

A Short Note on the Bounds of the Organizational Approach to MAS

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Abstract This short note claims that *societal* architectures, not just *organizational* architectures, are the appropriate architectural forms for framing the conception, design, and implementation of *full-fledged multi-agent systems*, that is, MAS that are able to computationally model all the essential characteristics of *general* social systems.

Keywords: Multiagent system. Organizational architectures. Societal architectures.

1 Overview

The *organizational level* is, typically, the highest architectural level focused on by current MAS research. That means that, in general, the structure of any currently conceived MAS architecture is made to range between a lowest architectural level constituted by the *population* of the agent system (its *set of agents*) and a highest architectural level constituted by an *agent organization* (a *network of organizational roles* structured by means of both a system of *interaction processes* and a system of *behavioral and interactional norms*, perhaps hierarchically structured as a system of *sub-organizations*). This way of conceiving MAS has dominated the area since the organizational approach consolidated itself, as illustrated by Figure 1.

The sequence of boxes in Figure 1 emphasizes the historical rise of the *highest* architectural MAS level since the beginning of the concern with *organizational issues* in the days of *Distributed Artificial Intelligence*, in the mid 1980's (see, e.g., [1,2]), which adopted from the start the *Theory of Organizations* as its main theoretical framework (as first suggested for complex software systems by Mark Fox [3]).

The figure also shows that, apparently, the architectural evolution of the area is stuck at the *organizational level* since the consolidation of this approach in the late 1990's (see, e.g., [4] and specially [5]), even though the MAS technology available since the early 2010's already allowed for structuring the highest architectural level of MAS in terms of an *inter-organizational network* (see, e.g., [6]) as

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well as full-fledged *agent societies* and *inter-societal agent systems* (as reinforced in the present paper).

From the paper’s point of view, the main reason for this lasting stationarity in the evolution of the hierarchical structure of the architecture of MAS resides in the attraction exerted by the practicality of the *organizational* perspective, which favors the *middle range* approach to social systems that Robert Merton once proposed, aiming at an easier integrated treatment of theoretical and empirical social analysis [7] (for the tight connection between the middle range approach and the study of organizations, see [8]).

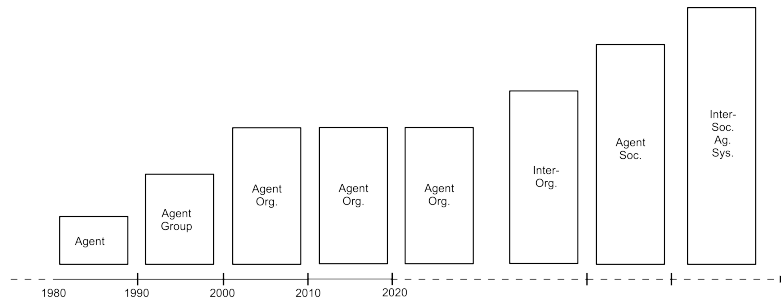


Figure 1. Historical evolution of the architecture of MAS.

The middle range approach states that social analysis should focus on specific issues, among the whole set of social issues present in a given society, without worrying to deduce *middle range theories* from so-called *grand theories*, so called for aiming to allow the derivation of all specific theoretical principles for all specific social issues, but which were criticized as “a proliferation of abstract categories devoid of concrete or testable hypotheses”, as mentioned by N. Smelser in the critical introduction to Talcott Parsons’ sociological theory [9], the paramount example of grand theory.

Nonetheless, even if such middle range approach is fruitful enough for social analysis concerning existent natural (human) societies, it is clearly deficient as an approach to the specification and design of *agent societies*, which have to have all its essential features consistently articulated under a *common set of theoretical principles*, which should be clearly understood and accepted by their designers, implementers, and users. In particular, such common set of theoretical principles should support some generally acceptable form of deductive reasoning about the above mentioned societal issues, and their possible agent-based modeling and realization.

This short note submits that MAS technology is ready to engage with a *societal* perspective to MAS, that is, with a research effort to develop concepts, methods, and techniques for dealing with the social issues arising in the conception, implementation, and use of MAS, on the basis of a *societal approach* to the architecture of agent systems.

2 The Organizational Architecture

In this paper, a MAS is said to have *organizational architecture* whenever it is composed of two main architectural levels, which we call:

- the *Populational level*: constituted by the *stratified set of agents* that inhabit the MAS, itself composed of two sub-levels, which we call:
 - the *Populational Categories*: constituted by *social categories (strata)*, of agents;
 - the *Populational Agents*: constituted by the *set of agents* themselves;
- the *Organizational level*, itself composed of two sub-levels, which we call:
 - the *Micro-organizational level*: constituted by the *set of organizational roles* that agents may perform;
 - the *Meso-organizational level*: constituted by the (possibly, hierarchically recursive) *set of organization units* (groups, organizations, institutions etc.), each implemented by a subset of *organizational roles*.

Also, the agents, organizational roles, and organization units of a MAS designed according to an organizational architecture are said to be the *organizational actors* of that MAS.

Optionally, an organizational architecture may include two more components:

- a *Material environment*: constituted by the *set of material objects* that the organizational actors of the MAS may operate on;
- a *Symbolic environment*: constituted by the *set of symbolic objects* (values, norms, organizational symbols, patterns of behavior and interaction etc.) that the organizational actors of the MAS may operate on.

Often, the whole MAS is taken as one single organization unit, the top level one, in the meso-organizational level of the MAS architecture. As shown in the next section, this *organizational architecture* for MAS clearly occurs as a sub-architecture of the basic form of what we call the *societal architecture* for MAS.

3 The Societal Architecture

3.1 Structural Features

The concept of *societal architecture* extends the *organizational* one with one higher organizational sub-level, which we call:

- the *Macro-organizational level*: constituted by the *set of societal systems*, each implemented by a (possibly, hierarchically recursive) *set of societal sub-systems*, themselves implemented by a (possibly, hierarchically recursive) subset of *organization units*.

For simplicity, in the following, the term *agent society* is taken to mean a MAS that is structured on the basis of a societal architecture.

As an illustration, Figure 2 sketches the *societal architecture* of a hypothetical agent society, indicating all its main structural components. The figure also illustrates how the concept of *societal* architecture encompasses the concept of *organizational* one. The abbreviations in Figure 2 mean the following:

- *Org* denotes the *organizational structure*;
- *Pop* denotes the *population*;
- *SEnv* and *MEnv* denote the *symbolic* and the *material* environments, respect.;
- the three organizational sub-levels (*macro*, *meso*, and *micro*) are denoted in the figure by Org_{Ω} , Org_{μ} , and Org_{ω} , respectively;
- the two populational sub-levels (*social categories* and *agents*) are denoted in the figure by Pop_{Cat} and Pop_{Ag} , respectively;
- the vertical dashed arrows denote the *implementation relations* established between the various architectural levels;
- the horizontal continuous arrows denote *interaction processes* between the elements of each architectural level;
- the dotted trapezoids denote the *scopes of encapsulation* of architectural elements that are proper to the societal systems and the organizations;
- *access relations* between the elements of the architectural level and the symbolic and material environments are not shown in the figure ¹.

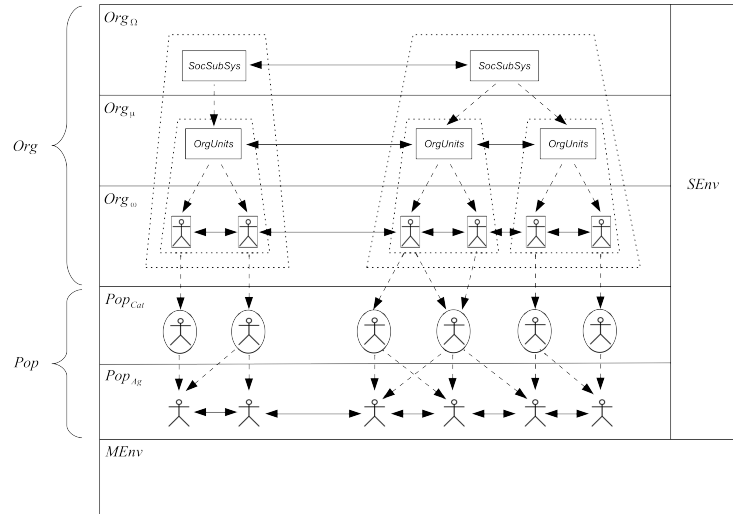


Figure 2. Sketch of the societal architecture of a simple agent society

¹ In particular, it is not shown that only agents access material objects directly, the elements of the other societal levels accessing them only through their symbolic representations.

Analogously to the concept of *organizational actor*, regarding the *organizational* architecture presented above, the concept of *social actor* can be used as a general concept for any of the elements and architectural components of the *societal* architecture, including MAS themselves, when structured according to this latter concept.

Notice that the scopes of encapsulation of organization units and societal sub-systems *do not encompass* the agents that implement them. This is in accordance to the principle of *separation* between organizational and populational structures, which allows for organizational structures to be treated as *first-class* computational entities, that is, which allows them to be conceived, and designed (and computationally realized in appropriate *organizational* and *societal platforms*, in accordance with the notion of *organizational artifact* [10]), independently of the agents that will put them in operation (see Section 5, for additional comments). Notice, also, that *organizational roles* are not *immediately* implemented by agents, but by social categories, agents being assigned to perform organizational roles only in connection to the social categories to which they belong.

3.2 The Macro-Level Components and their Functions

Although the *societal systems* are, in first instance, macro-level *structural* elements, having in general the form of $SubSys_1$ and $SubSys_2$ of Figure 2, they are also important regarding the macro-level *functionalities* they are capable of providing for any MAS that embodies a societal architecture. We consider here a few typical examples of societal systems, regarding their macro-level functions.

- *Production System* The *production system* of an agent society can be characterized as the societal system that regiments a set of *agents* (the *producers*) in order to continuously generate new objects in the society's *material* and *symbolic* environments, possibly consuming for that purpose some of the objects available, at each time, in those environments. Production systems that produce objects capable of storing *energy* are basic societal systems to agent societies where agents are embodied in physical bodies, which operate consuming energy (see, e.g., [11]), and also to agent societies whose social processes are regulated by economical principles (see, e.g., [12]).
- *Distribution System* The *distribution system* of an agent society can be characterized as the societal system that regiments a set of *agents* (the *distributors*) in order to continuously distribute, for consumption, among the society's population, the objects produced by the production system, specially those objects capable of storing energy, in societies whose populations are composed of agents embodied in physical bodies.
- *Educational System* The *educational system* of an agent society can be characterized as the societal system that regiments a set of *agents* (the *educators*) in order to capacitate some agents to participate in some of the society's societal systems (including the educational system itself).

- *Legal System* The *legal system* of an agent society can be characterized as a higher-level societal subsystem that regiments two lower-level societal systems (the *legislative* and the *judiciary*) in order to manage (create, modify, delete) the set of *positive norms* (the *legal order*) that regulates the social processes of the society on the basis of *sanction mechanisms* capable of sanctioning agents and organization units when they do not abide by those norms. In particular, the legal system of an agent society is supposed to manage legal orders regulating the production, consumption, and educational system of the society. Additionally, notice that *legal orders* are symbolic structures that are naturally stored in the *symbolic environments* of agent societies.

- *Ideological System* The *ideological system* comprises all the cultural elements that are present in the society, impacting on the behaviors and interactions of the social actors: morality, law, customs, traditional conceptions etc. In *agent societies*, they are all assumed to be symbolically represented in the *Symbolic Environment* (see, e.g., [13,14,15,16]).

- *Political System* The *political system* of an agent society can be characterized, in its minimal functionality, in the way proposed by David Easton [17], namely, as the societal system responsible for the *authoritative allocation of resources* among social actors. As such, it is naturally articulated, in a tight way, with the *legal* and the *ideological* systems, while essentially acting on the parameters that determine the structure and functioning of all the other systems, and specially of the *production* and *distribution* ones. In particular, the organization and functioning of *social movements* also belongs here.

- *Inter-societal systems* Inter-networked societies, with each society exchanging *services* with other societies, form systems that are naturally cast as systems of agent societies (see, e.g., [18]).

4 The Pragmatical Drawback of the Societal Approach

The main drawback of the *societal approach* to MAS is of a pragmatical kind: the work has to be based on *general sociological theories*, which are more *complex*, less *complete*, less *consistent*, and more prone to *ideological disputes* than the usual *organizational theories*.

On the other hand, it seems that any approach in line with, e.g.: Jonathan Turner's *Theoretical Principles of Sociology* [19] should satisfy the requirement of conceptual transparency and deducibility indicated at the beginning of this paper. In particular, its three volumes (1: *Macrodynamics*, 2: *Microdynamics*, and 3: *Mesodynamics*) fit well the basic structure of the *societal architecture* sketched above.

5 To Conclude: A Bird's Eye View of the State of the Art

Concerning the bases of the *organizational* approach to MAS, important references can be found in the informal proceedings of the COINE workshops and in the corresponding post-proceedings, published by Springer ². Also, the informal proceedings of the EMAS workshops and its corresponding post-proceedings, the latter also published by Springer ³, constitute a source of important references

Concerning the bases of the *societal* approach to MAS, an initial definition of the *Agent Society* model, which served as the basis for this overview, can be found in [20] and in the complementary references indicated there ⁴.

Concerning *platforms* for running *organizational* MAS, the current situation is that the platforms and frameworks that have been made publicly available are each specific to a particular organizational architectural model. No *universal* organizational MAS platform, allowing designers to experiment with variations and integrations of different organizational architectural models, is publicly available, even though current MAS technology can clearly support them (check out the works presented in the above mentioned COINE or EMAS workshops). In particular, the *organizational artifact* approach to the implementation of MAS organizations, proper to the JaCaMo platform [22], seems to be extendable to a *societal artifact* approach.

The situation concerning platforms or frameworks for running *societal* MAS is even worse, since simply no such platform or framework is publicly available, even though current MAS technology can clearly also support them.

Finally, three technical issues should be mentioned, which have not been investigated *as often and intensively* as necessary, nor at the *organizational* level, much less at the *societal* level:

- *modularization* (see, e.g., [23]);
- *typing* (see, e.g., [24]);
- *platform independent modelling languages* (see, e.g., [25]).

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² See <https://www2.pcs.usp.br/~coin> and <https://link.springer.com/conference/coin>.

³ See <https://emas.in.tu-clausthal.de> and <https://link.springer.com/conference/emas>.

⁴ More precisely, one should expect that, at some point in time, societal models conceived within *computational* conceptual frameworks (such as the one considered in this short note) be *formally articulated* with societal models conceived within *sociological* conceptual frameworks (such as that by Turner [19]), so that the former can serve as *formal semantical models* for the latter, thus furthering the research on *formal sociological theories* (see, e.g., discussions and opinions in [21])

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