Coordination Support in Multi-Agent Systems

(Extended Abstract)

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ABSTRACT

We propose the term *Coordination Support* to denote the services offered by the infrastructure used to deploy Multi-Agent Systems (MAS). In fact, these services provide a means to enact the coordination model defined in MAS design. We detail *Coordination Support's* functionalities and group them into different layers. Furthermore we extend them and propose an additional *Assistance* layer devoted to assist coordination rather than to enable it. *Assistance*'s functionalities range from providing information –about the coordination model and its state– to adapting agents' organisation.

Categories and Subject Descriptors

I.2.11 [**Articial Intelligence**]: Distributed AI - MAS

General Terms

Design, Standardization

Keywords

Coordination, Methodologies, Organizational Structure

1. INTRODUCTION

Developing a MAS is a complex task that involves dealing with distribution and interaction among autonomous entities —i.e. agents. A number of design methodologies and tools have appeared in the MAS area [1], all of them defining an agents' coordination model. By *Coordination Support* we denote those infrastructure mechanisms that facilitate agent interaction according to the underlying coordination model.

As MAS area has evolved, certain tasks have been abstracted and gradually provided by the infrastructure. Currently, some of these MAS infrastructures are developed in different abstraction layers [5]. We structure our *Coordination Support* scheme in a generic set of layers that embraces these previous approaches. Most of their functionalities are domain-independent. This simplifies MAS development by simplifying agent engineering. In addition, we propose an extra layer that provides an added value by assisting coordination further than enabling it: the *Assistance* layer. It may even have pro-active capabilities that let the MAS infrastructure take the initiative and act intelligently —e.g. adapting previous layers depending on system's evolution.

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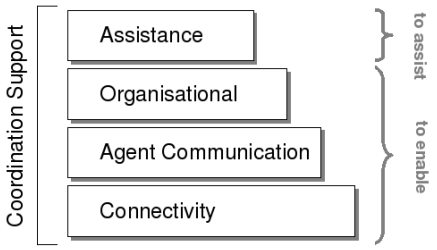

Figure 1: Coordination Support layers.

2. COORDINATION SUPPORT

Frequently, coordination is construed as an integration of different activities to obtain certain expected functionalities, avoiding harmful interactions and promoting beneficial ones. This description can be interpreted as cooperation among elements. However, we envisage coordination in a broader sense. From our point of view, it just denotes interaction among elements —including both cooperation and competence. Thus, we say agents are coordinated since they cooperate/compete towards certain goals –individual or collective– by interacting among them.

We view a MAS as its participants together with the infrastructure that allows their interaction. Hence, we regard MAS infrastructure as a *Coordination Support* for agents. We conceive it structured in the layered scheme depicted in Figure 1. In our approach, first three layers are devoted to enable agents coordination at different levels, and last layer is devoted to enhance it by assisting agents and/or adapting previous layers depending on system's evolution.

2.1 Connectivity layer

It allows the exchange of information among agents by defining (1) a physical connection, (2) a protocol to use this connection and (3) a reliable transport service. These functionalities can be covered by using the existing network standards and the corresponding widely used OSI Model.

2.2 Agent Communication layer

It allows knowledge exchange by defining (1) a message structure specification, (2) an ontology component, (3) a

content language and (4) a directory service to locate destination agents. These requirements are covered by Agent Communication Languages (ACL) generally based on the *speech act* theory.

2.3 Organisational layer

It provides a semantic context to interactions by defining an organisational dimension that includes (1) a social structure –i.e. roles and their relationships– and (2) social conventions –i.e. protocols and norms. In addition, it may define (3) an enforcement policy about these conventions, some (4) organisational goals or even (5) a directory to locate services offered by agents.

Agents should conform, and expect others to conform, social conventions. This reduces agents' complexity since it decreases the set of actions to choose from. Accordingly, it may exist an enforcement policy that determines how to detect violations and how to act in such cases. This is specially relevant to open MAS, where we cannot expect participants to follow social conventions.

Currently, Organisation Centred MAS approaches distinguish among the organisational model and its supporting infrastructure. For instance, an Electronic Institution (EI, [4]) is an organisation defined with ISLANDER that is supported by the AMELI infrastructure. Similarly, in $\mathcal{M}$OISE [2] the model is specified with S-$\mathcal{M}$OISE^{Inst} and supported by the S-$\mathcal{M}$OISE^{+} infrastructure. Both infrastructures provide full detection of social convention violations and apply imposition or punishment. In contrast, there are methodologies where the model is used to create agents that behave strictly according to its organisation specification.

2.4 Assistance layer

With the aim of assisting - rather than enabling- agent coordination, we propose this assistance layer as a new layer comprising additional services that alleviate agent implementation. These services comprise: assisting individual agents to use current social conventions (*Agent Assistance*); and adapting their organisation to varying circumstances (*Organisational Assistance*). In particular, we define five different assistance services:

Information. It provides agents with necessary and useful information to successfully participate in the MAS. The reason can be either because it is new for the agents, it has been updated or they asked for it. This way, agents do not need to periodically check for updates on certain pieces of information. Even they may not require to store them. For instance, this layer informs agents about new norms.

Justification. It justifies the consequences of participant actions —these consequences depend on the action itself, the current social conventions and the current context. For instance, depending on the enforcement policy, an action can be filtered out or performed with extra consequences –e.g. new obligations–, in both cases we suggest to provide a justification to the participant that performed it.

Advice. It provides agents with a set of alternative plans —i.e. action sequences. The way to create an *advice* can be as simple as indicating what other agents have performed on the same situation. Or it can be as complex as planning possible actions given some restrictions –e.g. social conventions– and goals. This functionality lets agents face some plans in compliance with social conventions, instead of facing all possible actions and sequences —so that they can plan at a higher level.

Estimation. It estimates consequences of an action that is not actually performed —e.g. checking if an action fulfils current social conventions. Even more, an estimation can also include a justification or an advice. Estimation may work as a decision support for agents, which can directly focus on evaluating action consequences instead of evaluating conventions. In fact, an agent could use a learning mechanism to acquire empiric knowledge about social conventions instead of analysing their specifications.

Adaptation. It adapts an organisation to fulfil its organisational goals to react to perturbations on the system. When an organisation deviates from its global goals due to changing circumstances -e.g. significant changes in agents' behaviours- the organisation needs to adapt itself accordingly. Hence, we propose goal fulfilment as the driving force to adapt the organisation. Hence, this layer requires to somehow (1) observe the system's evolution, (2) compare it with the organisational goals, and (3) update the organisation to improve goal achievement.

3. CONCLUSIONS

Considering a MAS from a coordination perspective, we define the *Coordination Support* concept. We structure it in different layers and define its functionalities. In addition to mechanisms to enable the coordination itself, we propose new functionalities focused on assisting it.

Currently, we have developed a MAS following our proposal in a P2P sharing network scenario [3]. Our *Coordination Support* prototype implements the *Assistance* layer using a multi-level distributed architecture we call 2-LAMA. Experimental results show savings both in time and network bandwidth requirements (further details can be found in [3]).

Finally, we hope our coordination support concept generates debate and research opportunities within the MAS community. Specifically, we claim that run-time assistance represents a new line, which we plan to further explore by focusing on adaptation mechanisms.

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