Towards a Conceptual Framework for Organizational Mechanisms in Multiagent Systems *

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Abstract. In this paper we propose a preliminary approach to organize multiagent systems, based on building mechanisms that either *i)* endow agents with some "extra" information that could help them to select actions from the environment based on perceived observations on it; *ii)* or manipulate the environment in order to fulfil some global objectives. The paper also gives some desired properties that these mechanisms should hold. Finally we present a discussion about concepts used in other organizational approaches can be considered as one of this two types of mechanisms.

1 Introduction

In recent years, there is a growing awareness that the notion of *organization* is crucial for the construction of multiagent systems. In particular, organizational concepts have been deeply studied in the field of Agent-oriented Software Engineering [9]. These organizational concepts are often used as first-class abstractions that provide structure to the different models and stages of MAS design, and thus help designers to cope with high levels of complexity that MAS applications usually need to cope with. A variety of proposals, such as Agent-Group-Role [4], MESSAGE [1], Roadmap [7], Electronic Institutions [3], OMNI [2] and MOISE [6], have been presented in order to organize a MultiAgent System (MAS).

The organizational abstractions presented in those approaches - e.g. roles, norms, organizational structures, groups, interactions, etc. - are mainly used to assure that agent behaviour that unfolds in different "parts" of the MAS is instrumental with regards to some (global) functionality. For instance, organizational concepts such as *roles* or certain types of *norms* can often be conceived

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as (hard) *constraints* on the capabilities and permissions of agents to perform certain actions. Organizational concepts are usually used within a MAS to make sure that certain undesired behaviours of participants are impossible.

However, organizational concepts can also be helpful to agents in their local decision making processes, since they provide some additional information that may endow an agent with more accurate *expectations* about future actions of its acquaintances and their consequences. Therefore, they can also be conceived as mechanisms that the systems and its participants use to better achieve their own (local) objectives.

In this position paper we argue that *organizational mechanisms* can be classified in two basic types: *i)* those that provide additional *information* about the environment (its state, possible actions, their expected outcomes, etc) and *ii)* those that *manipulate* the environment proper. We argue that a key characteristic for a multiagent system to be "organization-based" is to make use of a least one such mechanism.

The paper is organized as follows: section 2 presents the previous work in which this work is based on. Thereafter, section 3 presents different types of organizational mechanisms. Section 4 discusses how existing approaches from the field of organizational design methodologies can be conceived within the proposed conceptual framework. Finally, section 5 summarises our conclusions and points to future lines of work.

2 Background

Following the definition presented by Wooldridge in [8], a MAS provides a common environment where agents can act. The performance of those actions takes the system to different states. The set of actions an agent can perform in a state is the intersection between the set of actions which it has the ability of carrying out - its "physical" limitations - and the set of valid actions determined by the environment in that state - environment limitations[1]. The environment of an agent determines the consequences of its actions. Our approach to define the two types of possible mechanisms adopts the view based on that the environment of an agent is all around it; i.e. any other entity including other agents.

At each step, agents receive some observation from the environment, change their internal state and take an action, which is finally executed. The internal state of an agent possibly encodes its history of actions and observations received,

[1] There are two ways of modelling the environment limitations: *i)* in a certain instant of the system, the set of possible actions for an agent is limited only to actions which agents are able to perform; or *ii)* in a certain instant of a system, an agent can perform all actions which it has the ability of performing, but only some of them produce some result. Imagine a robot that is in front of a wall and tries to move forward. This situation can be modelled either as if the robot were able to move forward but the consequences are not those that should be expected (option *ii*) or as if the robot could not move forward because in this state this action is not possible (option *i*). In this work has been adopted the option *i*.

as well as its beliefs about the state of the environment and its own preferences. This internal state evolves by observing its environment. The agent's decision function reflects its behaviour or policy and determines which action it will take in the next step.

A particular type of agents are *rational agents*. Rational agents set out from an individual preferences over possible states of the world. This preference relation is usually represented by means of a utility function. Rational agents select their actions in order to maximize expected utility given by this function, based on their perception of the current world state (and its provenance).

3 Mechanisms for organizing MAS

As we have explained in section 1, an organization is a multiagent system that uses some organizational mechanisms. These mechanisms can be used either to give information about possible actions in the environment or to manipulate the environment to regulate the system. The next subsections give some guidelines to describe those types of mechanisms.

A MAS determines the actions that an agent can perform in a certain state. That is, the environment of an agent (all around it) can limit the set of all actions to a set of possible actions in a state of the system. These limitations can be seen as "physical" limitations, because of the characteristics of its environment can stop the performance of some actions in a state. For instance, in the traffic domain, the roads and the junctions could form part of the environment of an agent; and it being the set of possible actions: to move forward, to move back, to move right and to move left. A car represented by an agent which is in a junction composed by the main road and a road in the right side; in that state, the set of actions is defined by the environment because the agent only could move forward, back or right. In this sense, the environment determines the actions in a state of the MAS. In the same way, it can be said that the system defines the consequences of the actions in a state. In fact, its actions could depend of the rest of the agents, the characteristics of the resources embedded in the MAS, etc. In the presence of the performance of the same action in the same state, the MAS could transit to different states. In this sense, the consequences of the actions of an agent are determined by its environment. The environment of an agent is all around it in a state of a MAS, that is, the rest of the agents also form part of its environment.

Organizational mechanisms have the objective of organizing a multiagent system, in the sense of coordinating the actions of agents in order to avoid conflicts or helping them to get their goals or a global goal defined to the whole system. In order to get this, these mechanisms will be able, on the one hand, to provide some additional information to the agents in a state, in order to help them to select their next action, and on the other hand, to influence or change the consequences of the actions in order to obtain changes in the dynamics of the community.

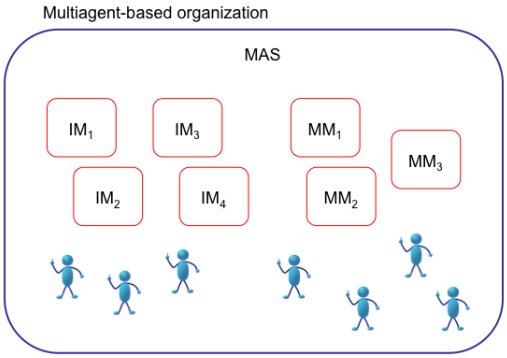

Fig. 1. Organizational approach for MAS

In figure 1 we describe the disposition of organizational mechanisms within the MAS. Both *IM* (information mechanism) and *MM*(manipulating mechanism) represent organizational mechanisms that try to organize the MAS.

3.1 Providing information to organize MAS

A rational agent embedded in a MAS has the faculty of perceiving an observation about a state of a MAS at any moment. From this observation it creates its new mental state and select their new action based on this state. A problem that comes up is that the perceived observation could be incomplete or even wrong. The aim of this kind of mechanisms is *to provide information about actions in given a state of the environment from a partial description about the internal mental state of an agent*. This description should contain the view that the agent has about the current system state and also preferences about preferred states.

This information can help agents to select what action perform in a certain state, since the more information an agent collects the better the agent will reason about selection of next action. Hence, without informative organizational mechanisms agents would only act taking into account their past experience.

In order to design organizational mechanisms that gives information about actions the following considerations should be hold:

- The mechanisms should be *useful* for the agents; that is, using the information provided by the mechanisms, the agents should increase their obtained utility than not using it.
- If the MAS is considered as an entity able to define a global utility function regarding its own purpose, and there exists an alignment between agents

and organizational preferences, then the use of the mechanism should be also *useful* for the overall MAS performances; that is the use of the mechanism by the agents also increases the global utility obtained for the system.
- The mechanism should be *adaptive*, so if some changes in the organization occur the mechanism should still be useful for the agents (and probably for the organization).

Consequently, we believe that the objective should be to design informative organizational mechanisms which are useful and adaptive for an organized MAS. It is only possible if the global utility function used to measure the activity of the organized MAS shares some preferences with some of rational agents members of that organized MAS. If the global utility function of the organized MAS captures preferences which are not important to the rational agents and the informative organizational mechanisms designed for influencing in the dynamics of the agents are based on these preferences, rational agents will not use these mechanisms, i.e. mechanism will not be useful for agents.

An informative organizational mechanism can be **not useful** for an agent or for an organization (MAS) due to three possible reasons: *i)* because the information provided by the mechanism is not truthful; *ii)* because the preferences implemented in the global utility function are not shared by the members of the system; or *iii)* because the cost of discovering the mechanism is high. It should be important to consider these reasons when designing adaptive and useful informative organizational mechanisms.

3.2 Manipulating the environment to organize MAS

As we have introduced before, another way to organize a MAS can be manipulating the environment of the agents. The idea behind that is the environment defines the consequences of the actions and determines which actions agents are possible to perform in one instant of the system. Thus, the modifications in the environment may produce modifications in rational agents in order to adapt their behaviors to keep on maximizing their utility function.

The changes in the environment can be classified in two types: *i)* modifications that produce changes in the consequences of the actions; and *ii)* modifications that limit the possible actions that environment define in this instant.

In the first type of manipulation the change in the behaviors of the agents is achieved because a modification in the consequences of an action can produce a variation in the utility of a rational agent. Implicitly, these variations introduce rewards or penalties to those agents and it may produce variations in the expected utility of rational agents and, they. An example of this way to organize a MAS in a simulation of a traffic scenario could be when a road is changed to a toll road. In that case if cars are implemented by rational agents and their utility function implements the preference of saving money, this modification in the environment will produce in this example a penalty for the action *to take that road*. If a modification in the consequences of an action produces a penalty or a reward to some agent depends of the preferences of agents. In the same

traffic example, if there exists some rational agent which prefers to save time and to save money is not a preference for it, the modification of that road will be a reward because the road will be less probably traffic jam.

The second type of manipulation in the environment is to change the actions space of an agent in the MAS. As we mentioned before, the environment defines the set of possible actions that an agent can perform in an instant of the system. Taking into account this, a way to organize a MAS is to limit or to extend the actions that an agent can perform. It is similar to define "the rules of the game", or to introduce or extend the "physical" limitations of an environment. Following the traffic example a change in the environment which produces an extension in the space of the actions of agents (cars) would be to create a new road, because it implies that the space of the actions of the cars is extended with the action "to take the new road". In the similar way the modification in the environment that closes a road produces a limitation in the possible actions of an agent can perform in an instant of the system.

These types of mechanisms to organize a multiagent system are always used related with some "superior" entity, for instance a designer or some agent or group of agent in charge of the manager of the system, etc. which define which are the preferences of the whole system, represented in the utility function of the system. Therefore, the manipulation of the environment will be done according to these preferences. That is, the objective of this type of mechanisms is design "the game of the rules" respect to some preferences relation defined by a "superior" entity.

A mechanism that manipulates the environment in order to organize a MAS should have these characteristics:

- either introduces rewards/penalties or limits/extends the actions that an agent can perform in an instant of the system making rational agents change their behaviors in order to maximize their preferences;
- manipulating the environment always according to a global utility function that represents the relation preferences of the whole system defined by some entity;
- a manipulation in the environment will be better than another when the utility measured by the global function defined to the whole system is greater in the first case than in the second.

The two different ways to organize a MAS are related, since when a mechanism that provides information to the agents is introduced in a system it implies that the action which allows agents to look up the information is added to the possible actions that agents can perform in the system. Similarly, when a mechanism that provides information is deleted from the system, the action "to obtain information" is deleted of the space of the actions of the agents. Moreover, when a mechanism that manipulates the environment is introduced a mechanism that provides information to the agents also can be introduced in order to inform agents about the modifications introduced. In the example of the traffic to situate a radar in a road is a mechanism that manipulates the environment introducing penalties/rewards and the announcement of this radar would be the

mechanism that provide information to the agents in order to avoid that cars (agents) exceed the speed limitations.

4 Discussion

Approaches such as Agent-Group-Role [4], MESSAGE [1], Roadmap [7], Electronic Institutions [3], OMNI [2], MOISE [6] have proposed the use of social concepts: roles, norms, interactions, etc. in order to organize a multiagent system. These concepts are implemented like a social layer which permits to organize the system. In the work presented, we propose that all of these social concepts can be classified like either mechanisms that provide information to the agents or mechanisms that manipulate the environment introducing penalties/rewards or/and limiting/extending the space of actions that an agent can perform.

The concept of role appears in these kind of methodologies as a main piece. A role can be defined like a mechanism which permits to categorize the agents either taking into account their permissions about what actions they can perform - the view most utilized - or taking into account their capabilities to perform actions [5]. In the first view, the roles are mechanisms which restrict the set of possible actions that an agent could have. When an agent plays a role in these methodologies it only can perform a set of actions. Otherwise, in order to perform some actions, agents need to fulfill some role. In this sense, roles can be classified as a mechanisms that manipulate the environment of the system introducing limitations in the space of actions that agents can perform. Since roles limit the actions which agents can perform in certain situation, because of some actions are only possible to perform playing some role. In the second view, roles categorize agents based on their capabilities performing some actions. So that, agents can decide with who do the action, but this approach of roles informs agents what type of agents is most specialize for one type of action. In this sense, roles are mechanisms that provide information to the agents about what action is better to perform (with action we refer to do something with someone), but agents can decide whether they take into account this information in order to select their actions.

When other methodologies define an organizational structure, i.e. a set of relationships between roles, limitations about the actions which can be performed by agents are defined. When an organizational structure defines that certain role only can act with another type of role, it is similar to limit the actions that an agent can perform when it has assigned this type of role. Therefore, organizational structures are mechanisms that manipulate the environment of the system limiting the space of the actions of agents that are playing some role.

Another important social concept used to organize a system is the norm. Norms indicate to agents what actions are permit and/or prohibit to perform. Thus, the system is organized avoiding conflicts and limiting the actions space of agents. Norms without a system in charge to enforce them are only mechanisms that provide information about what are the consequences of the actions. Meanwhile, the mechanism in charge to enforce norms is a mechanism that ma-

nipulates the environment introducing penalties and/or rewards to the actions implies by the norms. Using the traffic domain to illustrate that, the set of norms which governs the traffic is a mechanism that provides information to the agents because it specifies fines which agents get if they violate them. However, traffic cops, radars, etc, which are mechanisms to enforce norms, introduce changes in the environment because they introduce penalties when they impose a fine to the drivers when they violate some traffic norms. In this sense, these mechanisms can be classified like mechanisms that manipulate the environment. Another example of mechanism to enforce norms is the governors approach in Electronic Institutions [3]. In this case, it manipulates the environment limiting the actions that agents can perform, since governors are mediators between agents and the institution and they only allow agents to perform the actions permitted by the norms.

In conclusion, the social concepts used in different approaches about how to organize a multiagent system can be classified like either mechanisms that provide information to the agents or mechanisms that manipulate the environment introducing penalties/rewards or limiting the actions that an agent can perform in certain state of the system. That is, a MAS can be organized by providing information to the agents or by manipulating the environment in order to introduce penalties/rewards or to limit/extend the actions that an agent can perform.

5 Conclusions

This paper has presented a classification of organizational mechanisms, not only as a coercive method to keep agents from (globally) undesired behavior, but also as a means of helping the agents to select better between possible actions. From the perspective put forward by this position paper, whilst mechanisms that provide information to agents about actions in the environment attempt to endow them with some extra notion about consequences of actions, those that manipulate the environment are used to organize or coordinate agents' actions in order to be instrumental with respect to some global functionality of the system.

We are currently working towards a formalization of the notions regarding organizations, and organizational mechanisms in particular, multiagent systems. Our model will further characterize the different types of mechanisms that organize a MAS, specifying the properties that they should fulfill.

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