A Dialogic Dimension for the $\mathcal{M}$OISE+ Organizational Model

A. Hübner, G.P. Dimuro and A.C.R. Costa
PPGMC, Centro de Ciências Computacionais
Universidade Federal do Rio Grande
96201-900 Rio Grande, RS, Brazil
Email: {ale.hubner, ac.rocha.costa,gracaliz}@gmail.com

V.L.D. Mattos
DEMAT, Instituto de Ciências Exatas
Universidade Federal Rural do Rio de Janeiro
32890-000 Seropédica, RJ, Brazil
Email: viviane.leite.mattos@gmail.com

***Abstract*—The aim of this work is to propose a fourth dimension for the $\mathcal{M}$OISE+ multiagent system organizational model, focused in the communication between roles. For that, the model $\mathcal{M}$OISE+ is extended with a dialogic dimension that defines the protocols used for communication between roles. In order to interlink this new dimension to the other dimensions of the $\mathcal{M}$OISE+ model, new relations are added to the deontic specification, which are responsible for indicating which protocols should or could be used to achieve the goals that constitute the roles' missions. The use of the extended model is illustrated, with a case study in the modeling of the process of creation of an episodic graduate course in a particular communitarian university in Brazil.**

I. Introduction

It is possible to distinguish two structural levels in a Multiagent System (MAS), namely, the *organization* and the *population* structures. Basically, the population structure is composed by the agents themselves (and, of course, all the mechanism related to them, such as the ones for interaction and communication). The organization structure is related to the roles that may be played by the MAS population.

The PopOrg model [1], [2], [3], [4], for example, is a MAS organizational model that clearly separates those two structural levels.

On the other hand, in the PopOrg model, the notion of interaction between agents/roles is explained by means of *social exchanges* (i.e., exchange of services or objects [5], [6], [7]) between agents/roles in each structural level.

Since *communication* is one of the main tools that agents have to coordinate their actions in the exchanges that they perform at the population level (cf., e.g., [8]), the specification of the exchanges (and then, the communication) between roles may be a tool for the regulation of the exchanges between the agents that adopt such roles.

So, in the same way that the communication between agents is crucial to allow/regulate the exchanges that agents perform on their own, at the level of the MAS population, also the communication between roles can be a specification mechanism, at the organization level, tho allow/regulate the exchanges between agents when they adopt those roles.

This becomes particulary important in some kinds of organizations where the exchange processes promoted in their context demand an intensive communication flow between the organizational roles and/or groups of roles.

An example of such organization is the one of a university, considering, for example, its management processes, which are mainly coordinated by the communication between the roles (e.g, the president, a dean of the school, a head of department, a course coordinator, a professor, a department secretary), or between groups of roles (e.g., a department, a faculty, a scientific board, a school board, a research laboratory, a research group).

We have studied such management processes in a particular private communitarian university in Brazil, where it was observed those intensive communication flows guiding all such processes.

The MAS organizational model $\mathcal{M}$OISE+ [9], [10], [11], [12], [13], [14], [15], showed to be a practical organization model very suitable for our purposes, given in particular the very good set of tools that support it and help the design of MAS.

However, the $\mathcal{M}$OISE+ model presents only the following dimensions: the *structural* dimension (roles, role relations, inheritance relation, links, groups, etc.), the *funcional* dimension (global plans, missions, etc.), and the *deontic* dimension, which relates the other two dimension by stating the permissions and obligations of a role on a mission, thus lacking a dimension to specify communications between roles, which was essential in our application. Such lack of an explicit dialogic dimension in the $\mathcal{M}$OISE+ model, contrasted with the central position that dialogues play in our theoretical PopOrg model, motivated the present work.[1]

Thus, the aim of this work is to propose the introduction of a *dialogic* dimension in the $\mathcal{M}$OISE+ model, focused in the communication between roles at the MAS organization level, not in the communication between agents at the MAS population level. As a case study, we took the process of creation of an episodic graduate course at that particular private communitarian university.

[1]The definition of the $\mathcal{M}$OISE+ model was based on the $\mathcal{M}$OISE [16], [17] model, adding to it many facilities [9], [10], and offering a framework for the reorganization of multiagent systems [11]. Neither the original $\mathcal{M}$OISE+ nor in the $\mathcal{M}$OISE+ model, however, gave the status of a full dimension for the specification of the dialogues between roles.

The paper is organized as follows. Section II briefly presents basic concepts of MAS organization models, and, in particular, the $\mathcal{M}$OISE+ model, which is the one this paper is concerned with. Section III presents our proposal for introducing a dialogic dimension in the $\mathcal{M}$OISE+ model, allowing for the specification of the communication between roles. Section IV presents a case study related to the process of creation of an episodic graduate course at a particular private communitarian university in Brazil. Section V is the Conclusion.

II. MAS Organizational Models and $\mathcal{M}$OISE+

In the literature, it is possible to find many approaches for MAS organization modelling [18]. Most of them offer a set of computational tools to support their use in the modeling of MAS. The development of these tools may consider either an *agent-centered* or a *system-centered* conception [9], [19], [20]. The former takes the agents as the engine for the organization formation, focusing the organizational agent-level deliberative mechanisms to interpret and reason about the specification of the organization. In the latter, the main concern is the organizational infrastructure, i.e., the organization exists a priori (defined by the designer or by the agents themselves) and the agents ought to follow it.

In general, the MAS organization models present a declarative language for the organization modelling and also an organization architecture (see, e.g., the Islander editor [21] and the Ameli agent-based platform [22] for electronic institutions).

The $\mathcal{M}$OISE+ model, which is an organization-centered model, also presents those facilities [20], [23]. In $\mathcal{M}$OISE+, there is a language for specifying the MAS organization, which allows us to chose constraints and cooperation patterns to be imposed on the agents, in order to develop the *Organization Specification* (OS) . An *Organization Entity* (OE) is then created as the agents adopt the roles specified in the organization specification, i.e., a set of agents builds an organization entity by adopting an appropriate organization specification in order to achieve its purpose.

The $\mathcal{M}$OISE+ model considers three organizational dimensions: the organization structure itself, its functions, and the deontic relation among them to explain how a MAS organization collaborates for its purpose:

- *Structural Dimension* (roles, groups, relations): A role is conceived as a set of behavioral constraints that an agent accepts since it joins a group in the organization. For example, in the case of the organization of a university, the agent that adopts the role of a *professor* has some kind of authority over the one that is playing the role of a *student*.
- *Functional Dimension* (goals, global plans, missions): It defines a set of global plans for the MAS to achieve its goals, which are structured in a social schema, as a goal decomposition tree, where each goal may be decomposed in sub-goals, and the responsibilities for the sub-goals are distributed in missions. The mission are attributed to the roles and constitute the commitments of the agents that adopt such roles. Once an agent is committed with a mission, it is responsible to achieve the goals related to it. The mission may be attached to individual preferences, which are used in the case of establishing a preference order among missions.
- *Deontic Dimension* (obligations, permissions): It specifies the relations between the structural specification and the functional specification, establishing which missions each role is obliged or has the permission to realize.

The first two dimensions can be specified almost independently of each other, and, after, they are properly linked by the deontic dimension, which facilitates also the reorganization of the system.

A $\mathcal{M}$OISE+ organization specification is formed by a Structural Specification (SS), a Functional Specification (FS) and a Deontic Specification (DS). A a $\mathcal{M}$OISE+ organization specification can be represented as a XML file, using an specific format, which can be manipulated by the $\mathcal{M}$OISE+ editor.

III. A Dialogic Dimension for the $\mathcal{M}$OISE+ Model

As discussed in the Introduction, the specification of the interactions/exchanges between roles at the organization level may be an important tool for the regulation of the interactions/exchanges between agents that adopt those roles at the population level, and the communication is a fundamental tool that the roles/agents have in order to perform interactions/exchanges.

For example, in the GAIA methodology [24], whose underlying organization model allows to deal with adaptive multi-agent organizations [25], a role is defined by a set of four attributes: responsibility, permissions, activities and protocols. The protocols establishes the requirements for the interactions between roles (for example, to the role of *manager* may be associated the Contract Net protocol). Those protocols may be defined at the analysis phase. This association of protocols to roles generates an *interaction model*, which specifies the links between roles. Electronic institutions [21], [22] and the OperA model [26] are other organizational models where the specification of interactions also is a central feature.

On the other hand, the $\mathcal{M}$OISE+ organization model does not support a clear specification of how the interaction between roles may be conducted. In this paper, we propose the integration of a fourth dimension to the $\mathcal{M}$OISE+ model, namely the *dialogic* dimension, which allows for the specification of the communication between roles through protocols that should/may be used by them.

The idea of the inclusion of a dialogic dimension in the $\mathcal{M}$OISE+ model implies the addition of new relations in the deontic dimension, indicating which missions present goals that need communication between roles, and which protocols are required/permitted to be used while trying to achieve those goals.

The new organization configuration that we propose for the $\mathcal{M}$OISE+ model is shown in Fig. 1.

The protocols defined in the dialogic dimension are abstract, i.e., they do not specify the details of the communication

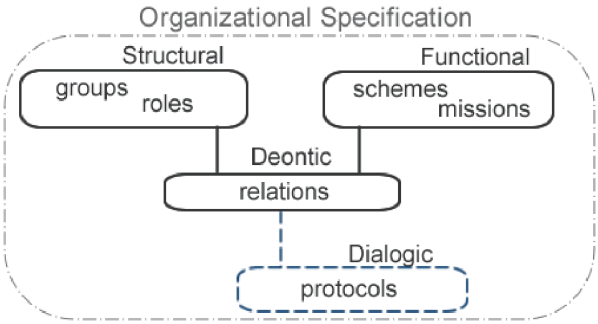

Fig. 1. The $\mathcal{M}$OISE+ model extended with the Dialogic Dimension

operations to be used. The specification of how those abstract communication operations are to be realized by the communication primitives effectively available for the agents, when they adopt the roles involved in those communications, is defined separately, in a so-called *Dialogic Specification* (DLS), which is treated as a new separate part in the PopOrg specification, complementing the specification of how the population structure implements the organization structure.

The Deontic Specification of the $\mathcal{M}$OISE+ is extended with the element `deontic-links`, which is responsible for defining which protocol is to be used by each role that has a goal whose achievement demands an interaction with another role (see XML Code 1; note that the `deontic-relation` element is original to the $\mathcal{M}$OISE+ model).

XML Code 1. Communication in the deontic specification

```
<deontic-specification>

  <deontic-relation type="permission" role="role[x]"
     mission="m1" />
  <deontic-relation type="permission" role="role[y]"
     mission="m2" />
  <deontic-relation type="obligation" role="role[z]"
     mission="m3" />

  <deontic-links  mission="m1" >
    <link type="obligation" goal="g1" protocol="p1"
        />
  </deontic-links>

  <deontic-links  mission="m2" >
    <link type="obligation" goal="g2" protocol="p2"
        />
    <link type="permission" goal="g3" protocol="p3"
        /
  </deontic-links>

</deontic-specification>
```

A set of `deontic-links` like

```
<deontic-links  mission="m2" >
  <link type="obligation" goal="g2" protocol="p2" />
  <link type="permission" goal="g3" protocol="p3" />
</deontic-links>
```

says that whenever a goal has the mission `m2`, it has the obligation of using protocol `p2` to achieve goal `g2` of `m2`, and the permission to use protocol `p3` to achieve goal `g3` of `m2`.

Although the communication protocols are defined abstractly in the dialogic specification, the parameters and performatives of FIPA ACL [27] are used in order to structure the message in the communication specification, as can be seen in the XML Code 2 (a generic specification) and in XML Code 3 (an instantiated specification).

XML Code 2. A generic communication protocol

```
<dialogical-specification>
  <protocol-definitions>

    <protocol id="px" >
      <seq>
        <msg id="1" send="roleX" receiver="roleY
            " >
          <content type="request" language="
              Prolog" says="requested(Request)"
              />
            <return reply-with="X" />
        </msg>
        <msg id="2" send="roleY" receiver="roleX
            " >
          <content type="inform" language="
              Prolog" says="reply([X1 = V1, X2
              = V2, ... Xn = Vn])" />
            <return in-reply-to="X" />
        </msg>
      </seq>
    </protocol>

  </protocol-definitions>
</dialogical-specification>
```

XML Code 3. An instantiated communication protocol

```
<dialogical-specification>
  <protocol-definitions>

    <protocol id="p1" >
      <seq>
        <msg id="1" send="professor" receiver="
            student" >
          <content type="request" language="
              Prolog" says="?- location(you,(
              City,Country))" />
            <return reply-with="address" />
        </msg>
        <msg id="2" send="student" receiver="
            professor" >
          <content type="inform" language="
              Prolog" says="\+ City = pelotas,
              Country = brazil" />
            <return in-reply-to="address" />
        </msg>
      </seq>
    </protocol>

  </protocol-definitions>
</dialogical-specification>
```

In both codes, it is possible to observe the `XML` elements and attributes used in the implementation of a particular example of a dialogic specification:

- The element `<protocol>` has the attribute `id`, which is responsible for linking the dialogic specification with the deontic specification;
- The element `<msg>` may have from 2 to 4 attributes: `send`/`receiver` (indicates who send/receive the message), `propagate` (sends the message for a group), and `to` (indicates the final target of the message, when it is forwarded);

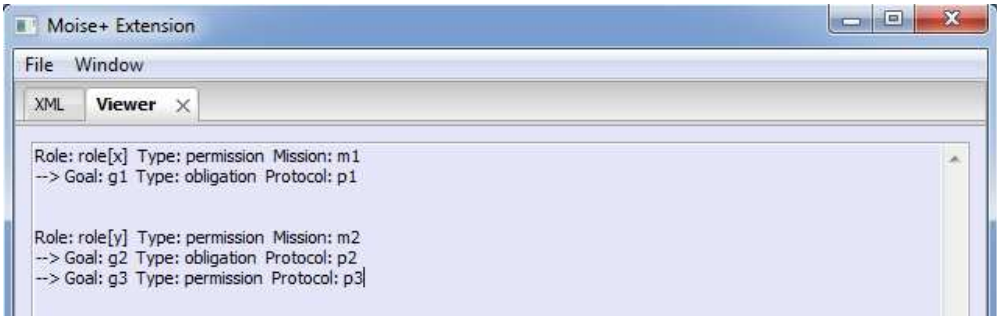

Fig. 2. The viewer tool

- The element `<content>` has 4 attributes: `type` (defines an interpretation for the message), `from` (indicated the first sender of the message), `says` (carries the content of the message), and `language` (specifies the language, which, in this case, is Prolog);
- The element `<return>` may have 1 or 2 attributes: `reply-with` (contains the identification label for an returning answer), and `in-reply-to` (contains the identification label of the received message).

Note that, for a particular application, a particular ontology for role communication would be specified.

In order to help the user, we implemented a viewer tool (Fig. 2), which joints the dialogic specification with de deontic specification, allowing to view, in a structured and organized way, all the protocols that the roles use to execute their duties.

IV. Application Example

For the case study of this work, we selected one of the management processes that we found in the context of a particular private communitarian university in Brazil, namely, the management process of episodic graduate courses (the course that should occur just once), which can be divided into 4 stages: (i) creation, (ii) promotion and advertisement, (iii) classes and advising, and (iv) closing.

In the first stage, called the *creation* phase, which encompasses the conception and the formalization of the course, the role `professor` is the one who has the idea to propose the course.

Then, this *proponent* `professor` starts to collect related material, exchanging ideas with its colleagues (also with the role `professor`), and also talking with the role `dean of department` to which it proposes informally the creation of the course.

Observe that, at this phase, there is an intensive flow of communication between the group `faculty`, i.e., between the proponent `professor` and the other `professor`s, and between the roles `professor` and `dean of department`.

The proponent `professor` also uses a lot of communication in order to ask for services and instructions, give and receive information/suggestions, to receive and discuss informal reports, etc., during the creation phase.

After an informal analysis if there is a good probability to have the course proposal approved in the higher management and scientific instances of the university, the proponent `professor` develops an schema of the course pedagogical project.

Then, the `dean of department` constitutes a group, the `work team`, which is composed by roles of `professor`s. This work team is supposed to have meetings in order to elaborate the formal course pedagogical project.

After that, the proponent `professor` requests that the `Control and Planning Consultancy` to elaborate the financial analysis (costs, incomings) of the proposal. After that, the proponent `professor` formalizes its proposal, jointing the course pedagogical project with the respective financial analysis.

In the sequence, the `department secretary` opens a formal process, which is evaluated in the various management and scientific instances of the university, such us: `Department Consultant Council`, `Graduate Board`, `Administration Board`, and `Superior Scientific Council`.

After been approved in all those instances, the process goes to the second stage, which is the *promotion/advertisement* of the course.

If the course attracts a sufficient number of applications that guarantees that it will be economical viable, then it is finally approved, and it advances the other stages, namely, the *classes and advising*, and finally the *closing*.

In this paper, we show just the first stage of this process, namely, the creation process. After the conceptual modeling phase, where all the structure the university, related to this application, was depicted, identifying all the roles, groups of roles, relations, interactions between roles and between roles and groups, global plans, missions, etc., we developed the organization specification of a MAS for simulating the creation process, using the $\mathcal{M}$OISE+ model.

Figures 3, and 4 show a sample of UML sequence diagrams, illustrating how the role communication protocols of the dialogic specification are visually designed.

After the visual design phase, the XML representation of the protocols are written. For example, the sequence diagram of Fig. 3 generates the protocol shown in the XML Code 4.

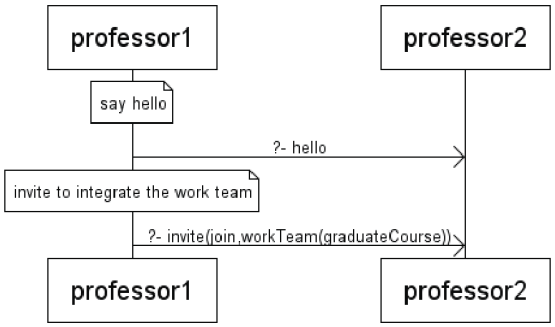

Fig. 3. Partial diagram of a role communication protocol

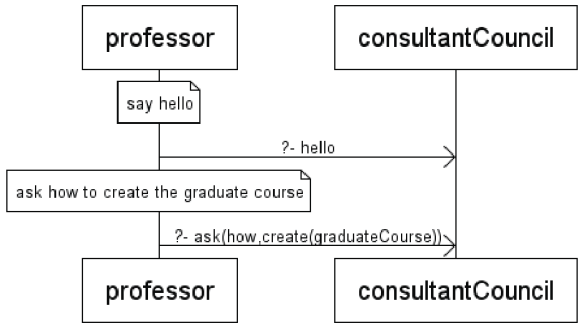

Fig. 4. Partial diagram of a role communication protocol

XML Code 4. Protocols of the Dialogic Specification

```
<dialogical-specification>
  <protocol-definitions>

    <protocol id="p1" >
      <seq>
        <msg id="1" send="professor1" receiver="
            professor2" group="faculty">
          <content type="inform" language="
              Prolog" says="?- hello" />
        </msg>
        <msg id="2" send="professor1" receiver="
            professor2" group="faculty">
          <content type="cfp" language="Prolog"
              says="?- join(workTeam(
            graduateCourse))" />
        </msg>
      </seq>
    </protocol>

  </protocol-definitions>
</dialogical-specification>
```

Figure 5 shows the deontic dimension, with the dialogical elements that were added for the specification of the protocols to be used in the interactions between roles in the creation phase of the management process of episodic graduate courses.

V. Conclusion

It is possible to find in the literature several organizational models for the modeling of multiagent systems. This work was concerned, in particular, withe the $\mathcal{M}$OISE+ model. The $\mathcal{M}$OISE+ model is an improvement over the $\mathcal{M}$OISE model that allowed its use in different contexts when modeling MAS systems. However, some elements were not considered in $\mathcal{M}$OISE+ model, such us the specification of communication protocols.

In this paper, we discussed the importance, in some specific applications, of having tools for the specification of the interactions/exchanges that use communication between roles at the MAS organization level, which may help the regulation of the interactions/exchanges that use communication between the agents that adopt those roles at the MAS population level.

This work proposed an extension to the $\mathcal{M}$OISE+ organizational model, which incorporated a dialogic dimension used to specify the communication between roles, where the protocols applied in the role communication are defined.

The dialogic dimension was connected to the deontic dimension by the adding new relations that are responsible for indicating which missions have goals that need role communication, specifying permission and obligations to use communication protocols. The dialogic dimension was modeled with the specification of the protocols using the XML language.

We developed an application related to the creation phase of the management process of a episodic graduate course in a particular private communitarian university. This case study was particulary interesting for the purpose of validating our proposal, since that this kind of organization and its management processes presented a large communication flow between the roles.

Acknowledgment

This work is part of a larger project (RS-SOC: Rede Estadual de Simulação Social), being run under the FAPERGS/CNPq/PRONEX context, where the political aspects of dialogical features of social organizations are being investigated. The work is supported by FAPERGS/CNPq/PRONEX (Proc. 10/0049-7) and CNPq (Proc. 483257/09-5, 307185/07-9, 304580/07-4). We thank Jomi Hübner for helping us with the $\mathcal{M}$OISE+ tools and also for his valuable suggestions.

References

[1] A. C. da Rocha Costa and G. P. Dimuro, "Semantical concepts for a formal structural dynamics of situated multiagent systems," in *Coordination, Organizations, Institutions, and Norms in Agent Systems III*, ser. LNAI, J. Sichman, P. Noriega, J. Padget, and S. Ossowski, Eds. Berlin: Springer, 2008, no. 4870, pp. 139–154.

[2] ——, "A basis for an exchange value-based operational notion of morality for multiagent systems," in *Progress in Artificial Intelligence, 13th Portuguese Conf. on Artificial Intelligence, EPIA 2007*, ser. LNAI, J. Neves, M. Santos, and J. Machado, Eds. Berlin: Springer, 2007, no. 4874, pp. 580–592.

[3] ——, "A minimal dynamical organization model," in *Handbook of Research on Multi-Agent Systems: Semantics and Dynamics of Organizational Models*, V. Dignum, Ed. Hershey: IGI Global, 2009, pp. 419–445.

[4] ——, "Introducing social groups and group exchanges in the PopOrg model," in *Proceedings of AAMAS 2009*, vol. 1. Budapest: IFAAMAS, 2009, pp. 1297–1298.

[5] J. Piaget, *Sociological Studies*. London: Routlege, 1995.

[6] G. Homans, *Social Behavior – Its Elementary Forms*. New York: Harcourt, Brace & World, 1961.

[7] P. Blau, *Exchange & Power in Social Life*. New Brunswick: Trans. Publish., 2005.

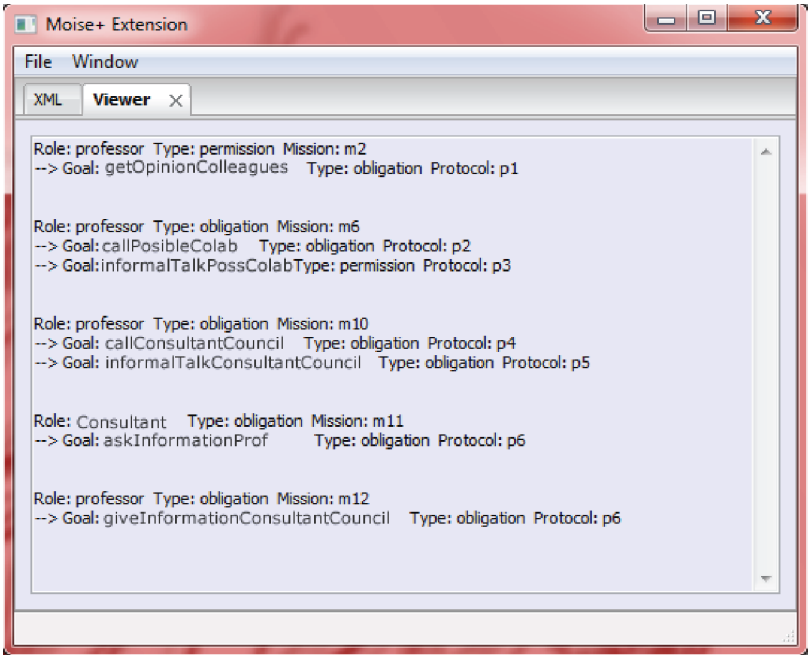

Fig. 5. The Extended Deontic Specification

[8] M. Wooldridge, *An Introduction to MultiAgent Systems*. Chichester: Wiley, 2002.

[9] J. F. Hübner, J. S. Sichman, and O. Boissier, "A model for the structural, functional, and deontic specification of organizations in multiagent systems," in *Advances in Artificial Intelligence, Proceedings of the 16th Brazilian Symposium on Artificial Intelligence*, ser. LNCS, G. Bittencourt and G. Ramalho, Eds., vol. 2507. Springer, 2002, pp. 118–128.

[10] ——, "MOISE+: towards a structural, functional, and deontic model for MAS organization," in *Proc. of the First Intl. Joint Conf. on Autonomous Agents and Multiagent Systems*. New York: ACM, 2002, pp. 501–502.

[11] J. F. Hübner, O. Boissier, and J. S. Sichman, "Programming MAS reorganisation with MOISE+," in *Foundations and Practice of Programming Multi-Agent Systems*, ser. Dagstuhl Seminars Proc., J. Meyer, M. Dastani, and R. Bordini, Eds., no. 06261. IFBI, 2006.

[12] J. F. Hübner, J. S. Sichman, and O. Boissier, "Developing organised multi-agent systems using the MOISE+ model: programming issues at the system and agent levels," *International Journal of Agent-Oriented Software Engineering*, vol. 1, no. 3/4, pp. 370–395, 2007.

[13] J. F. Hübner, R. H. Bordini, and G. Picard, "Jason and MOISE+: Organisational programming in the agent contest 2008," in *Dagstuhl Seminar on Programming Multi-Agent Systems*, ser. Dagstuhl Seminars Proc., R. Bordini, M. Dastani, J. Dix, and A. E. Fallah-Seghrouchni, Eds., no. 08361, 2008.

[14] J. F. Hübner, "Moise+ framework and ora4mas," in *Proceedings of Lorentz Workshop on Rich Cognitive Models for Policy Design and Simulation*, W. Jager, C. Jonker, and V. Dignum, Eds., Leiden, 2009.

[15] J. F. Hübner, O. Boissier, and J. S. Sichman, "Using jason and MOISE+ to develop a team of cowboys," in *Programming Multi-Agent Systems*, ser. LNAI, J. Meyer, M. Dastani, and R. Bordini, Eds. Berlin: Springer, 2006, no. 5442, pp. 238–242.

[16] M. Hannoun, O. Boissier, J. S. Sichman, and C. Sayettatinho, "MOISE: An organizational model for multi-agent systems," in *Proc. of Intl. Joint Conferences, 7th. Ibero-American Conf. on Artificial Intelligence (IBERAMIA'00) and 15th. Braz. Symp. on Artificial Intelligence (SBIA'00)*, ser. LNAI, vol. 1952. Berlin: Springer, 2000, pp. 152–161.

[17] M. Hannoun, O. Boissier, J. S. Sichman, and C. Sayettat, "Moise: An organizational model for multi-agent systems," in *Proceedings of the International Joint Conference, 7th Ibero-American Conference on AI, 15th Brazilian Symposium on AI, IBERAMIA/SBIA 2000*, ser. LNAI, M. C. Monard and J. S. Sichman, Eds. Berlin: Springer, 2000, no. 1952, pp. 152–161.

[18] V. Dignum, Ed., *Handbook of Research on Multi-Agent Systems: Semantics and Dynamics of Organizational Models*. Hershey: IGI Global, 2009.

[19] C. Lemaytre and C. B. Excelente, "Multi-agent organization approach," in *Proceedings of II Iberoamerican Workshop on DAI and MAS*, F. J. Garijo and C. Lemaytre, Eds., Toledo, 1998.

[20] J. F. Hübner, J. S. Sichman, , and O. Boissier, "Developing organised multi-agent systems using the moise+ model: Programming issues at the system and agent levels," *International Journal of Agent-Oriented Software Engineering*, vol. 1, no. 3-4, pp. 370–395, 2007.

[21] M. Esteva, D. de la Cruz, and C. Sierra, "ISLANDER: An electronic institutions editor," in *Proc. First international joint conference on autonomous agents and multiAgent systems, AAMAS 2002*, ser. LNAI, C. Castelfranchi and W. L. Johnson, Eds. Berlin: Springer, 2002, no. 1191, pp. 1045–1052.

[22] M. Esteva, Rodríguez-Aguilar, J. A., B. Rosell, and J. L. Arcos, "AMELI: An agent-based middleware for electronic institutions," in *Proc. Third international joint conference on autonomous agents and multi-agent systems, AAMAS 2004*, N. R. Jennings, C. Sierra, L. Sonenberg, and M. Tambe, Eds. New York: ACM, 2004, pp. 236–243.

[23] J. F. Hübner, J. S. Sichman, and O. Boissier, "S-MOISE+: A middleware for developing organised multi-agent systems," in *Coordination, organizations, institutions, and norms in multi-agent systems*, ser. LNAI, O. Boissier, V. Dignum, E. Matson, and J. S. Sichman, Eds. Berlin: Springer, 2006, no. 3913, pp. 64–78.

[24] M. Wooldridge, N. R. Jennings, and D. Kinny, "The gaia methodology for agent-oriented analysis and design," *Autonomous Agents and Multi-Agent Systems*, vol. 3, no. 3, pp. 285–312, 2000.

[25] L. Cernuzzi and F. Zambonelli, "Dealing with adaptive multi-agent organizations in the gaia methodology," in *Proceedings of AOSE 2005*, 2005, pp. 217–228.

[26] V. Dignum, "A model for organizational interaction: based on agents, founded in logic," Ph.D. dissertation, University of Utrecht, Utrecht, 2003.

[27] Foundation for Intelligent Physical Agents, *FIPA 97 Specification Part 2: Agent Communication Language*, Oct. 1997, version 2.0. [Online]. Available: http://www.fipa.org/spec/f8a22.zip