

Social Viewpoints on Multiagent Systems

Guido Boella
 Dipartimento di Informatica
 Università di Torino - Italy
 guido@di.unito.it

Luigi Sauro
 Dipartimento di Informatica
 Università di Torino - Italy
 sauro@di.unito.it

Leendert van der Torre
 CWI - Amsterdam
 The Netherlands
 torre@cwi.nl

1. Introduction

An important aim in the field of multiagent systems is to study emergent social structures, such as sets and collectives.

Castelfranchi [5] introduces concepts like groups and collectives from social theory in agent theory, both to enrich agent theory and to develop experimental, conceptual and theoretical new instruments for the social sciences. In this paper we contribute to this project by addressing the following questions:

1. How to relate conceptual models based on the mind, power [4], dependence [6], or coalitions [7]?
2. How to use these models and relations in agent theory?
3. How to formalize these models and relations between them?

2. Hierarchy of structural views on MAS

We distinguish four structural viewpoints on multiagent systems in an abstraction / refinement hierarchy, as visualized in Figure 1.

Roughly, the most refined view describes the structure of the mind of cognitive agents including at least their action repertoire and goals. The power view abstracts from the actions of individual agents and describes only the goals (sets of) agents can reach. The dependence view is a relational

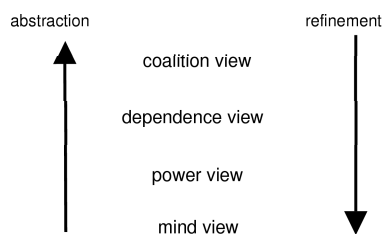


Figure 1. *Abstraction / refinement hierarchy*

variant of the power view, that describes how agents depend on each other to fulfill their goals. Finally, the coalition view describes which agents can cooperate to see to their goals.

Consider for example the left side model in Figure 2, in which agent a_1 can see to goal g_2 of agent a_2 , agent a_2 can see to goal g_3 of agent a_3 , and agent a_3 can see to goal g_1 of agent a_1 . We say that agent a_1 has the power to see to goal g_2 , that agent a_2 depends on agent a_1 for fulfillment of its goal g_2 , and, if all the three agents cooperate, then they can form a coalition $\{a_1, a_2, a_3\}$ that can see to all goals.

Figure 1 is an abstraction hierarchy, because some systems which can be distinguished at a more refined level, become indistinguishable at a more abstract level. Consider for example the right side model in Figure 2, in which the dependence between each pair of agents has been reversed: agent a_1 can see to goal g_3 , agent a_2 can see to goal g_1 , and agent a_3 can see to goal g_2 . In the three most refined views, these two models can be distinguished. E.g., in the first model agent a_1 depends on agent a_2 , whereas in the second model agent a_2 depends on agent a_1 . In the coalition view they are indistinguishable, because in both models the set of agents $\{a_1, a_2, a_3\}$ can see to $\{g_1, g_2, g_3\}$.

Each structural view can be related to a behavioral view, but we do not suggest that such behavioral views can be structured in an abstraction / refinement hierarchy too.

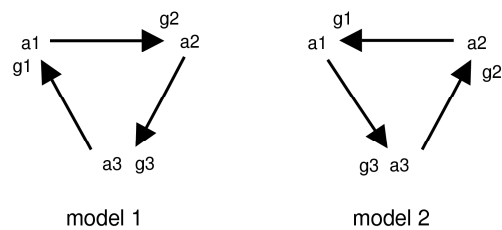


Figure 2. *Indistinguishable in coalition view*

3. Implications for agent theory

A formalization of the hierarchy consists of four different formal theories, together with abstraction and refinement procedures. Castelfranchi shows how the hierarchy can be used to deal with the micro-macro dichotomy by giving a micro explanation of complex social phenomena (emergence), and by describing how macro phenomena influence micro behavior (immergence). Moreover, it has two important uses in agent theory.

First, mechanisms and algorithms defined in abstract theories can be used in more refined ones, and vice versa, the abstraction of agent theories leads to new theories to be studied. For example, Castelfranchi [5] introduces a theory of goal-based coalitions, which extends the usual notion of coalitions [7]. Moreover, he suggests that coalition theories based on social agents can be distinguished from coalition theories developed in classical game theory.

Secondly, phenomena studied in agent theory, such as cooperation, coordination, authorization, delegation, trust management systems, et cetera, can be analyzed at varying abstraction levels using distinct conceptual models.

For example, in previous research [1] we use norms to define obligations of BDI agents, that like desires are used to generate goals, but the role of norms in power structures, dependence networks and coalition theories remains mainly unexplored. As a more complicated example, we have proposed a model of the creation of a new norm [3] based on the three steps of merging individual desires into a group goal, individualizing the group goal into norms (together with sanctions), and acceptance of the norm in case the agents recognize that it leads to fulfillment of their desires. At other abstraction levels, we can for example characterize the generation of the group goal as a struggle for power, and the acceptance relation as a recognition of a coalition.

4. Towards formalization

The starting point of the following four theories is the rule based multiagent system we have developed in earlier work. [1, 2, 3] First we define the four views, then we define the abstraction / refinement relation.

Mind view $\langle A, G, X, goals : A \rightarrow 2^G, skills : A \rightarrow 2^X, R : 2^X \rightarrow 2^G \rangle$ consists of a set of agents A , a set of goals G , a set of actions X , a function *goals* that relates with each agent the set of goals it is interested in, a function *skills* that describes the actions each agent can perform, and a set of rules R that relate sets of actions with the sets of goals they see to.

Power view $\langle A, G, goals, power : 2^A \rightarrow 2^{2^G} \rangle$ does not contain actions or skills, but contains a function *power* that relates with each set $S \subseteq A$ of agents the sets of goals G_S^1, \dots, G_S^m .

Dependence view $\langle A, G, goals, dep : 2^A \times 2^A \rightarrow 2^{2^G} \rangle$ does not contain powers, but it does contain a function *dep* that relates with each pair of sets of agents all the sets of goals on which the first depends on the second.

Coalition view $\langle A, G, goals, coal : 2^A \rightarrow 2^{2^G} \rangle$ contains a function *coal* that relates sets of sets of goals with sets of agents. A set of agents corresponds to a potential coalition and the related sets of goals are the outcomes they can assure themselves.

Since the abstraction / refinement relation between the dependence view and the coalition view is quite complicated, we first show the relation between the mind view and the power view and then directly the relation between the power view and the coalition view.

In the power view a set of agents $S \subseteq A$ has the power to see to the sets of goals G_S^1, \dots, G_S^m if, in the mind view, for any $1 \leq i \leq m$, S has a joint set of actions able to see to all goals in G_S^i independently from the actions of the other agents $A \setminus S$.

In the dependence view the set of agents $S_1 \subseteq A$ depends on the set of agents $S_2 \subseteq A$ for the set of goal $G' \subseteq G$ if, in the power view, all the members of S_1 are interested in G' , S_1 does not have the power to see to G' , but $S_1 \cup S_2$ has.

In the coalition view, for $S \subseteq A$ we have $coal(S) \subseteq power(S)$, and moreover (1) any coalition is self-interested in the sense that if $G_S^i \in coal(S)$ then for any goal of G_S^i there exists a member of S interested in it and (2) the union of two coalitions is not a coalition if they are not correlated, in the sense that the formation of one of them cannot influence the formation of the other one.

There are many ways in which the hierarchy can be further exploited. For example, we can attribute mental attitudes to coalitions [2], and define the power of coalitions, dependencies between coalitions, et cetera.

References

- [1] G. Boella and L. van der Torre. Attributing mental attitudes to normative systems. In *Procs. AAMAS03*, pages 942–943, 2003.
- [2] G. Boella and L. van der Torre. Groups as agents with mental attitudes. In *Procs. AAMAS04*, 2004.
- [3] G. Boella and L. van der Torre. The social delegation cycle. In *Procs. DEON04*, LNCS. Springer, 2004.
- [4] S. Brainov and T. Sandholm. Power, Dependence and Stability in Multiagent Plans. In *Procs. AAAI99*, pages 11–16, 1999.
- [5] C. Castelfranchi. The Micro-Macro Constitution of Power. *ProtoSociology*, 18-19, 2003.
- [6] R. Conte and J. Sichman. Multi-Agent Dependence by Dependence Graphs. In *Procs. AAMAS02*, pages 483–490. ACM Press, 2002.
- [7] M. Pauly. A Modal Logic for Coalitional Power in Games. *Journal of Logic and Computation*, 12:146–166, 2002.