

The Role Concept for Agents in MultiAgent Systems

Gabriela Lindemann-von Trzebiatowski, Ines Münch

Humboldt University of Berlin
Department of Computer Science, Artificial Intelligence
lindeman|muench@informatik.hu-berlin.de

Abstract. Modeling social action in multi-agent systems asks for modeling of internal states of other agents. Where communication does not suffice to transfer the necessary information to determine these states, generic sets of expectations for behavior and competences are in demand. We introduce a localized, functional notion of *roles* that act as these sets of expectations. We discuss the identification of formal and practical roles in organizational structures and give an example where this role concept has been put to use.

1. Introduction

Multi-agent Systems offer the opportunity to model organizational courses with heterogeneous goals by the integration of heterogeneous agents (i.e. agents that pursue partially contradictory goals). The notion *cooperation of agents* may be replaced by the more accurate term *interaction* or – more general – by *interference*. Agents and actors can have positive as well as negative interference. It is not decisive for the functionality of a whole system that local goals of single agents or actors are completely congruent but that the activity of individual components is coordinated with respect to the behaviour of the whole system. (An example of negative interference is the limitation of access rights within a computer network, which may pose a negative interference towards a user trying to access classified data, but is eventually beneficial for the functionality of the system as a whole.)

In cooperative environments, where several agents and actors have common goals, *social action* must be distinguished from *joint action*. A social action means an action which is directed by a goal that is related to the mind of another agent. Consequently, social agents demand models of each other representing inner states (*beliefs*), goals (*desires*) and action decisions (*intentions*) [Castelfranchi 98].

Instead of the concept of acquaintance between actors we consider the concept of the position of actors in organizational connections. The positional concept asks for generic sets of expectations of the behavior and competencies from one agent/actor to another. This is where our concept of local roles comes into play, where roles are defined by position, personality and interaction situation. Roles are not independent of the sociological structure or environment where they evolve. In our considerations we restrict to organizations. In sociological organizational theory the phenomenon of organizations is well discussed. In formalizing the occurrence of roles in organizations we will follow the sociological context of Giddens [Giddens 88] who investigated acting in social structures and Ortman [Ortman et.al. 90], [Ortman 95] who considered formal relations in organizations.

In Sociology the concept of roles and role theory goes back to the Fifties, see [Merton 57], [Dahrendorf 67]. With the deeper investigation of Multi-Agent-Systems in the sense of simulation of human behaviour by artificial actors leading to hybrid systems the concept of roles has got a renaissance. Nowadays sociologists as well as computer scientists use this term as a bridge in common interdisciplinary work [Odell/Parunak/Bauer 00], [Schimank 00], [Parunak/Odell 01].

The delegation of action competence to other agents or actors is an instance of social action. The necessary differentiation of the model of other agents is derived from the grade of delegation (only executive or independent), the level of delegation (domain dependent or higher control) and the complexity of the interaction situation.

2. A role concept for the construction of social agents

From the point of view of socionics, social behavior of agents is vital for modeling the complete bandwidth of interaction in real organizations. To that end, both position dependent and personality dependent aspects of an actor are modeled. In the following, we introduce a model for the construction of social behavior of agents which is oriented on the conceptual range of the sociologist H. Geller [Geller 94].

An agent may fulfill several roles, each determined by the agents defined position and current personality structure. A position defines how the actor fits in the organized social system or a hybrid multi-agent system. It establishes the competencies of the actor, including necessary qualifications and access rights. The dependencies to other actors, e.g. derived from a division of labor, are part of the definition of the partners involved in mutual interactions. Division of labor is not only carried out under the aspect of the position of an actor but based on personality and position which characterize the role concept.

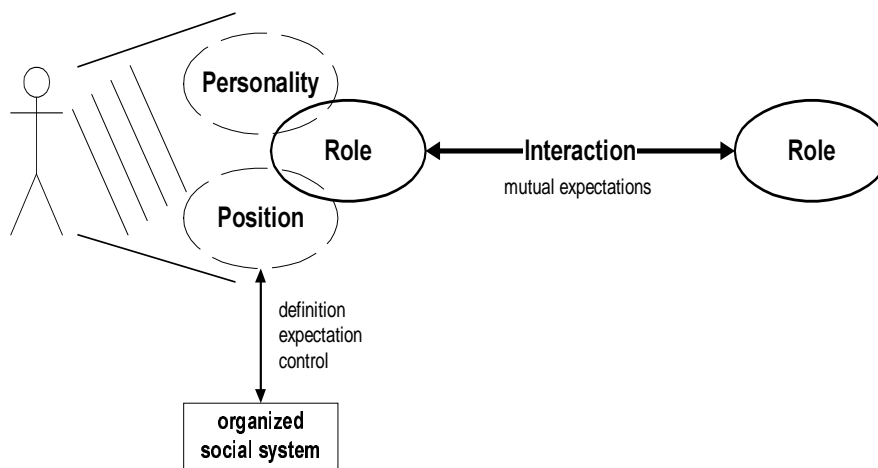


Figure1: Personality, Position and Role

A role becomes a kind of “interface” to the environment. Between individual agents and actors, interaction takes place in the course of the execution of the according roles.

The establishment of exact protocols is not required for each interaction. Instead, the behavior and action scope of the agents vary with respect to ‘personality’, position and the tasks that are given by the interaction situation. ‘Personality’ refers here to a set of typical motivations and strategies of an agent or actor, that is pursued independently of the position given by the organized social system.

A flexibility in the role that is adopted at a given moment allows for multiple modes of interaction. In this case, however, role changes have to be known to the agents taking part in the interaction. This can happen by communication, observation or by a triggering through external (environmental) signals available to both agents.

Furthermore, the interaction history may influence the current interaction; (obviously) by changing of the interaction situation, but also by adaptations that are reflected in the 'personality' of the agent. By variation of the personality type, different behavior strategies can be evaluated and consequently adopted in later interaction situations. Thus, an agent may undergo a learning process and also indirectly influence interactions of other actors by changing its role.

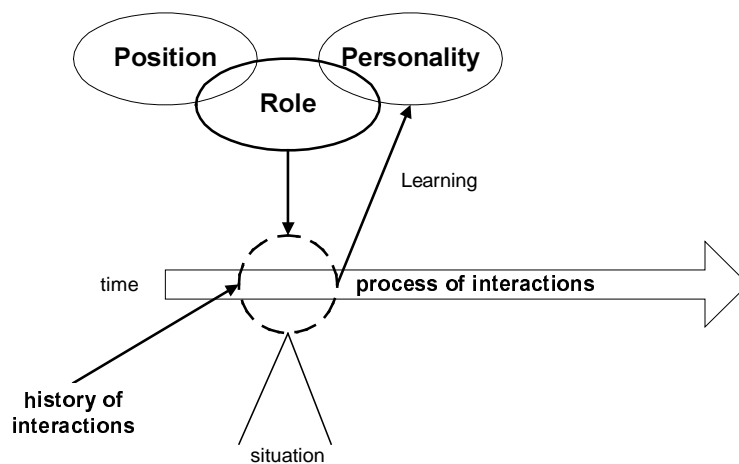


Figure 2: Learning as part of an interaction process

Internal organizational structures evolve by the social and functional differentiation of roles in complex organizations. This leads to the formation of groups, where these roles can appear temporary as well as long-lasting. Groups are defined by the roles they involve and vice

versa. A group consists of a number of actors which occupy various roles inside the group.

With respect to the organizational roles of groups, roles may not be identified only at the level of individual agents, but may enclose the interaction of whole groups.

3. Roles as modeling tools

While roles tend to be seen in observational terms, as tools for the specification and evaluation of systems [Kendall 98], their true importance for the implementation of MAS lies in providing models of other agents for distributed action. If interaction situations become too complex to communicate all relevant internal states between agents (or where this is not practical), roles may provide generic sets of expectations for behavior and competence.

In existing hybrid MAS, this modeling is usually highly asymmetrical between artificial agents and human actors, and for good reason. The nature of tasks delegated from humans to the artificial agents is usually only executive, with control tasks being the domain of individual humans. Furthermore, it is often not reasonable to have the system adapt to individual human users beyond customization of the user interface, as this may lead to inequalities in the treatment of the users. Consequently, the role of the human actors is in most cases defined by access rights and interface only.

On the other hand, task delegation from humans to technical system demands clear mental models of individual components of the system. These models do not need to be technically adequate, but functional adequacy is crucial (a typical example for this is the desktop metaphor of contemporary PC operating systems). Where humans interact with agents within MAS, these agents have to appear transparent and consistent in their behavior and the tasks they fulfill. This condition leads to more differentiated roles than the alternate direction (from agents to human actors).

Where only artificial agents interact with each other, the complexity of roles is not hampered by transparency or equality constraints.

Here, roles are determined by the communication constraint (the inability to communicate all internal states in a given interaction situation) and the complexity of the delegated task.

4. Organizational structures and roles

When speaking about roles in organizations it is necessary first to analyse the structure of organizations. Organizations are highly complex social objects that have external influence in being part of society and standing in relation to other ones (after their origin) as well as internal mechanisms responsible for the reproduction and evolution of them. In our considerations we focus to the internal structure and abstract from a special organizational type like hierarchy or flat network.

Organizations can be characterized by five kinds of internal structural views, which are the

- formal
- communication
- knowledge
- authority and
- competition

structure. A real organization will have specific forms in each of these sub-structures. For example, a hospital is *formal* a strict hierarchical institution, but *communication* takes place criss-cross and sometimes there is more *authority* practiced by a nurse than by a doctor.

Depending on pre-defined structural properties of organizations a variety of special positions is offered. As an instance, in universities these are in the science sector professor, scientific collaborator, student and others. Each of these positions is described by a number of rules what

holders are allowed to do or not – *authority*-, what they have to know – *knowledge*-, with whom they have to *communicate*, stand in *competition* and what *formal* rights they have.

As owner of a position in an organization an actor get a formal role. Actors in formal roles are exchangeable when they only **take** the (formal) role. But humans have a personality. For that reason they will always **make** a role bringing in their creativity [Schimank 00]. This individual part of a role we call the practical role.

Formal roles are equipped with the entry to accessory resources. These could be economic ones like money ore organizational ones like the authority to issue directives.

The investigation of the different types of resources in organizations leads to Bourdieus capital theory [Bourdieu 85]. He distinguishes five capital sorts which correspond to the five mentioned organizational sub-structures (see table below).

Organizational sub-structure	Capital type
formal communication knowledge authority competition	organizational social cultural symbolic economic

Table 1. Correspondence between organizational sub-structures and capital types

When humans are acting in a complete role (formal and practical) these acts are dealing with organizational and individual ressources belonging to different capital types. Modeling of formal roles in a computational manner can be done by transforming organizational structures e.g. into sets of rules. The accessory resources can be represented by a suitable object description. The formal part of a role can a serve as a basic set the expectations of the behavior and competencies what agents or actors have about another in this role.

Modeling personality of agents in their individual or practical roles as the social component can be implemented in a set of acting and negotiation strategies (egoistic, giving in, ..). This part of agents behaviour is not known a priori by the concerned participants of a MAS. But during interaction they have the possibility to recognize it by a learning process (see Figure 2).

5. The model in UML notation

There are two types of knowledge of agents. Each agent knows its organizational and its dispositional conditions. The word “agent” in the following is replaced by “actor”, the used concepts are legally in general for agents and real actors.

The organizational knowledge of an actor

The organizational knowledge of an actor is shown in figure 3. The definitions we use referencing [Esser 00].

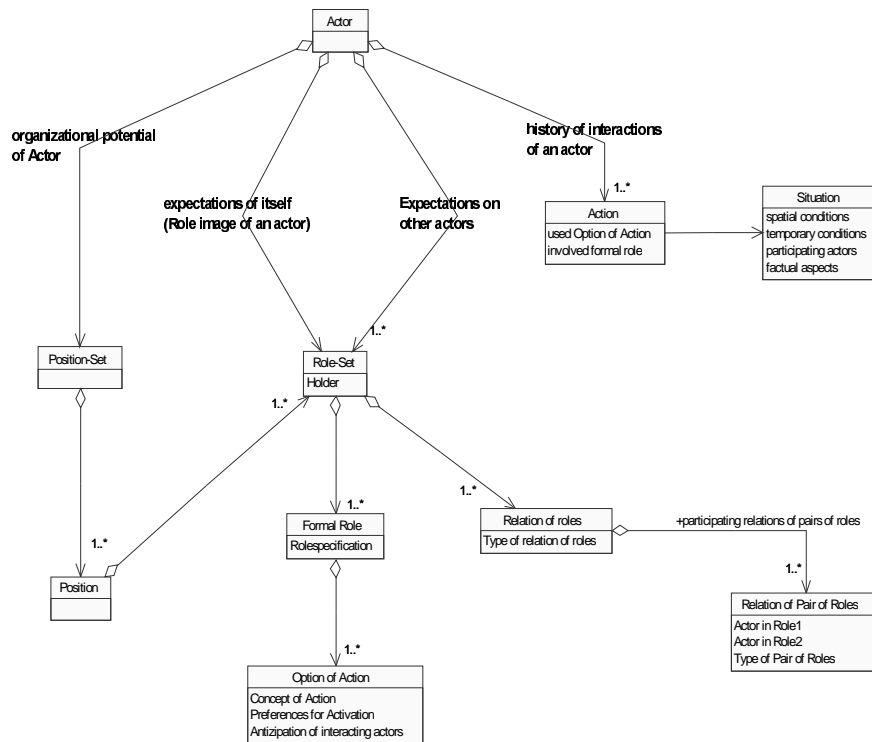


Figure 3: Organizational Knowledge of an actor

The organizational knowledge of an actor consists of four parts. The first part is its organizational potential, its set of positions defined as a contract to the other actors. It configures its rights, duties, to-do-tasks and the available capital. The whole set of positions an actor fulfills its defined as its position-set. A position is a functional fixed place in the society. A role set is a set of separate roles systematically connected by one position. The other actors of this society expect their fulfillment. So the role sets of an agent are the second part of its organizational knowledge, which are results because of the position distribution. In the same way (as role sets) we describe the expectations of one agent to the others. A role set defines the formal roles of an actor that concretely described with rights, obligations, tasks and necessary knowledge in public role specifications.

These formal roles allow the access to options of actions in the society. Relations of roles are reciprocally relationships between actors defined by role expectations. A basic relation of roles is the relation of a pair of roles, consisting of two actors in two roles in determined type.

The fourth part of organizational knowledge is the history of (inter)actions of this actor (sometimes called social knowledge) with a special view to the situations, indicated by their spatial and temporary conditions, interacting actors and factual aspects. The facts of situations are the learning material of actors for adapting their behavior, evaluating the experiences in different situations.

The personality of an actor

In addition to the organizational knowledge each actor proceeds of its individual dispositions (see figure 4) – its personality.

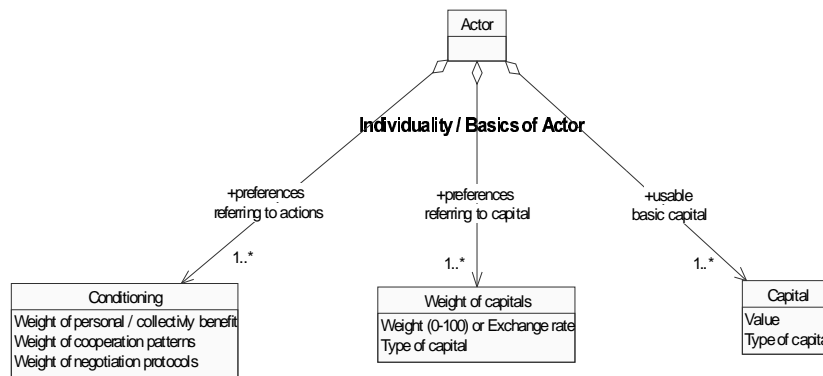


Figure 4: Dispositional Knowledge of an actor

The dispositional knowledge of an actor describes its individual preferences referring to actions and capital. Each actor uses a basic set of weights to decide which action in which situation it performs. The conditioning weights are principal forming the “character” of an actor.

They show its tendencies for using determined cooperation patterns and negotiation protocols and the degree of personal benefit an actor expects in summary of actions for itself. The weights of capitals give an orientation of the ambitions of an actor to get the different types of capital (see chapter 3). Independent of the roles an actor fulfills it has its usable basic capital, e.g. qualifications.

6. Roles in ChariTime - a Multi-agent system for appointment management

Our application scenario ChariTime is a multi-agent system for appointment scheduling in a large hospital, we presented it in an extended manner in MASHO-Workshop on ECAI2000.

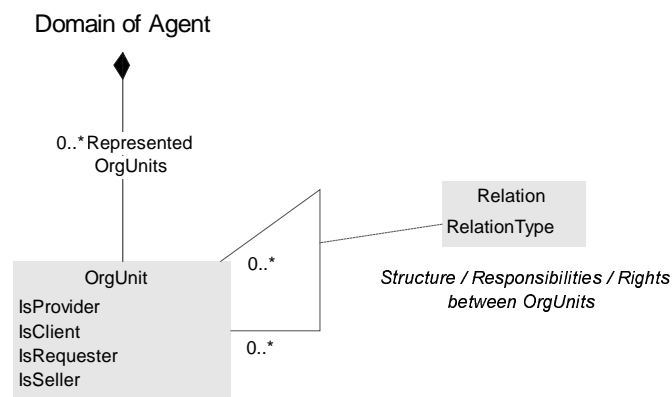


Figure 5: Domain of an agent and relationships between organizational units

In ChariTime an agent stands in for the interests of organizational units, persons (here patients) or departments (here diagnostic units). On the basis of the responsibility of agents for real organizational units in different roles they must actively supervise environmental conditions in the system.

So there is a common public knowledge about the roles of agents and the relations between their corresponding organizational units (see figure 5).

The concrete roles of an agent in ChariTime are defined in the setting of an organizational unit by specifying its properties (IsProvider, IsClient and so on). The following example explains the role of a service provider (property *IsProvider* is true). The illustration (figure 6) shows, which data are necessary and how they are mirrored into the object model.

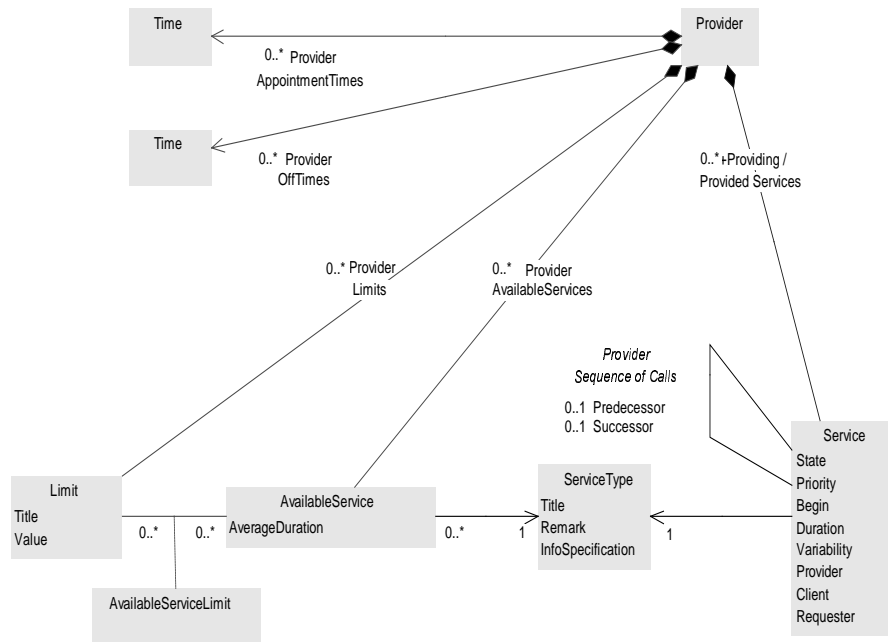


Figure 6: Knowledge for the role of a service provider in ChariTime

The provider of a service has knowledge about the whole spectrum of its available services (*ProviderAvailableServices*) including their *AverageDuration* (*execution time*).

Each type of service contains a reference to the “typed description” (*ServiceType*) under which it is offered to potential recipients of a service. Regularly working times, breaks and out-times per weekday of a service provider are registered in the form of block-times (*Provider-OffTimes*) which indicate the general non-availability of a service provider. Additionally each service provider commits oneself to possible time intervals in which the system is allowed to schedule the appointments of services – *ProviderAppointmentTimes*. In addition to these temporal restrictions personal interests of the human members of the provider produce limitations as well (*Limits* and *AvailableService-Limits*).

The main benefit of using roles in this system is to have an explicit way to model the formal tasks and knowledge that are delegated from real organizational units to their representative agents. Furthermore, such a structure of domain knowledge allows an incremental development of the application by adding new roles step by step. In this case study we don't want to use the concept of personality of an agent because of the stability of the agent behaviour in a real application.

7. Conclusion

Roles can act as tools for description and modeling in MAS. They are determined by the position of the agent within the reflected organization, the ‘personality’ (properties relevant for the interaction) of the agent and they are specific to the interaction context. Therefore, roles are inherently heterogeneous over the system, that is, agents may fulfill different roles depending on the agent they are interacting with. The roles may even differ towards a single agent, whenever the context of the interaction changes.

This leads to a localized concept of roles that mimics the specific expectations in terms of behavior and competences of one agent towards another agent within an interaction situation. Such models are necessary for planning, cooperation, delegation and sometimes confrontation, as these acts involve social goals (i.e. goals related to ‘mental states’ of other agents).

Formal roles allow for generic models of agents with unknown internal states (beliefs, desires and intentions) that may aid, where communication and observation are insufficient to derive enough information to predict the dispositions for action.

Usually, roles are seen from the perspective of the whole system, a stance helpful for the specification of the MAS. However, this external viewpoint may be inadequate where roles become heterogeneous, as it is the case in social simulation, hybrid MAS or in MAS with complex interaction, but limited communication. Here, an internal, localized role concept cannot only support development and description of the MAS, but may be vital for cooperative action of agents. In the latter case, roles become an integral part of the actual implementation of the MAS.

If role adoption is flexible, different modes of interaction become possible between agents. In this case, communication or observation of the currently active practical roles will have to take place.

Roles that adapt within the course of the interaction history can mirror learning processes of the agents and allow for dynamic systems that are more flexible than those with fixed, predefined modes of interaction.

In hybrid MAS, where both human actors and artificial agents are interaction partners, role modeling is typically asymmetric; to maintain transparency and equality constraints, human users are usually not modeled beyond their access rights and their interface to the system.

On the other hand, human users need to derive clear, functionally adequate and consistent concepts of the roles played by actively participating components of the MAS to delegate tasks successfully. In social simulation or technical MAS, these constraints do not apply, and roles aid the reproduction or specification of interactions that involve social goals.

Finally, the role concept is highly flexible in designing agents with a social behaviour where the implementation of sets of rules, resources and strategies is variable.

References

- Bourdieu, P.: *Sozialer Raum und 'Klassen'/Leçon sur la Leçon. Zwei Vorlesungen*, Frankfurt a.M., 1985
- Castelfranchi, C.: *Modelling Social Action for AI Agents*. Artificial Intelligence, Vol.103, 1998
- Dahrendorf, R.: *Homo Sociologicus: Versuch zur Geschichte, Bedeutung und Kritik der Kategorie der sozialen Rolle*, in: ders.: *Pfade aus Utopia. Arbeiten zur Theorie und Methode der Soziologie*, München 1967, S. 128-194
- Esser, H.: *Soziologie, Spezielle Grundlagen, Band 5: Institutionen*, Campus 2000
- Geller, H.: *Position. Rolle. Situation. Zur Aktualisierung soziologischer Analyseinstrumente*, Opladen: Leske + Budrich, 1994
- Giddens, A.: *Die Konstitution der Gesellschaft. Grundzüge einer Theorie der Strukturierung*, Frankfurt/New York, 1988
- Kendall, E. A.: *Agent Roles and Role Models: New Abstractions for Intelligent System Analysis and Design*, in: Proceedings AIP '98, 1998
- Lindemann, G., Münch, I., Schulz-Schaeffer, I.: *An Approach to Model Hybrid Organizations in the Context of Appointment Management*, in: MASHO-Workshop, ECAI 2000, Berlin, 2000
- Merton, R.: *The Role-Set: Problems in Sociological Theory*, British Journal of Sociology, VIII (pp.106-120), 1957
- Odell, J., Van Dyke Parunak, H., Bauer, B.: *Extending UML for Agents*, in: Proc. of the Agent-Oriented Information Systems Workshop at the 17th National conference on Artificial Intelligence, Gerd Wagner, Yves Lesperance, and Eric Yu (eds.), Austin, TX, pp.3-17accepted paper, AOIS Workshop at AAAI 2000.
- Odell, J., Van Dyke Parunak, H., Bauer, B.: *Representing Agent Interaction Protocols in UML*, in: Paolo Ciancarini and Michael Wooldridge (eds.), *Agent-Oriented Software Engineering*, Springer-Verlag, Berlin, pp. 121-140, 2001.
- Ortmann, G.; Windeler, A.; Becker, A.; Schulz, H.-J.: *Computer und Macht in Organisationen. Mikropolitische Analysen*. Opladen, Westdeutscher Verlag, 1990
- Ortmann, G.: *Formen der Produktion. Organisation und Rekursivität*, Opladen, 1995
- Parunak, H. Van Dyke: *Applications of Distributed Artificial Intelligence in Industry*, in: G. M. P. O'Hare / N. R. Jennings (Eds.): *Foundations of Distributed Artificial Intelligence*, New York: John Wiley & Sons, 139-164, 1996

Parunak, H. Van Dyke, Odell, J.: *Representing Social Structures in UML*, in: Proc. of the Agent-Oriented Software Engineering Workshop, Agents 2001, Michael Wooldridge, Paolo Ciancarini, and Gerhard Weiss (eds.), 2001.

Rao, A. S. and Georgeff, M. P. 1995. *BDI Agents: From Theory to Practice*. In Lesser, V. ed. Proceedings of the 1st International Conference on Multi-Agent Systems (ICMAS):312--319. MIT Press.

Schimank, U.: *Handeln und Strukturen*, in: K. Hurrelmann (ed.): *Grundlagentexte Soziologie*, Juventa Verlag, Weinheim und München, 2000

Stone, P.: *Layered Learning in Multi-Agent Systems*, PhD Thesis, Carnegie Mellon University 1998