between social roles (e.g. king and subjects). It exists *"between two of more individual organisms when there is some adjustment of their respective interests, by convergence of interest, or by limitation of conflict that might arise from divergence of interests"*. There are two ideas in structural functionalism that are of special interest here:

- The *biasing effect* of social structure: Norms and social institutions impose external constraints on an agent's freedom of choice. They are primitive notions, not reducible to any other, that actually influence the behavior of a "socialized" autonomous agent. Still, they are not assumed to completely determine agent behavior, but just bias self-interested action in a certain ("socially desired") direction.
- The *teleological character* of social structure: Seen from the outside, social structure induces the co-ordination of the behavior of autonomous agents towards a global function of society. From an agent's perspective social structure induces a specific form of cooperation in the sense of mutual adjustment of individual action.

2.2 A Basic Organizational Model

In section 2 we have discuss different types of organization, from emergent, implicit models to explicit structural frameworks. Organization models should enable both the specification of social structure and the participation of heterogeneous, external agents. Often role-based models are adopted for agent organizations (e.g. [21, 32]). In the remainder of this paper, we assume a basic organizational model containing roles, agents and interactions.

- *Organizational structure* consists of roles, their relationships and pre-defined (abstract) interaction patterns. Organizational structure must reflect and implement the global objectives of the organization. *Roles* have objectives determined by the global aims of the organization, and can be grouped into groups. Role objectives determine possible dependencies between different roles. Roles describe classes of agents, their activities, and possibly their norms and behavior rules. Roles are related to other roles by *dependency relations*. Desired *interaction patterns* between roles can be specified.
- An agent participates in the organization (system) by playing one or more roles. Role enactment is achieved either by allocation by the system developers that determine which available agent is the most adequate for a task, or is decided by the agents themselves. In both cases, analysis techniques are needed to support enactment decision, which compare and evaluate different role allocations [20]. The set of agents that at a given moment is active in an organization, is called the *population*. An agent population achieves the animation of organizational structures.
- *Interaction* between different agents realize the organizational objectives. Activities in a society are the composition of multiple, distinct and possibly concurrent interactions, involving different agents, playing different roles. Actual interactions form the *behavior* of the organization.

Even though, not all MAS models recognize explicitly these concepts, we feel that by raising these concepts to the status of first-class modelling entities [17], we allow for the specification of open systems, and can describe both emergent and designed organizations. Similar modelling approaches have been advocated in [4, 8].

2.3 Organizational properties and utility

One of the main reasons for having organizations, is to achieve stability. However, environment changes and natural system evolution (e.g. population changes), require the adaptation of organizational structures. Reorganization is the answer to change in the environment. As reorganization is contrary to stability, the question is then: under which conditions is it better to reorganize, knowing that stability will be (momentarily) diminished, and when to maintain stability, even if that means loss of response success. In order to answer this question, it is necessary to define the *utility* of an organization.

Organizational success means the organization's ability to bring all its information and assets to bear, and the ability to recognize and take advantage of fleeting opportunities. Success is one way to measure the utility of a system. Reorganization is therefore desirable if it leads to increased utility of the system. That is, the reorganized instance should perform better in some sense than the original situation.

Given the assumption of agent autonomy, it is also necessary to define agent utility, as each agent should, in principle, be able to determine whether a reorganization results in increased utility for the agent itself. Utility is thus evaluated differently from the perspectives of the society and of the agents.

Society Utility We define the utility of an organization based on organization properties:

- *Interaction success*: how often do interactions result in the desired aim.
- *Role success*: how often do enacting agents realize role goals.
- *Structure success*: how well are global objectives achieved in an organizational structure.

For example, a given combination of structure and population is said to be successful if the overall success of the organization is higher in that situation than for others. This is an example of a reorganization at behavior level. At structural level, reorganization implies a change of structure. Society utility depends also on the cost of the reorganization. That is, any function to measure organization utility must take in account both the success of a given structure, and the cost of any change needed to achieve that structure from the current situation [11].

Agent Utility is different for each agent, taking in account issues such as its own goals, resource production and consumption. Basically, we can assume that rational agents will participate in a society if it individual utility increases. Furthermore, different social attitudes will result in different evaluations of individual utility. That is, the utility function of a social agent may take on account some measure of society utility, whereas for a selfish agent only individual concerns matter.

3 REORGANIZATION ASPECTS

Agent systems often operate under uncertainty, in dynamically changing environments, and often unreliable communication. The need for techniques to make agent systems more flexible and adaptive is therefore high. Dynamic adaptation, during agent operation, often results in better performance, and more robust systems [1].

The first step in the development of a model for dynamic reorganization of agent societies, is to identify and classify situations of change in organizations.

3.1 Reasons for Reorganization

We are interested in how and why organizations changes. It is evident that environment changes are the obvious triggers to reorganization, but when does one decide that a role should be added/deleted from the current structure, or that interactions should have different aims or follow modified patterns. There are different gradations of change,

from a slight adaptation of an interaction instance to drastic changes in the social structure of the organization.

Organizational studies often relate reorganization to flexibility. Flexibility can be defined as *"ability to do something other than that which was originally intended"* [7]. In human societies, reorganization manoeuvres have both a temporal and an intentional aspect. The timing of reorganization can be either *proactive* - preparing in advance for an unpredictable future change - or *reactive* - making adjustments after an event has occurred. The intentional aspect of a reorganization, may be *offensive*, in which case the organization aims at gaining competitive advantage, or *defensive*, aiming at organizational survival. Evans uses these to develop a framework of four manoeuvres, as follows [7], [6]:

- *pre-emptive* (proactive, offensive): allows to take advantage of possible future events and is most useful where the future is unpredictable and where the exploitation of innovation is a tool of competition.
- *protective* (proactive, defensive): applied before unpredictable events attempt to limit the damage caused by an unknown future.
- *exploitive* (reactive, offensive): taken after an event, in order to capitalize on existing opportunities.
- *corrective* (reactive, defensive): taken to prevent more damage, and usually used when other tactics fail, to ensure continuing existence.

This classification of reorganization manoeuvres applies to human organizations and comes from Organizational Theory research. In MAS, motivation for reorganization is somewhat different. Firstly, the intentional aspect (defensive, offensive) is not really relevant. That is, it often does not matter whether reorganization aims at minimizing damage or maximizing gain. Secondly, the ability to reason on the timeliness of reorganization (proactive, reactive) is for a great deal dependent on the capabilities of the agents enacting organizational roles. Proactive reorganization requires high-level reasoning capabilities. That is, in order to make a proactive reorganization decision, agents must be endowed with mechanisms to reason and evaluate current and desired behavior and utility. Reactive reorganization, on the other hand, only requires agents to be able to sense and react to environment events, and therefore simpler agents are sufficient.

Moreover, proactive situations often imply a modification of behavior: agents dynamically change their behavior, that is, the way they enact their roles, can change the patterns of interaction, or even the definition of the roles or their relationships. That is, the expected effects of change can be evaluated without drastic structure changes. In this way, organizations can test 'what-if' situations and reason whether a more permanent, structural change, should be required. Reactive reorganization will often result in modifications of the structure of the organization.

3.2 Types of Reorganization

In early work in reorganization, restructuring was only possible in the initialization phase of the system. During the actual problem solving phase, the structure was fixed. Later on, approaches have allowed to dynamically adapt the system structure [12]. Current implementations of organizational adaptation include approaches based on load balancing or dynamic task allocation. The later is often the case in organizational self-design in emergent systems that, for example, include composition and decomposition primitives that allow for dynamic variation of the organizational structure (macro-architecture) while the system population (micro-architecture) remains the same [26]. Another common approach is dynamic participation, which is the situation described in the above section. In this case, agent interaction with the organization is modelled as the enactment of some roles, and adaptation occurs as agent move in and out of those roles [4, 11, 27]. However, few of these systems allow agents to change the problem-solving framework of the system itself [1].

Based on the above considerations, we identify the following reorganization situations:

Behavioral Change In this case the organizational structure stays the same but the agents currently enacting roles, decide (collectively or individually) to use different protocols for the same abstract interaction described in the structure. This is the case when:

1. *A new agent joins the MAS*. In this case, a new agreement should be made specifying e.g. the expectations and obligations of the society towards role enactment, and possibly incorporating some of the agent's own requirements.
2. *An agent leaves the MAS*. In this case, it is necessary to determine whether organizational operation is still completely or partially possible.
3. *Interaction pattern instantiation*. In this case, the agents currently enacting an interaction pattern agree on a specific protocol that complies with the pattern specification. Such protocols can be different, depending on the agents' current evaluation of the environment and/or their own goals and behavior rules.

Structural Change In this case a decision is made concerning the modification of one or more structural elements.

1. *Organizational Self Design*: that is, dynamic variation in emergent societies, resulting from changes in the interaction between agents.
2. *Structural Adaptation*: In this case, designed societies are adapted to environment changes by adding, deleting or modifying its structural elements (e.g. roles, dependencies, norms, ontologies, communication primitives).

Intuitively, behavioral changes have a more temporary character, and do not influence future activity of the organization, whereas structural change is meant to accommodate permanent modification, and as such direct the activity of future instantiations of the organization. This raises the question of reorganization decision. That is, how does a decision for (structural) reorganization is taken, by whom and based on what knowledge? In our research, we are mostly concerned with structural change. However, in this paper we will discuss both types in order to make clear the differences between them, both in complexity as in modelling possibilities.

3.3 Reorganization Decision

Previous research has described both advantages and disadvantages for centralized and distributed problem-solving structures. In particular, work on the application of the military notions of Command, Control and Communications (C3) [4] to MAS focuses on the authority to effect changes at different levels [28]:

- *Command*: is the authority and responsibility to determine the objectives of the organization. Given that, in our definition, organization objectives are directly related to social structure, this means that command is also the authority to determine and update the social structure of the organization.

[4] The C2 model refers only to Command and Control.

- *Control*: is the authority to specify and modify detailed plans for achieving objectives, that is, the authority to modify interactions and behavior.
- *Communications*: involve the sharing information about the environment, the state of the organization, the state of the achievement of objectives, and the state of execution of the plans. Such information is necessary in order to determine C2 action.

The Command, Control, and Communication (C3) model has been primarily used to describe organizations that operate under mission critical circumstances [10].

Communications imply the ability to determine what knowledge is needed to enable reorganization decisions. That is, meta-level of communication - about the functioning of the organization itself. This is different from operational-oriented communication that is geared to operational issues, and expected activity. In principle all participants can gather and communicate knowledge about performance and environment, but assuming open systems, not all information will be reliable or trustworthy.

Both command and control can be centralized, distributed or external. External command and control means that change comes from outside the organization (possibly by the designer) without intervention from the agent population. As we are concerned with dynamic reorganization, this situation is not interesting and will not be further detailed. In centralized command and control situations, C2 decisions are property of one role in the organization. It corresponds to a master/slave relationship between agents acting at the different levels of autonomy. C2 empowered roles, can *direct* change. Distributed command and control means that (all) roles are collectively responsible for a change decision. C2 changes are thus achieved by collaboration or consensus. In [1] three types of decision-making styles are identified, that relate to centralized and distributed decision-making situations:

- *Command-driven*: the agent does not make any decisions on how to pursue its (role) goals, and some other agent has authority over it (child in a hierarchical relation)
- *True consensus*: Agent works as a team member, sharing decision making control equally with other agents. (network relation)
- *Locally autonomous/master*: The agent makes decisions alone and may or not have control over other agents (parent or root in a hierarchical relation).

These kinds of relationships refer to the decision making process, that is how roles depend on other roles to realize their objectives, and how agents decide when and to whom to delegate. However, they don't say who and how is permitted to change the structure of the organization. In the classification of reorganization at the beginning of this section, typically the first situation, behavioral change, refers to agent-based decision concerning change, while the second, structural change, concerns 'top-down' change, that is change external to the operating agents, that must be accommodated by those agents. Figure 1 depicts the relations between the different perspectives on reorganization.

In this scheme, we identify two different aspects of change:

1. **Decision**: concerns the way change decisions are reached. Relates to the decision-making style [1].
2. **Authority**: who can change the organization. Relates to the C2 model. Communication relations do not directly modify the organization but can guide decisions on plan and/or social change. Communication in this sense refers to the meta-observation of organizational behavior, and not to operational communication (which concerns role enactment).

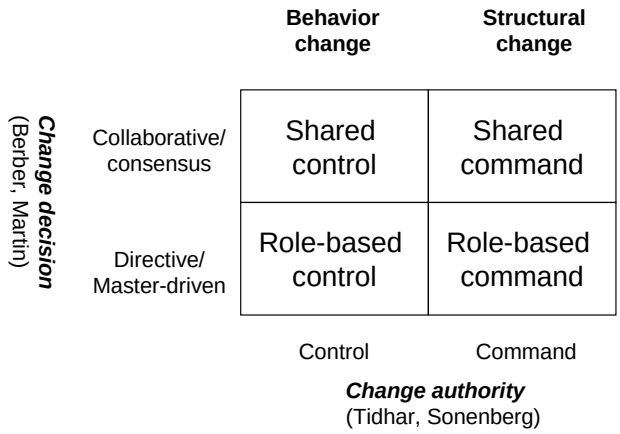

Figure 1. *Dimensions of change.*

Figure 1 only considers dynamic reorganization situations and not external reorganization, or re-engineering. In the collaborative case, change is achieved through coordinated decision between enactors of roles. In the directive case, some roles have the authority to change plans and/or social structure. The first column in 1 relates directly to Behavioral Change situations. Changes have only 'local' effect, do not change the social structure of the organization. The second column relates to Structural Change. Change concerns the social fabric of the organization (e.g. roles, interaction patterns, norms and ontologies) and affect future populations and activity of the organization.

An example of a *role-based control* domain is a rescue operation. In the field, every participant has its own role and interactions are globally known in forehand (the organization structure). However, the rescue leader must have the capability to assess the actual situation and enforce changes where needed (the organization behavior). A soccer game is an example of *role-based command*. The coach has the authority to change the organizational structure of the team, e.g. replacing defenses for forwards, if the environment so requires (that is, they are loosing and really need to score). Collaborative project teams often work according to the *shared control* principle. Roles are usually fixed (engineer, analyst, etc.) and the team is collectively responsible to access and adapt its behavior to changes in the environment (e.g. the project is delayed). Finally, institutions often adapt to change by *shared command*. Imagine the merge of two different university departments. Structural adaptation to the situation will require negotiation and consultation with all parties involved (typically the heads of the different groups) to reach a consensus. In the following, we further discuss the consequences of social change for organizations and agents.

4 REQUIREMENTS FOR REORGANIZATION

Change is a result of observation of the environment. Making sense of a situation begins by identifying relevant patterns and access current response possibilities. Sense-making is however more than sharing information and identifying patterns. It involves the ability to generate options, predict outcomes and understand the effect of particular courses of action. These are capabilities that few software agents are endowed with. Hence, enabling dynamic reorganization

has consequences for the capabilities required from the agents involved, and therefore makes sense to identify which reorganization type is most appropriate for a given situation, and what is then needed from the agents. Sense-making furthermore, requires to keep system history, also across different role enactors.

4.1 Organizational requirements

A characteristic of reorganization is *timeliness*, that is adequate response at the appropriate time (not to be confused with speed). This implies the need to access when and how often, and at which level to change. *(Too often, too quick:loss of predictability, Too slow, too late: rigidness)* Another characteristic is *resiliency*, that is, flexible but durable and consistent with its (meta) norms and objectives. An interesting study by Carley et al, explores the resiliency of organizations by studying their performance when key leaders were removed [3]. Different domains will have different appreciations of timeliness and resiliency. For instance, in rescue operations, timeliness is often directly related to speedy response. That is, a quick, even if suboptimal, adaptation will be preferred over the optimal solution if that one only arrives after it is too late (e.g the house has already burned down). On the other hand, that in institutions (such as an university department), timeliness is often related to consensus. That is, the good time to change is when all parties are conscious of the need to change and agree on the changed model.

In [4] we have identified three types of coordination in organizations: hierarchy, market and network. Hierarchies limit interaction between agents to direct superior/subordinate relations. Interaction between and among all agents is encouraged in networks, and in markets, interaction reflects supplier/consumer relations and are determined by transaction costs. Intuitively, it seems that hierarchical style of dependency, requires less reasoning power from the agents performing children roles: they just take they 'orders' from above. Hierarchical coordination is therefore well suited for directive reorganization styles. On the other extreme, in network relations all agents must be able to reason about the why and how of role performance, which re-quires more intelligence on the agents' side. In networks, collaborative reorganization is more adequate.

In our previous research, we determined that the effectiveness of the three coordination types is not the same in all situations [5]. For instance, hierarchies perform well in familiar, repetitive situations, where many resources are shared, and communication is reliable. On the other hand, networks seem to perform better in unfamiliar situations, where few resources need to be shared, and parallelism can be exploited [18]. Adaptive reorganization styles seem to be related to coordination types. Our research on coordination methodologies should be extended in order to describe the characteristics and requirements for reorganization.

4.2 Challenges for agents

The different reorganization types have consequences for the capabilities required from participating agents: must agents be able to understand reorganization, reason and adapt accordingly, or it suffices that they are given another 'script'? A initial description of the capabilities of agents, in the different reorganization situations, as described in fig 1, is given below:

Behavioral change: Change at behavior level, which means that enacting agents evaluate and enact environment changes. It does not affect future enactments and therefore there is no need for organizational memory.

Role-based control: One or more roles in the system are empowered to change enactment plans and/or operational objectives. Meta communication is not really necessary, since for the other roles change is 'imposed'.

Shared control: Agents must be able to sense changes in the environment and evaluate their consequences for current operation. Behavior change occurs through consensus between all agents.

Structural change: Aims at accommodating long-term changes, such as new situations or objectives. Need for agents to react to permanent environment changes and decide on how to incorporate those in the organization structure. Change at social level implies a need for society level learning. That is, by keeping an organizational memory, the society itself can reflect on the difference between desired and actual behavior and decide on social level changes (roles, norms, etc.).

Role-based command: One or more roles are empowered to create/delete other roles, change relationships, laws or language. Changes are 'imposed' on other agents.

Shared command: Agents must be able to sense environment changes and evaluate their consequences for the current and future structure and activity of the organization. Changes occur through consensus and high communication skills are required from all agents, on meta issues.

In directive situations, agents enacting directive roles (or *directors*), must be able to monitor and evaluate the overall behavior of the system, according to some success factors and determine what adaptation is required. When an agent monitors itself, it may have direct access to its own internal state information but this is usually not possible, when monitoring others. Even if the monitored agents cooperate, they cannot, in complex domains, continuously communicate their internal state to the monitor, as it is intrusive of their operational activity, and requires reliable communications [15]. Instead, the director uses plan and role recognition, and so can infer the agents unobservable state from their observable behavior. The need for communications, as in C3, is reduced as the directive agent can form its decisions independently from the information it receives from others, while it is still possible to benefit from focused communications with the others. The director communicates changes in interaction or behavior to the other agents, but can only assume that the others will in reality realize those changes (because it cannot access internal behavior and motivations leading other agents' actions).

In collaborative situations, all agents need high meta reasoning and communicative capabilities in order to access changed situation and negotiate how the group should adapt to it.

5 CONCLUSIONS

In this paper, we have discussed reorganization aspects in different types of agent systems. Current methodologies for MAS design focus on the analysis of initial conditions and their consequences for MAS design, but do not often provide guidelines for reorganization and adaptation of the organizational structure later on. If we consider the two extremes of organizational structure: emergent organizations and designed social structures, the preliminary research presented in this paper, shows that a tradeoff between structure (predictability) and flexibility is needed. On the one hand, reorganization is inherent in emergent societies, that require little intelligence and meta-reasoning/communication for participating and are highly flexible.

However, the global behavior of emergent organizations cannot be predicted and changes cannot be guided, which makes this type less suitable for situations where coordinated and goal-directed global action is required (such as Robocop teams and rescue operations). On the other hand, in designed social structures, that exhibit predicable and controllable behavior, dynamic change implies the need for highly intelligent and communicative agents (at least some of them) that can reason about and negotiate change.

Further work is needed on methodologies for reorganization. Future research should indicate conditions and requirements for change, ways to incorporate changes in (running) systems, and how to determine when and what change is needed. For this purpose it is crucial to determine the utility of a complete organization and its structure in a more concrete way. This should get precise enough to define functions that indicate the change of utility of an organization given a certain type of reorganization.

A specific issue is which factors influence the choice for a behavioral change or a structural change. I.e. at what point is a behavioral change of a number of agents no longer enough and should the structure be changed. Another important research direction is the development of conceptual formal models that enable the specification of dynamic reorganization of agent societies.

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