Organisational Mechanisms for Regulating MAS*

Roberto Centeno, Holger Billhardt, Ramón Hermoso, and Sascha Ossowski

Centre for Intelligent Information Technologies (CETINIA)
University Rey Juan Carlos, Madrid (Spain)
{roberto.centeno, holger.billhardt, ramon.hermoso, sascha.ossowski}@urjc.es

Abstract. In this paper, we propose a general formal framework for organising multiagent systems whose participants are rational agents. This model is based on the idea of *organisational mechanisms*. These are mechanisms introduced in a multiagent system with the aim of influencing the behaviour of the agents towards more effectiveness with regard to some objectives. We define two kinds of organisational mechanisms: i) *informative mechanisms* which provide additional information to agents, that may persuade agents to behave in a certain way, and ii) *regulative mechanisms* which produce changes in the environment of the agents, that may impose certain behaviours. Finally, we present a discussion about how the social concepts proposed by different organisational paradigms can be considered as either informative or regulative organisational mechanisms.

1 Introduction

In the last years, the concept of *organisation* has become very important in the field of multiagent systems (MAS). This concept changes the focus in the design of MAS from an agent-centred approach to an organisation-oriented approach where the problem consists in designing the rules of the game rather than the individual components. Proposals, such as [4, 3, 6] or the model proposed in [2], have been presented in order to organise MAS.

Most of them use a set of organisational concepts, e.g. roles, norms, groups, interactions, etc; to control and modify the dynamics or behaviour of the agents with regard to the global objective of the organisation. In general, such concepts are used to limit the freedom of choice of the agents and, thus, to assure that agents behave in a desired way. In our opinion, this view of organisation is just one possible vision. We believe organisational concepts may provide agents with useful additional information that allows them to better estimate the expectations of certain actions.

* The present work has been supported by the Spanish Ministry of Science and Innovation through its FPI grants programme and through the projects "Agreement Technologies" (CONSOLIDER CSD2007-0022, INGENIO 2010) and "THOMAS" (TIN2006-14630-C03-02).

In this paper, we define a general formal framework for organisations, based on the idea of *organisational mechanisms*, that includes both previously mentioned points of views.

The paper is organised as follows: section 2 presents some notations and necessary definitions. Thereafter, section 3 presents our formal framework for organisations and defines the different types of organisational mechanisms. Section 4 analyses how common organisational concepts can be classified in terms of informative and regulative organisational mechanisms and provides conclusions and some ideas for future work.

2 Notations and Basic Definitions

Our formal framework relies on two basic concepts, *rational agent* and *multiagent system*[1]. We consider that both concepts are closely related. In particular we consider that agents are always embedded in a multiagent system and this system specifies the environment of the agents.

A multiagent system (MAS) is composed of a set of agents which can perform a possibly infinite number of actions[2]. The performance of those actions takes the system through different environmental states with certain probability (external influences may affect the consequences of actions). Furthermore, in each different environmental state, agents can perform a set of actions restricted by the environment.

Agents are considered independent, autonomous software components that are able to perceive observations about their environment and, based on these observations, take actions. At each step, agents receive an 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, its beliefs about the state of the environment, as well as its own preferences.

A particular type of agents are *rational agents*. Rational agents rule their behaviour based on their preferences about their internal states. These preferences can be represented by means of an utility function. They select their actions in order to maximise this utility function. Supposing that agents are generally not omniscient, they are unable to calculate the consequences of actions and, thus, have to estimate them. The estimation may change when new knowledge is available.

3 Organised Multiagent System

The general idea of organising a multiagent system is to provide some mechanisms that influence the behaviour of the agents. Such mechanisms may either

[1] A formal definition of these concepts can be found in [1].

[2] including an action of doing nothing, which allows for modelling asynchronous behaviours.

impose certain behaviours or they may persuade agents to behave in a certain way. Formally, we define an organised multiagent system as follows:

Definition 1. *An organised multiagent system (OMAS) is a tuple* $\langle \mathcal{RA}, \mathcal{A}, \mathcal{X}, \Phi, x_0, \varphi, \mathcal{OM} \rangle$ *where:*

- $\mathcal{RA}$ is a set of rational agents;
- $\mathcal{A}$ is a possibly infinite action space that includes all possible actions that can be performed in the system;
- $\mathcal{X}$ is the environmental state space;
- $\Phi : \mathcal{X} \times \mathcal{A}^{|\mathcal{A}g|} \times \mathcal{X} \rightarrow [0..1]$ is the MAS transition probability distribution, describing how the environment evolves as a result of agents' actions;
- $x_0 \in \mathcal{X}$ stands for the initial state of the MAS;
- $\varphi : \mathcal{A}g \times \mathcal{X} \times \mathcal{A} \rightarrow \{0, 1\}$ is the agents' capability function describing the actions agents are able to perform in a given state of the environment. $\varphi(a, x, ac) = 1$ ($\varphi(a, x, ac) = 0$) means that agent a is able (not able) to perform action ac in the state x.
- $\mathcal{OM}$ is a non-empty set of organisational mechanisms.

As stated before, organisational mechanisms can influence the behaviour of agents towards more effectiveness with regard to some objectives. This can be seen from two different points of view: *i)* the micro perspective, and *ii)* the macro perspective. From the micro perspective, an organisational mechanism may help agents to take better decisions regarding their *individual utility* function - *informative mechanisms*. From the macro perspective, a system itself may have some *global utility* function which corresponds to a preference relation on the states of the environment, and an organisational mechanism may improve the utility of the system by persuading or imposing agents to behave in a determined way - *regulative mechanisms*. In the following sections we define both types of mechanisms in more detail.

3.1 Informative Organisational Mechanisms

A rational agent has to evaluate the expected utility of each possible action (or of the actions it is aware of) in order to decide which action to take next. This decision is based on the agent's own individual knowledge and experience. In real world scenarios, the knowledge of agents about the entire system is usually limited and thus, their decisions are made on more or less accurate estimations. Hence, from the point of view of the agents, any additional information may improve the accurateness of their estimations, and, thus, help them to take "better" decisions. Informative organisational mechanisms may provide such information.

Definition 2. *An informative organisational mechanism* Γ *is a function* $\Gamma : \mathcal{S}' \times \mathcal{X}' \rightarrow \mathcal{I}$ *that given a partial description of an internal state of an agent and taking into account the partial view that the mechanism has of the current environmental state, provides information, where:*

– $\mathcal{S}'$ represents the set of possible partial descriptions of agents' internal states;
– $\mathcal{X}'$ is the set of partial views of environmental states;
– $\mathcal{I}$ represents an information space.

We have chosen a very general definition of informative organisational mechanisms in order to cover all possible instantiations. The information provided may consist of a set of actions an agent can take but it is possibly not aware of, a recommendation of a particular action which is eventually a "good action" for the agent, or information about the consequences that a given action may have. All informative organisational mechanisms have in common that their usage is not imposed. Agents are free to use such mechanisms at their own discretion.

Informative organisational mechanisms may improve the performance of individual agents and may have effects on the global performance of an organised multiagent system with respect to a global utility function. In this sense we have defined several desirable properties. These properties should be taken into consideration when designing mechanisms and may also serve to prove certain characteristics of organised multiagent systems. The defined properties state when an informative organisational mechanism is useful for an agent in a particular internal state, when is strongly useful for an agent along a time period or when the mechanism is effective regarding a global utility function during a time period. Since these definitions we have also defined when an informative mechanism is more useful and effective (for an agent in an internal state, along a time period or for a OMAS) than another one. More details in [1].

3.2 Regulative Organisational Mechanisms

As regulative organisational mechanisms we consider mechanisms that produce changes in the environment with the aim to improve a system's behaviour from a global, macro level perspective, that is, with respect to some global utility function. Such mechanisms rely on the existence of some entity (e.g., the system designer, a system manager, ...) that defines the preference relation over system states represented through the global utility function, and that has sufficient authority to impose certain changes in the system.

The rationale behind such mechanisms is that rational agents are perceptive to modifications in the environment because such modifications may change the consequences of actions. Thus, rational agents, with the aim to maximise their individual benefit, may adapt their behaviour to such changes.

We consider two types of possible changes in the environment: *i)* introduction of incentives: rewards and penalties (i.e., changes in the MAS transition probability distribution), which may produce variations in the expected utility of an agent's action, hence they would change their decisions accordingly; and *ii)* of the action spaces of agents: new actions may be added or eliminated either for all agents or for particular agents (i.e., changes in the agents' capability function)[3]. We define regulative organisational mechanisms accordingly:

[3] Note that the system is changed in such a way that agents are not able to perform the eliminated actions

Definition 3. *Let* $MAS = \langle \mathcal{A}g, \mathcal{A}, \mathcal{X}, \Phi, x_0, \varphi \rangle$ *be a multiagent system and* $\mathcal{X}'$ *the set of possible partial descriptions of the environmental states of* MAS*:*

- *An incentive mechanism,* Υ_{inc}*, is a function* $\Upsilon_{inc} : \mathcal{X}' \rightarrow [\mathcal{X} \times \mathcal{A}^{|\mathcal{A}g|} \times \mathcal{X} \rightarrow [0..1]]$ *that given a possibly partial description of an environmental state of* MAS *produces changes in the transition probability distribution of* MAS
- *A coercive mechanism,* Υ_{coe}*, is a function* $\Upsilon_{coe} : \mathcal{X}' \rightarrow [\mathcal{A}g \times \mathcal{X} \times \mathcal{A} \rightarrow \{0, 1\}]$ *that given a possibly partial description of an environmental state of* MAS *produces changes in the agents' capability function of* MAS
- *A regulative organisational mechanism for* MAS *is either an incentive mechanism or a coercive mechanism for that* MAS*.*

Regulative mechanisms may be implemented at design time as fixed mechanisms for the whole life cycle of a MAS (as it is done in many approaches). They may also be introduced when necessary and may even adapt their functioning to each particular situation of the system. In contrast to informative organisational mechanisms, agents can not decide to "use" regulative mechanisms. They are just confronted with the new state of affairs.

As for informative mechanisms, in a similar way, we have defined the effectiveness of regulative mechanisms with respect to some global utility function during a time period, and when a regulative mechanism is more effective than another one.

4 Conclusions

Many authors have proposed the use of social concepts: roles, norms, interactions, and so on to regulate or organise the activities of agents in a MAS [4, 3, 6, 2]. According to the different approaches, the use of such social concepts can be considered as either informative or regulative organisational mechanisms as we propose in this paper.

The concept of role appears in these kind of methodologies as a main piece. They are mechanisms which restrict the set of possible actions that an agent can perform. From our point of view, such schemes can be classified as regulative organisational mechanism (in particular coercive mechanisms), since role assignments limit the action spaces of agents. But the usage of roles can also be considered from another perspective [5], where role taxonomies are used to reflect the capabilities of agents rather than to establish permissions and obligations and, hence, can be seen as informative mechanisms.

Another important social concept is the norm. In a classical view, a normative system indicates to agents what actions are permitted and/or prohibited in a certain situation. Now, if such a system establishes prohibitions and permissions and is coupled with a mechanism that imposes these restrictions in a way that no agent is able to violate them (e.g. the governors in Electronic Institutions [4]) then the normative system is a coercive mechanism. On the other hand, if a normative system defines penalties if agents violate the norms, then the mechanism turns into an incentive mechanism.

In this paper we have presented a formalisation of multiagent organisations that aims to be a general framework for organisational paradigms. The framework defines an organised multiagent systems by means of two types of organisational mechanisms: *informative* and *regulative* mechanisms.

Informative mechanisms influence the behaviour of agents by providing potentially new information which the agents can use to improve their decisions. They can not be imposed and agents can use them at their own discretion.

On the other hand, regulative organisational mechanisms which rely on some global utility function and on some entity that has sufficient authority to impose environmental changes. We differentiate two types of regulative mechanisms: *i)* incentive mechanisms - that change the consequences of certain actions in the system - , and *ii)* coercive mechanisms - that restrict or increase the action space of agents. Regulative mechanisms reflect the approach used in most organisation based methodologies in multiagent system.

In our future work we plan to specify more detailed organisational mechanisms for particular scenarios by imposing certain restrictions on different parameters of a system. Our long term goal is to create a set of organisational mechanisms - appropriate for different kinds of MAS - that can be used in multiagent system design.

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