Letter From the Guest Editors

Agents Organizations: A Concise Overview

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1. Introduction

Agent organizations are an emergent area of multi-agent systems (MAS) that relies on the notion of openness and heterogeneity of MAS and poses new demands on traditional MAS models. These demands include the integration of organizational and individual perspectives and the dynamic adaptation of models to organizational and environmental changes [6]. Organizational self-design will play a critical role in the development of larger and more complex MAS. As systems grow to include hundreds or thousands of agents, we must move from an agent-centric view of coordination and control to an organization-centric one. However, in order to be able to adapt and evolve, this latter will need to coexist with a dynamic and (partially) emergent organization, based on the former. Practical applications of agents to organizational modeling are being widely developed but formal theories are needed to describe interaction and organizational structure. Furthermore, it is necessary to get a closer look at the relation between organizational roles and the agents that fulfill them.

The overall problem of analyzing the social, economic and technological dimensions of agent organizations, and the co-evolution of agent and human social and personal structures in the organization, provide theoretically demanding, interdisciplinary research questions at different levels of abstraction. Organizational research is increasingly recognizing the advantage of agent-based and other AI models for gaining insight in organizational issues and in exploring dynamic processes and configurations. On the other hand, organizational research has been active in the field of organizational modeling for many years, and has developed insights and theories that are very useful for MAS researchers.

2. Agent Organizations

In closed domains, the design of MAS can suffice with the idea that agents are mere performers of organizational roles or functions, interacting according to fixed protocols and unable to deviate from expected behavior [25]. As such, agent autonomy is rather limited. In open domains, agents are self-governed autonomous entities that pursue their own individual goals based only on their own beliefs and capabilities.

Comprehensive models for MAS must, on the one hand, be able to specify global goals and requirements of organizations but, on the other hand, cannot assume that participating agents will act according to the needs and expectations of the system design. Concepts as organizational rules [24], norms and institutions [5, 7, 8], and social structures [15] arise from the idea that the effective engineering of MAS needs high-level, agent-independent concepts and abstractions that explicitly define the organization in which agents live [25]. These are the rules and global objectives that govern the activity of an enterprise, group,

organization or nation. Given that agents might deviate from expected behavior, open societies need mechanisms to systematize, defend and recommend right and wrong behavior, for instance by proposing a reputation mechanism which can inspire trust into the agents that will join them [4, 17]. Norms are commonly used means to describe such expected behavior. Finally, organizational models must provide means to represent concepts and relationships in the domain that are rich enough to cover the necessary contexts of agent interaction while keeping in mind the relevance of those concepts for the global aims of the system.

In the sequence, we will briefly describe some core notions of the field. First, we present a definition for the term organization. In [18], a possible taxonomy is proposed to better characterize the several dimensions associated with MAS organizations. These dimensions, *formation*, *focus*, *description level, representation* and *adaptation*, are briefly described in the sequence. After defining these concepts, a relation between agents´ interactions and organizations is presented.

2.1. Definition

As it occurs with other basic concepts in the MAS field, there is not a single, universally adopted semantics for the term organization. One of the most generic ones was proposed in [2]:

> " *A MAS organization may be seen in a simplified manner as a set of constraints adopted by a group of agents in order to facilitate their goals achievements*".

In other words, the very fact of belonging to an organization limits the agent autonomy, since he has to cope with the organizational constraints if his behavior is organization compliant.

2.2. Organization Formation

The models used to describe or project an organization are classically divided in two points of view [14]: (i) agent centered, where the organization is functional and instrumental to the agents´ goals and (ii) organization centered, where the agents are fungible and functionally subordinated to the organization. While the former takes the agents as the engine for the organization formation, the latter sees the opposite direction: the organization exists a-priori (defined by the designer or by the agents themselves) and the agents ought to follow it. A MAS organization maybe hence formed either by an *emergent* or by a *predefined* way.

In emergent organizations, the agents of the system do not have necessarily a previous common goal to achieve. Interactions among agents emerge dynamically, as a consequence of their behavior aiming to achieve their own goals. There is not a single objective description of an organization, this latter may be defined as a pattern of distributed mental notions relating each agent with others, like joint intentions or commitments. An example of this type of organization genesis is dependence-based coalition formation [3, 19].

In predefined organizations, agents have a common predefined goal, and hence cooperation occurs as a pattern of fixed, top-down interactions, that are sometimes called "orchestrated interaction" [3]. These organization models, however, may be focused on different aspects, as described next.

2.3. Organization Focus

Some models of MAS organizations stress the importance of its *structural aspects*. These aspects concern the definition of a set of prototypical functions, called *roles*, to be executed by agents in the organization. This dimension also defines the types of links among these roles (authority, communication, etc.), as well as some rules to form collective entities composed by a set of roles, usually named groups or divisions within the main organization. Examples of these models may be found in [9, 10, 11].

Another class of models is focused on organizational *functional aspects*. These aspects main concern is the functioning of the organization, for instance, the specification of global plans, policies to allocate tasks to agents, the coordination to execute a plan, and the quality (time consumption, resources usage, etc.) of a plan. In this group, the global purposes are better achieved because the MAS has a kind of organizational memory where the best plans to achieve a global goal are stored. Examples of these models are [16, 20, 22].

A third class of models concerns *deontic aspects*. The idea is that the global purpose of the organization is accomplished while the agents execute their plans/tasks, following the obligations and permissions entitled by the roles they are playing. These models define obligations and permissions that agents that play certain roles in an organization may have, regarding their knowledge (what do they have right to know?), their actions (what actions are they obliged to execute?) and resources (which resources may be used by them when trying to achieve their goals?). In some models, these aspects are not represented separately [7], while in others these aspects are represented apart from the structural and functional dimensions [12, 13].

One should notice that these classes are not necessarily exclusive within an organizational model. There are some more comprehensive models where several of these focus are dealt with, as in [13, 21].

2.4. Organization Description Level

In every organizational level that uses the role notion, there exist at least 2 different description levels.

The first one, that may be called *abstract* organization, does not contain any reference to the real agents, i.e., it consists only of the organization roles, their links and groups, global plans and permissions/obligations. It may be seen as a kind of recipe of how should collective activity occur. On the other hand, when real agents start to play these organizational roles, a *concrete* organization is instantiated. This latter is effectively the one that is supposed to achieve the organizational top-level goals.

2.5. Representation of the Organization

As presented in section 2.2, MAS organizations may be divided in two points of view: agent centered and organization centered. An important aspect of these points of view is the nature of the organization representation. While in an agent centered approach agents have *subjective* representations (within their minds), in an organization centered approach there is quite always a single, *objective* description of the organization, which is independent of the subjective representations that agents may have of this organization.

In [12, 13, 18], it is presented an extension to this classification, by the introduction of a MAS *observer*. This extension leads to a classification of 4 different situations, depending whether the agents themselves observe the organization:

- Agent centered, not observed by the agents: the organization formation is emergent, but the agents can not represent it, its detection is possible exclusively by an external observer of the MAS, like in cooperative behavior of ant-like agents;
- Agent centered, observed by the agents: the organization formation is emergent, and the agents can represent it, for instance by joint intentions and commitments in their mental states, like in dependence-based coalition formation [3, 19];
- Organization centered, not observed by the agents: the organization formation is predefined, but the agents can not represent it, the organization concepts are used in design time, like in [23, 25];
- Organization centered, observed by the agents: the organization formation is predefined, and the agents can represent it, as the models presented in [6, 11, 13].

2.6. Organization Adaptation

When considering predefined organizations, their temporal behavior may be *static* or *dynamic*. While the first ones maintain their structure and functionality over time (or these are changed off-line by a system designer), in the second group agents themselves have a meta-level reasoning mechanism about their organization, which enables them to change either their structure or their functioning. A more comprehensive discussion of the several aspects of reorganization in MAS may be found in [12].

2.7. Interactions and Organizations

As described in [18], agent's interactions and organizations are not independent aspects of a MAS. If we consider emergent organizations, as described in section 2.2, a first result may be stated as:

> *"Agents interactions may eventually create dynamic organizations"*

Whenever the same interaction patterns are repeated several times, involving the same agents, these interactions may be captured by pre-established structures, thus avoiding the inherent complexity of bottom-up emergent organization formation, like the model proposed in [19]. As a consequence, collective behavior will be more efficient, since the organization formation is carried on a priori.

Hence, if one considers pre-defined organizations, as described in section 2.2, a second result may be stated as:

> "*Agents organizations limits agents interactions, aiming to optimize the achievement of global goals*"

Consequently, these dimensions of MAS make a virtuous circle: interactions build dynamic organizations, and pre-defined static organizations limit agents´ interactions in order to achieve more efficiently the MAS global goals.

3. Overview of the Special Issue

We have received 19 submissions for this special issue, from researchers currently working in many different countries such as Brazil, France, The Netherlands, Italy, Portugal, UK and USA. Each of these submissions was carefully revised by at least 3 different reviewers that were selected for their expertise and current work on multi-agent organizations. The papers appearing in this issue are therefore the result of a very strict selection process. Of the 19 submissions, 5 high quality papers were accepted for publication. After acceptance, the authors of these 5 papers were asked to enhance their final versions, based on the feedback provided by the referees.

These papers offer a broad perspective of the different issues and approaches to the field of Agent Organizations:

- **Analysis of Organizational Effects:** The paper "Analyzing, Modeling and Predicting Organizational Effects in a Distributed Sensor Network" by Bryan Horling and Victor Lesser describes how a system employing different types of organizational techniques has been used to address the challenges posed by a distributed sensor network environment. The organizational design of a distributed system defines how entities act and interact to achieve local and global objectives. The article describes the architecture in detail, and provides empirical results demonstrating the effects the organization has on the system's performance across several different metrics;

- **Tools for Agent Organizations:** The paper "Systems of Exchange Values as Tools for Multi-Agent Organizations" by Gracaliz P. Dimuro, A. C. Rocha Costa and Luiz A. M. Palazzo presents an account of Piaget's theory of exchange values as an approach to social interactions. It complements Piaget's theory with Homans' behaviorist theory of exchange values. By considering the exchange values to account for social interactions, and a theory built up by such a prominent psychologist as Piaget, it lays the basis of an organizational approach for MAS;

- **Application of Agent Organizations:** The paper "Analyzing Requirements of Knowledge Management Systems with the Support of Agent Organizations" by Renata Silva Souza Guizzardi and Anna Perini discusses the use of the Agent Organization paradigm as basis for the development of a support system for Knowledge Management (KM). They present a strong claim to the importance of the initial phases of a system's development, aiming at grasping the requirements of the system to be, both in terms of the individual perspective of the organizational members and the overall objectives of the organization. This analysis process rests on an iterative workflow in which agent-oriented modeling plays a crucial role in understanding the domain's (organization) stakeholders needs for KM systems, basically, by tracing system requirements back to the stakeholders goals;

- **Adaptation of Agent Organizations:** The paper "A Swarm Based Approach to Adapt Organizations of Agents" by Paulo R. Ferreira Jr., Denise de Oliveira and Ana L. C. Bazzan discusses the action-selection and sequencing problem when different agents can perform a goal task in different ways. At the high-level coordination, the specification of the organizational issues is crucial. However, in dynamic environments, agents must be able to adapt to the changing organizational goals, available resources, their relationships to another agents, and so on. This problem is a key one in multi-agent systems and relates to models of learning and adaptation, such as those observed among social insects. The paper tackles the process of generating, adapting, and changing multi-agent organization dynamically at system runtime, using a swarm inspired approach;

- **Automatic Formation of Agent Organizations:** The paper "Automatic Formation and Analysis of Multi-Agent Virtual Organization" by Qinhe Zheng and Xiaoqin Zhang describes experience gained by implementing a multi-agent system that simulates an artificial marketplace, for which the authors have derived several decision-making mechanisms in various stages of a virtual organization. A virtual organization (VO) is defined as the temporary teaming of enterprises. By sharing physical, human and knowledge resources via information technologies, a virtual organization enables member enterprises to share skills, costs, access to one another's markets and, at the same time decrease the risk of investments. In order to realize this new generation of business model, the ability to form and operate virtual enterprises is very important. The paper presents a negotiation protocol and a bid selection algorithm for agents to form a virtual organization.

We would like to express our gratitude to the editor-in-chief of the Journal of the Brazilian Computer Society, Paulo Cesar Masiero, for giving us the opportunity to publish this special issue. We would also like to take this opportunity to acknowledge and thank all the authors who have sent their contributions to this special issue. Finally, we would like to thank our colleagues Alexis Drogoul, Ana Bazzan, Andrea Omicini, Anna Perini, Carles Sierra, Christian Lemaitre, Frank Dignum, Geber Ramalho, Guido Boella, Guilherme Bittencourt, Gustavo Alberto Gimenez-Lugo, Hans Weigand, Helder Coelho, Jacques Wainer, James Odell, Javier Vazquez-Salceda, Jeremy Pitt, Jomi Fred Hübner, Jordi Sabater, Juan Antonio Rodríguez, Leendert van der Torre, Liz Sonnenberg, Ludger van Elst, Luis Antunes, Nico Roos, Olivier Boissier, Olivier Gutknecht, Paulo Cesar Masiero, Rogier van Eijk, Rosaria Conte, Tim Norman, Ulisses Cortez, Vasco Furtado, and Vera Strube de Lima. Without their hard work of carefully reviewing in a timely way all the submitted papers, we would certainly not be able to produce such an exciting special issue, which we hope will please the readers.

References

1. G. Abdelkader. Requirements for achieving software agents autonomy and defining their responsibility. In **Proceedings of the AAMAS-03 Work-**

shop on Autonomy, Delegation, and Control: From Inter-agent to Organizations and Institutions. Melbourne, Australia, 2003.

2. O. Boissier and Y. Demazeau. ASIC: an architecture for social and individual control and its application to computer vision. . In J. Perram, and J. P. Müller, editors, **Applications of Multi-Agent Systems – Proceedings of MAAMAW 1994**, LNAI series, vol. 1069, pg. 135-149. Springer-Verlag, Heidelberg, 1996.
3. C. Castelfranchi, M. Micelli and A. Cesta. Dependence relations among autonomous agents. In E. Werner and Y. Demazeau, editors, **Decentralized AI 3**, pg. 215-227. Elsevier Science Publishers, Amsterdam, 1992.
4. R. Conte and M. Paolucci. **Reputation in artificial societies: social beliefs for social order**. Kluwer Academic Publisherrs, Amsterdam, 2002.
5. R. Conte, C. Castelfranchi and F. Dignum. Autonomous Norm Acceptance. In J. P. Mueller, M. P. Singh, and A. S. Rao, editors, **Intelligent Agents V**, LNAI series, vol. 1555, pg. 45-60. Springer-Verlag, Heidelberg, 1999.
6. V. Dignum. **A model for organizational interaction: based on agents, founded in logic**. SIKS Dissertation Series 2004-1. 270 pages. SIKS, Amsterdam, 2004. PhD Thesis.
7. V. Dignum and F. Dignum. Modeling agent societies: coordination frameworks and institutions. In P. Brazdil and A. Jorge, editors, **Progress in Artificial Intelligence – Proceedings of APIA 2001**, LNAI series, vol. 2258, pg. 191-204. Springer-Verlag, Heidelberg, 2001.
8. M. Esteva, J. Padget, and C. Sierra. Formalizing a language for institutions and norms. In J.-J.CH. Meyer and M. Tambe, editors, **Intelligent Agents VIII**, LNAI series, vol. 2333, pg. 348-366. Springer-Verlag, Heidelberg, 2001.
9. J. Ferber and O. Gutknecht. A meta-model for the analysis and design of organizations in multi-agents systems. In Yves Demazeau, editor, **Proceedings of the 3rd International Conference on Multi-Agent Systems (ICMAS 1998)**, pg. 128–135. IEEE Press, Washington, 1998.
10. M. Fox, M. Barbuceanu, M. Gruninger, and J. Lon. An organizational ontology for enterprise modeling. In M. Prietula, K. Carley, and L. Gasser, editors, **Simulating Organizations: Computational Models of Institutions and Groups**, chapter 7, pg. 131–152. AAAI Press / MIT Press, Menlo Park, 1998.
11. M. Hannoun, O. Boissier, J. S. Sichman, and C. Sayettat. MOISE: An organizational model for multi-agent systems. In M. C. Monard and J. Sichman, editors, **Advances in Artificial Intelligence – Proceedings of IBERAMIA/SBIA 2000**, LNAI series, vol. 1952, pg. 152–161. Springer-Verlag, Heidelberg, 2000.
12. J. F. Hübner, J. S. Sichman and O. Boissier. Using the MOISE+ for a cooperative framework of MAS reorganization. In A. Bazzan and S. Labidi, editors, **Advances in Artificial Intelligence – Proceedings of SBIA 2004**, LNAI series, vol. 3171, pg. 506–515. Springer-Verlag, Heidelberg, 2004.
13. J. F. Hübner, J. S. Sichman and O. Boissier. A model for the structural, functional and deontic specification of a MAS organization. In G. Bittencourt and G. Ramalho, editors, **Advances in Artificial Intelligence – Proceedings of SBIA 2002**, LNAI series, vol. 2507, pg. 118–128. Springer-Verlag, Heidelberg, 2002.
14. C. Lemaître and C. Excelente. Multi-agent organization approach. In F. Garijo and C. Lemaître, editors, **Proceedings of the II Ibero-american Workshop on DAI and MAS**, pg. 7-16. Toledo, Spain, 1998.
15. V. Parunak and J. Odell. Representing social structures in UML. In M. Wooldridge, G. Weiss, and P. Ciancarini, editors, **Agent-Oriented Software Engineering II**, LNCS series, vol. 2222, pg. 1-16. Springer-Verlag, Heidelberg, 2002.
16. M. Prasad, K. Decker, A. Garvey, and V. Lesser. Exploring organizational design with TÆMS: a case study of distributed data processing. In Toru Ishida, editor, **Proceedings of the 2nd International Conference on Multi-Agent Systems (ICMAS 1996)**, pages 283–290. AAAI Press, Menlo Park, 1996.
17. J. Sabater and C. Sierra. Reputation and social network analysis in multi-agent systems. In C. Castelfranchi and W. L. Johnson, editors, **Proceedings of the 1st. International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS 2002)**, pg. 475-482. ACM Press, New York, 2002.
18. J. S. Sichman. **Raciocínio social e organizacional em sistemas multiagentes: avanços e perspectivas**. 235 pages. Escola Politécnica da USP, São Paulo, 2003. Associate Professorship Thesis (In Portuguese).
19. J. S. Sichman, R. Conte, Y. Demazeau and C. Castelfranchi. A social reasoning mechanism based on dependence networks. In Tony Cohn, editor, **Proceedings of the 11th. European Conference on Artificial Intelligence (ECAI 1994)**, pg. 188-192. John Wiley & Sons Ltd., New York, 1994.
20. Y. So and E. Durfee. An organizational self-design model for organizational change. In **Proceedings of the AAAI-93 Workshop on AI and Theories of Groups and Organizations: Conceptual and Empirical Research**, pg. 8-15. Washington, USA, 1993.

21. M. Tambe and W. Zhang, W. Towards flexible teamwork in persistent teams. In Yves Demazeau, editor, **Proceedings of the 3rd International Conference on Multi-Agent Systems (ICMAS 1998)**, pg. 277–284. IEEE Press, Washington, 1998.
22. G. Weiß. **Some studies in distributed machine learning and organizational design**. Technical Report FKI-189-94, Institut für Informatik, Technische Universität München, 1994.
23. M. Wooldridge, N.R. Jennings and D. Kinny. The GAIA methodology for agent oriented analysis and design. **Autonomous Agents and Multi-Agent Systems**, 3(3):285-312, 2000.
24. F. Zambonelli. Abstractions and infrastructures for the design and development of mobile agent organizations. In M. Wooldridge, G. Weiss, and P. Ciancarini, editors, **Agent-Oriented Software Engineering II**, LNCS series, vol. 2222, pg. 245-262. Springer-Verlag, Heidelberg, 2002.
25. F. Zambonelli, N. Jennings, and M. Wooldridge. Organizational abstractions for the analysis and design of multi- agent systems. In P. Ciancarini and M. Wooldridge, editors, **Agent-Oriented Software Engineering**, LNCS series, vol. 1957, pg. 98-114. Springer-Verlag, Heidelberg, 2001.