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Multi-Agent System Development Based on Organizations

Estefania Argente, Vicente Julian, Vicente Botti [1,2]

Departamento Sistemas Informaticos y Computacion
Polytechnic University of Valencia
Valencia, Spain

Abstract

Organizational models have been recently used in agent theory for modeling coordination in open systems and to ensure social order in multi-agent system applications. In this paper, we propose the employment of Organization Theory for the analysis and design of multiagent systems. Thus, we first discuss the current state of the art of organization-oriented multiagent system methods, placing emphasis on their organizational features. We also review human organizational structures, and we propose several guidelines for implementing agent organizations by means of Organization Theory. Our final aim is to employ well-known human organizational structures to develop multiagent systems.

Keywords: human organizations, agent coordination, multiagent systems.

1 Introduction

Several methods for modelling open multiagent systems have been developed recently, such as OperA [8], OMNI [9], E-Institutions [11]. These approaches are mainly focused on roles, norms, and social rules. Other methods, such as GaiaExOA [29] and new Tropos [14] also take into account the organizational structure of the system, considering that a specific topology will force the use

[1] Email: eargente@dsic.upv.es

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of several roles that depend on the selected structure. Therefore, they propose the use of organizational patterns in the analysis and design phases.

Since human organizations have been widely studied by economists, engineers, psychologists and sociologists, we believe that Organization Theory [25,24,13] can be used as a basis for the analysis and design of multiagent systems. Therefore, human organizations can be applied for detailing a multiagent system (MAS) structure.

In this work, we propose the use of Organization Theory concepts, which are based on human organizations, in both the analysis and design of MAS. We will analyze organization-oriented methods, taking into account how they identify organizational topology, which organizational designs they consider, when this identification is made (i.e. at which step of the methodology), and what kind of processes or models they produce. Moreover, we will analyze whether or not these methods take into account human organizations and also what types of human organizations they are. Furthermore, we aim to benefit from Organization Theory knowledge to develop MAS methodological guidelines for determining suitable system organizations.

The remainder of this article is structured as follows: the current MAS organizational approaches are analyzed in section 2, emphasizing the organizational features that these approaches have. Then, several models of human organizations are described and how they can be implemented using agent coordination and organizational structures. Finally, several guidelines for a better analysis and design of multiagent systems by means of organizational concepts are proposed.

2 Multiagent system organizational approaches

In the analysis and design of MAS, methodologies have evolved from an initial view of the system that is centered on the individual aspects of agents to a current view of the system as an organization in which agents form groups and hierarchies and follow specific behavioral rules. Therefore, we can distinguish between two different methodological approaches: agent-oriented and organization-oriented methodologies. In the agent-oriented approaches, the MAS designer focuses on the individual actions of the agents, so MAS are designed in terms of agent mental states (such as beliefs, intentions, goals, commitments, etc.). They also consider that agents are benevolent, all have common goals, and cooperate in order to achieve those goals. Therefore, they are only suitable for closed systems. In this work, we concentrate on the organization-oriented methodologies since there are already many reviews of the agent-oriented ones such as [18,27].

In organization-oriented methodologies, the MAS designer focuses on the organization of the system, taking into account its main objectives, structure, and social norms. Two different trends can be observed when comparing several approaches. On the one hand, methods such as Roadmap [19], Agent-Group-Role [12], Tropos [14], MESSAGE [2] and INGENIAS [17] detail system roles, groups, and relationships, but they do not explicitly consider social norms. On the other hand, methods and frameworks such as Civil Agent Societies [7], SODA [23], GaiaExOA [29], Electronic Institutions [11], OperA [8] and OMNI [9] are focused on the social norms and explicitly define control policies to establish and reinforce them. The main aim of methods of this kind is the design of open multiagent systems, in which agents with self-interested behavior can participate. These agents can be controlled by means of social norms and a proper organizational structure.

Apart from social norms, we consider that a suitable organizational structure that establishes specific interactions and relationships between roles is also important for designing open multi-agent systems. This organizational structure has not been properly taken into account by many MAS methods. In the following section, we will analyze organization-oriented MAS methodologies, focusing on the organizational concepts.

2.1 Survey of Organization-oriented MAS Methodologies

These methodologies are still quite recent. They are mainly focused on the analysis phase, whereas design and implementation phases are missing or are redirected to agent-oriented methodologies, which do not offer enough tools to model organizational concepts. Therefore, there is still a gap between analysis and design, which must be specified clearly, correctly and completely. After making a thorough study of organization-oriented methods, we present a brief summary that focuses on the topological aspects of the MAS, which describes how these methods identify the organizational structure and which human designs are included.

Roadmap [19]. Although it is defined as a methodology for open multiagent systems, it is more similar to agent-oriented methods than to organization-oriented methods. This is due to the kind of models that it uses (based on Gaia [28]) and the steps that it follows in the analysis and design phases. First a use case model is defined and then role, protocol, and interaction models are detailed. The only topological abstraction employed is a role hierarchy. This hierarchy is composed of atomic roles at the leaf nodes and composite roles at the other nodes, which group together agent roles and localized organizations.

Agent-Group-Role [12]. It only considers groups (a set of agents that share common features) as a topological structure, and it assumes that groups

are dynamically created during the execution of the system. In the first step of the methodology, the main groups of the application are identified, taking into account whether the group represents a set of similar agents or a functional-based system (where functions are related with roles). Then, a general organizational structure is defined, in which groups, roles, role restrictions and relationships are modelled. Later, organizational dynamics are detailed, such as the creation of groups, the joining/exit of agents into/from groups, the authorization process for agents to join groups, the enactment of roles, etc. This methodology is rather lacking in implementation and development tools. Furthermore, micro-level aspects (such as the main features of the role, the functionalities, etc.) must be completed using other methodologies like Gaia [28]. It might be difficult to identify groups without doing a previous analysis of relevant goals, tasks, and roles in the system. Some guidelines for an initial requirement analysis and determination of groups are needed.

Tropos. In the lastest version [14], this approach adopts an organizational viewpoint and explicitly studies the identification of the organizational structure. It proposes using generic multiagent structures that are based on human organizations. In the initial requirements phase, an organizational model is defined, detailing the main actors, the goals and the dependencies. In this model, several organizational topologies are considered (such as a simple structure, a bureaucracy, a matrix and some virtual organizations, like a joint venture). During the design phase, several social agent patterns are assigned to organizational topologies: broker, matchmaker, mediator, wrapper, etc. Therefore, this methodology analyzes the multiagent system from an organizational point of view, specifying the most suitable human structure and social agent patterns for the system. However, social rules are not taken into account and there is no model to determine the global rules to be applied in the organization as a whole or in multiple organizational roles.

MESSAGE [2] and **INGENIAS** [17]. They identify all the use cases in the system and then they specify an organizational model, where groups, members, work flows, and organizational goals are detailed. Thus, several work flows, and the actors (agents and roles) participating in those work flows are defined for each use case. The actors are then grouped according to their functionality or the resources that they need. In these methods, groups are identified but no human organizational design is considered. Social norms are not explicitly modelled (they are implicitly assumed in the organizational structure) and organizational dynamics are not considered (i.e. how agents can join or leave the system, how they can form groups dynamically, what their lifecycle, etc.).

Civil Agent Societies [7]. More than a methodology, it is a framework

for designing open agent-mediated electronic marketplaces. In these marketplaces, several services for controlling organizational dynamics are considered: the joining of agents into society (socialization service), legal interactions between agents (notary service) and system recovery from agent behavioral failures (exception management service). Permissible agent roles and role interaction protocols are determined in this framework, and then they are organized in a specialization hierarchy, which represents the social norms. The only topological design that is taken into account is the market, so contracting processes are established between agents. This framework is an interesting approach as it offers a way to control agent behavior and organizational dynamics during the execution of an open system. However, it needs a complementary methodology for the analysis and design of the MAS.

SODA [23]. It initially identifies tasks to be done and relates them to roles (if limited resources and competencies are needed) or to groups (if several competencies and access to different resources are needed). Later, a social model is considered in the design phase. Groups are assigned to agent societies and are designed on specific coordination media that provide abstractions that are expressive enough to model the society interaction rules. These coordination models (such as first come/first serve, market-like bidding, task decomposition) also occur in human societies. Therefore, although this methodology does not specifically take into account human organizational designs, it does consider several human coordination mechanisms.

GaiaExOA [29] (Gaia Extended with Organizational Abstractions). It is an evolving extension of the Gaia methodology [28] for designing open MAS. In the analysis phases, the main organizational goals of the system and its expected global behavior are identified. The organization is divided into suborganizations when necessary; each suborganization has a specific structure. Then, models that describe the environment, roles, interactions and social rules are specified. This methodology proposes that a specific topology for the system will force the use of several roles that depend on the selected topological pattern. It has an iterative process for modelling roles and interactions, in which the preliminary role and interaction models are defined (according to the application domain). Later, in the architectural design phase, a specific topology and regime control is selected, so that new roles and interactions that depend on the topology can be added. The intrinsic and extrinsic features of the roles are analyzed (i.e. which features are or not dependent on the topology). If there is a change in the organizational topology, roles can be better defined. This methodology lacks a catalogue of organizational patterns to support the development of applications. Recent papers [15] have been published, detailing some social patterns for GaiaExOA (such as the pipeline

pattern), but there is still a lot of work to be done.

E-Institutions [11]. It is a framework that is focused on the design and implementation of an open MAS. It allows the definition of social norms and agent behavioral control. This framework provides several tools [10] to define and implement electronic agent institutions. However, it does not consider any explicit topology for the system and only takes into account several hierarchical role relationships (e.g. role subsuming functions). System structure is organized by means of interaction scenes and transitions, where a scene is a communicative process between agents. Those scenes are defined after analyzing role relationships, but without taking into account any human organizational topology. Therefore, the scene identification and development process would be easier if human organizational topology were considered.

OperA [8]. It describes the desired behavior of the society and its general structure by means of an organizational model, where roles, interactions, and social norms are described. Organizational dynamics are also detailed using a social model and an interaction model. In the social model, agents are assigned to roles using social contracts that describe an agreed behavior within the society. The interaction model describes the actual behavior of society during its execution. These last two models cannot be defined in the analysis and design phase, as they are a consequence of the actual agent interactions. Therefore, only the organizational model can be clearly defined. Initially, the most suitable coordination model is selected. Apart from the agents related with the domain of the application, this coordination model implies several facilitator agents, such as matchmaker, gatekeeper, notary, monitor, etc. Moreover, OperA takes into account three coordination models: market, hierarchy and network. When these models are related to human organizations, the market model is equivalent to virtual organizations (like price-systems, general markets); the hierarchy model is equivalent to bureaucratic systems; and the network model is equivalent to teams or groups, which implies trusting societies where mutual interests and collaboration between agents exist. Although this methodology represents an important approach for modelling open multiagent systems, there are still many aspects that can be improved. For example, if the system is composed of several topological models or substructures, OperA does not offer any guidelines to distinguish or combine the substructures between them. Other topological systems, such as matrix organizations or chain of values systems, should also be taken into account. Several facilitator agents that are derived from the selected topology are mentioned in the methodology, but there are no guidelines for inserting them into the final system or combining them with the other roles.

OMNI [9]. It is a recent extension of OperA, which combines the OperA

methodology with the HARMONIA framework [26]. This framework translates norms from an abstract level (in which organizational statutes and values are defined) to a procedural level (where social norms are implemented). In OMNI, the strengths of both approaches are unified, but it still lacks suitable tools for analysis and design. The ISLANDER toolkit [10] can be used for the description of norms, scenes and transitions, but the OperA organizational model must be completed by hand.

2.2 Discussion

Organizational-oriented MAS methodologies should take into account organizational goals, organizational structure (topology, role hierarchy, interactions, and social norms), organizational dynamics (i.e. agents joining the organization, role enactment, agents' life cycle, behaviour control), and organizational environment. A comparison of the aspects considered by several organizational oriented methods is shown in Figure 1.

In summary, we conclude that there is currently no methodology that offers a complete method for analyzing, designing, and implementing open multiagent systems. There are interesting approaches, like OperA and E-Institutions, for controlling external agent behavior and organizational dynamics. However they are only concerned with dialogic interactions. OperA is mainly focused on the analysis phase. Other approaches, such as MESSAGE and INGENIAS, offer good software tools and processes for the analysis and design of the system, but do not take into account social norms. With respect to organizational topology, most of the methods only consider groups as a topological design. It would be interesting if they took into account human organizational designs, such as hierarchy, bureaucracy, matrix, teams, and virtual organizations so that a better analysis of the system could be made. For example, several roles and relationships that are intrinsically related to each human topology could be distinguished and later used during the modelling phases of the multiagent system.

With respect to norms, the normative multiagent system approach [1,22] models a formal framework of explicit rules of behavior that apply to a set of agents and that provide additional rules for detecting violations and applying sanctions. This approach is also related to Electronic Institutions and OperA frameworks, as all of them are focused on detailing norms and rules for controlling agent behaviour in an open multiagent system. However, the normative multiagent system approach does not deal with the system structure and how its topology would affect the whole system performance.

We propose that the study of Organization Theory can be applied in the agent field. Well-known human organizations might be used as a basis to

Organizational features		Roadmap	AGR	Civil Agent Societies	E-Institutions	SODA	MESSAGE	INGENIAS	GaiaExOA	Tropos	OperA
Objectives		√				√	√	√	√	√	√
Structure	Topology								√	√	√
	Roles	√	√	√	√	√	√	√	√	√	√
	Interactions	√	√	√	√	√	√	√	√	√	√
	Social Norms		√	√	√	√			√		√
Dynamics	Agent Joining		√	√	√	√					√
	Role enactment	√	√	√	√	√	√	√	√	√	√
	Behaviour control		√	√	√			√	√		√
Environment		√				√	√	√	√	√	
Implementation					√			√		√	

Fig. 1. Comparison of organizational features considered in several approaches

describe roles, patterns, and connections that are intrinsically related to each topology. A review of the most well-known human organizations is provided in the following section.

3 Human Organizations

An organization is a social entity that has a specific number of members and that differentiates the functions played by the members. Organizations represent a powerful way to coordinate complex behavior in human societies. Human organizations have been widely studied by economists, engineers, psychologists, sociologists and, recently, by AI researchers. Organization Theory [25,24,13] analyzes how they work, their main features, the most relevant characteristics of the members, the general roles the members adopt, the member relationships, the chain of command, the rules and norms that govern the organization, etc.

According to the literature [24,13], there are two types of organizations: mechanical and organic organizations. In mechanical organizations, tasks are precisely defined, and they are broken down into separately specialized parts. There is a strict hierarchy of authority. Knowledge and reasoning processes are also centralized at the top of the hierarchy. Communications are mainly vertical (between supervisors and subordinates). Three examples of organizations of this kind are a simple structure, a bureaucracy and a matrix structure.

In organic organizations, tasks are adjusted and redefined by means of collaborative work in groups. There are fewer levels of authority and control, so both knowledge and task control are distributed. All members must contribute to the common task of the department. Communications are mainly

horizontal between members of the same department, or even between different departments. In this way, they can offer quick and flexible answers. Examples of organizations of this kind are team structures and virtual organizations.

We present the advantages and disadvantages of these organizational structures in the following sections.

3.1 Mechanical Structure

A **simple structure** [24] represents an organization with few departments, where an individual centralizes the capture of decisions. This structure presents a high grade of control (i.e. the manager directs a large number of personnel), a flat structure, little standardization of work activities and few rules. This type of organization is often employed in small companies (in which manager and owner are the same person) as well as in large companies (during periods of temporary crises) when control is centralized in one individual.

This organization is very simple: responsibilities are clear, communications are direct, and the capture of decisions and their execution is rapid. However, this type is only recommended for small organizations, as there is little formalization and the manager must handle lots of information. Since everything depends on a single person, if this person fails or makes a wrong decision, the company might go out of business.

There are models that are similar to a simple structure, such as a single-person, a simple hierarchy and a chain of values. A *single-person* structure [13] consists of only one actor, who does all tasks, reacting to the environment when necessary. In a *simple hierarchy* structure [13], the organization is divided into two levels: the upper level and the lower level. The upper level is composed of one actor, who is in charge of making decisions. The actor also coordinates low level tasks and has enough authority to make changes in the organization behavior, as s/he has complete information about the system. On the other hand, the lower level is formed by actors who carry out basic tasks. These actors have to communicate with each other through the upper level. Thus, system coordination is achieved by means of hierarchical relations and authority. Finally, the *chain of values* structure (or supply chain) [14] consists of several actors who are arranged in a chain, who try to reach their goals in different states of a production process. Every participant of the chain adds a new value at every step of the process.

A **bureaucracy structure** [24] is mainly characterized by operative, routine tasks with high specialization. There are also many rules and formalized regulations. Therefore, it is composed of diverse departments, with a low level of control (i.e. managers control a small group of persons); therefore many levels of management can be established (depending on the total size of the

company). Authority is centralized and decision-making follows a chain of command. Organizations of this type were very popular in the fifties and sixties, specially for multinational corporations.

Among its advantages, this structure allows standard activities to be done in a very effective way. Specialists are put together in same departments, facilitating communications among personnel. Thanks to the widespread presence of rules and regulations and the standardization of operations, decision-making is centralized in executive managers.

However, the high specialization of tasks can create conflicts in units or departments; so managers might be more focused on achieving their own unit goals than the general goals of the organization. In addition, managers can be excessively concerned with following the rules, and they may not know what to do when faced with new situations. Therefore, this type of organizations has difficulties responding to environmental changes.

Two different bureaucratic models can be distinguished [24], according to the way in which departments are divided: functional and divisional structures. In *functional* structures, tasks and departments are grouped based on technical specialization or business functions. This structure prevails in small and medium-sized companies and allows organizations to achieve large scale economies, with savings of personal, better contact among specialists (as they are in the same department) and better training. Decision-making and communication lines are simple and intelligible. However, managers tend to turn into specialists more than into general practitioners so then conflicts can arise between functions of different departments. In *divisional* structure, departments are established by autonomous divisions that contain all functions needed. These divisions can be established by manufacturing products, by types of clients, by geographical areas, etc. This model offers a more flexible and autonomous structure, though it needs duplication of resources.

A **matrix structure** [24] combines both functional and divisional structures, so that personnel have two supervisors: the functional department manager and the product manager. Therefore, there are two chains of control. This type of structure is very common in engineering and project management companies.

It facilitates coordination between personnel when there are numerous complex and interdependent activities. It improves communications and extends flexibility. It also reduces the possibility that members focus on the individual goals of their departments more than on the general organization goals. Likewise, it facilitates the effective location of specialists due to its functional topology.

However, there may be confusion in decision making as there are two chains

of command. Moreover, this structure promotes power struggles and can create tension, which can be diminished by using bureaucratic techniques, such as a higher formalization of rules.

3.2 Organic Organizations

A **team structure** [24] eliminates departmental barriers and decentralizes the decision making. Teams or groups [13] represent a system with several actors that have a common goal: the accomplishment of the system global task. This task is divided into subtasks, which are assigned to the most qualified members of the group. Moreover, members share all information and they are in constant communication with each other. Coordination among actors is obtained using mutually accepted decisions and plans.

A **virtual organization** [24] consists of a company that outsources the main commercial functions that it needs. Several contact networks are created, which allow the company to contract manufacture, distribution, marketing, and other commercial functions that managers believe can be done by others in a better way or at a lower cost. It offers flexibility, but it reduces management control on fundamental parts of the organization.

There are three types of virtual organizations [13]: a simple market, a collective organization, and a general market. A *simple market* consists of several disjoint organizations that negotiate the production or contracting of services. Thus, a company does not need to create a new unit for every new functionality; it can contract this functionality on the market. Control of the global organization is exercised by means of the product price, which must reflect the marginal cost of the product, in order to use resources without waste. A *collective organization* consists of several separate organizations that cooperate together to reach common goals, establishing long-term contracts. A *Joint Venture* structure [14], which is similar to a collective organization, consists of the union of two or more intra-industrial associates to obtain benefits on major scale and with a low maintenance cost. A specific actor, called a joint manager, takes charge of the strategic operations and the coordination of the organization, controlling the use of resources among associates. Finally, in a *general market*, several organizations contract different services from each other for short or long periods of time. A great level of competition is established. Moreover, every organization must analyze whether its own goals correspond with the needs of other organizations.

		Human Organizations				
		Simple	Bureaucracy	Matrix	Team	Virtual
Organizational features	Centralized capture of decisions	√	√	√	X	X
	Work specialization	X	√	√	√	X
	Generalist members	X	X	X	√	√
	Departmentalization	X	√	√	X	X
	Span of control	√	X	√	X	X
	Formalization of tasks	X	√	√	X	X
	Coordination between specialists	X	√	√	√	X
	Authority	√	√	√	X	X
	Chain of command	X	√	√	X	X
	Several direct managers	X	X	√	X	X
	Department goals	X	√	X	X	X
	Organization goals	√	X	√	√	√
	Shared information	X	X	X	√	√
	Flexibility	X	X	X	√	√
	Business functions outsourcing	X	X	X	X	√

Fig. 2. Human organization features

3.3 Discussion

In order to determine the most suitable structure for the system that is being studied, designers have to tackle the following questions: how to subdivide tasks into independent, formalized, and standardized subtasks (if possible); which of them have dependencies; how to group tasks and by what means (geographical, functional, product, process, client); where control and decisions have to be made; what kind of environment will be considered (dynamic, static, opened, closed); who members of society have to report their results to; which rules and formalized processes are needed, etc. All these questions allow designers to better determine the main organizational features [24] so that an initial design of the topological structure can be defined: centralized decision-making; work specialization (the degree to which tasks in the organization are subdivided into separate tasks); departmentalization (basis on which jobs are grouped together); span of control (number of subordinates a manager can efficiently and effectively direct); formalization (degree to which jobs within the organization are standardized); authority or chain of command (line of authority that clarifies who reports to whom); flexibility, etc. A relation of human organizations and organizational features is shown in Figure 2. These features can be employed to better analyze a specific problem and select which structure is more suitable for it, independently from the final use of agent concepts.

When studying human organizations, we have seen that there are several features that are comparable to agent systems. Well-known human organizational structures could be used for the deployment of multiagent systems.

The following section describes several relations between human organizations and agent systems and presents some guidelines for MAS development using human organizations.

4 Implementing Agent Organizations by means of Organization Theory

Each organization structure has one or more agent coordination techniques that can be used in the multiagent system implementation. We propose matching human organizations and agent coordination methods, taking into account similarities in functionality and relevant features.

A *simple structure* can be implemented using the organizational structuring of agents. This coordination type can be resolved in two ways. A master/slave architecture can be used, where a master can obtain information from agents of the group, create plans, and assign tasks to individual agents in order to assure global coherence. A blackboard architecture can also be used, where agents read and write on a general blackboard and a master agent controls what is read and written by the agents.

A *bureaucracy structure* can be implemented by means of the organizational structuring of agents with several levels of hierarchy or authority, in which a major standardization and formalization of tasks is needed. The Contract-Net protocol [4] can also be used. If an agent cannot solve the problem that has been assigned to him/her by means of his/her knowledge or local resources, s/he divides the problem into subproblems and selects those subordinate agents that have the necessary knowledge and resources to solve these subproblems. The assignment of subproblems is carried out by means of a contracting mechanism (Contract-Net), in which the agent manager advertises a specific contract; agent contractors send offers in response to the advertisement; and the manager evaluates these offers, granting the established subproblem to the contractor with the most appropriate offer. This coordination type should be employed when: (i) tasks have a well-defined hierarchic nature; (ii) the problem has a thick-grain decomposition; (iii) a minimal coupling between subtasks exists. In [16], both Contract Net protocol and agent cloning approaches are proposed for implementing agent hierarchies. Agents can response to overloaded conditions by cloning.

A *matrix structure* can be implemented by means of a cooperative negotiation agent structure in which its functional part is dedicated to the pursuit of the global goals of the company, whereas its divisional part implies distribution of agents through the system. In [5], a MACRON organizational architecture is described, in which agents form a matrix organization. Indi-

vidual agents are separated into predefined functional groups, which contain agents that can access a particular type of information. Agents have to report to two managers: a functional manager that controls each functional group, and a query manager (generated depending on the user actions) that sends queries to agents.

A *team structure* can be implemented by means of the distributed multiagent planning for agent coordination [3]. In this case, every agent is provided with a model of the plans of the other agents. The agents communicate with each other to construct and update their individual plans and the models of the others until conflicts are eliminated. This technique has been employed in the Generalized Partial Global Planning framework [6]. In [16], some discovery mechanisms, such as contract net protocol and matchmaker intermediaries, are considered to dynamically discover new members of the team.

A *virtual organization* can be implemented by means of negotiation techniques, classified in [21]: (i) negotiation based on game theory, which consists of an interactive process of offers and counteroffers in which every agent chooses a deal that maximizes the expected utility value; (ii) negotiation based on plans, in which agents plan their activities separately and later coordinate them by means of a separate coordinating agent; and (iii) negotiation inspired by human and technical approximations of artificial intelligence, specially using argumentation [20] in which agents (besides negotiating offers and counterproposals) attach certain arguments to their offers to support them. Moreover, short-term contract between units can be created by means of coalitions [16], in which teams or agents are formed with a specific purpose in mind and later dissolved when that need not longer exists. Congregations of agents [16] can also be used to model virtual organizations as they represent agents with similar or complementary characteristics that work together to obtain local utility through their joint effort. Finally, Joint Venture organizations can be implemented using agent federations [16], in which agents cede some amount of autonomy to a single delegate, who represents the group.

5 Conclusions

Human organizations have largely dealt with coordination problems and adaptability to the environment. Organization Theory can be used as a guideline by company managers to evaluate organizational behavior and apply appropriate actions in order to redirect the organization towards greater efficiency and productivity. Therefore, according to several aspects such as environment, size of the company, its purposes, its technology, etc., it will be more suitable to apply a specific organizational design. For example, if the company is small, a

simple structure is normally used. As the company increases in size, a major formalization of tasks and high grade of departments is needed, giving place to a bureaucratic structure. However, if the company needs higher coordination between specialists and a division based on products, a matrix structure might be more appropriate. As information and control become more complex, the company will need to outsorce certain products and services to others, so a virtual organization structure is needed.

The organizational metaphor is suitable for a wide range of software systems [29]. On the one hand, many systems are entrusted to control and give support to the activities of organizations in the real world. For example, manufacturing control systems, information systems, etc. On the other hand, other software applications must face problems for which human organizations can act as a source of inspiration (for example, sharing of resources, negotiation of services).

This paper has shown that current organization-oriented MAS methods make little use of human organizational designs, which could be very useful for understanding and modeling a system. The topological structures of human organizations have many similarities with the coordination techniques and structures adopted in agent systems. This relation should be used for the analysis and design of multiagent systems. Therefore, as soon as a specific structure for the system has been determined, it is possible to establish an initial idea of which agent organization might be the more appropriate for the final implementation of the system. This initial idea will have to be refined later according to the restrictions imposed by the problem to be solved.

Our future work is focused on analyzing several problem domains and identifying which organization structures are the most appropriate for them. We want to develop MAS meta-models that describe the relevant roles, relationships, and rules needed in those structures. These meta-models should also be included in some supporting guidelines for the employment of organization-oriented MAS methodologies.

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