Reorganisation and Self-organisation in Multi-Agent Systems

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Abstract. In the last years, social and organisational aspects of agency have become a major issue in multi-agent systems' research. The conducted works may be structured along two main points of view: an agent-centred point of view (ACPV) and an organisation-centred point of view (OCPV). In both approaches the central notion of multi-agent organisation dynamic is considered. In ACPV, this notion leads to a kind of informal, bottom-up, emergent phenomena that we regroup under the general term of *self-organisation*. In OCPV, this notion gives birth to a huge set of works related to the *reorganisation* of the formal, top-down, pre-existent organisations that are installed in the MAS. In this paper, we propose to position these two approaches to build a comprehensive picture of organisation dynamic in multi-agent systems.

1 Introduction

Our aim in this paper is to study and propose a comprehensive view of how one could make multi-agent organisations adapted to dynamics, openness and large-scale environment. In the multi-agent domain, the SASO and the COIN communities are the two that are mainly considering such topics.

SASO (*Self-Adaptive and Self-Organizing systems*) community[3] studies organisation from the point of view of emergent phenomena in complex systems. In multi-agent systems context, we can characterise this point of view as *agent-centred* (ACPV). In fact, designers of such systems first focus on parts of the system-to-be, namely the agents. By designing proper local behaviours and peer-to-peer interactions, the global function of the system is the result of complex interactions and dynamics within the agent society. However, such an engineering approach often inject unpredictability or uncheckability, since the global behaviour is more than the juxtaposition of agents' behaviours. COIN (*Coordination, Organisation, Institutions and Norms in agent systems*) community[4] aims at engineering effective coordination or regulatory mechanisms as a

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[3] see the SASO Conferences at http://www.saso-conference.org/

[4] see the COIN International Workshop Series at http://www.pcs.usp.br/~coin/

key problem for the design of open complex multi-agent systems. Contrary to the SASO approach, COIN focuses on an *organisation-centred* point of view (OCPV), in which the designer designs the entire organisation and coordination patterns on the one hand, and the agents' local behaviours on the other hand. At runtime, the agents may consider the constraints imposed by the defined organisation as compulsory or possible guidelines for the coordination of their local behaviours. Systems designed using OCPV can therefore ensure some invariants stemming from the organisation specification.

As we can see, *organisation* is at the intersection of both approaches. This paper mainly aims at clarifying the differences and the common points between these two views focusing on the dynamic dimension. Since there is no universally accepted definition of MAS reorganisation, in this paper, we use *reorganisation* to denote the adaptation of the organisation as promoted in the OCPV, top-down approaches. We use the term of *self-organisation* to denote the ACPV, bottom up approaches where, de facto, an adaptation and modification of the emergent organisation is installed. We propose different possibilities of convergence and complementarity between these processes. The remainder of the paper is structured as follows. In Section 2, we first provide a comprehensive view of the concept of organisation in MAS. Section 2.4 dresses up a comparison of the two points of views with respect to the adaptability and checkability properties. Section 3 analyses the adaptation of organisations in ACPV (self-organisation) and OCPV (re-organisation), so as to propose in Section 4 definitions of self-organisation and reorganisation concepts. Finally, Section 5 concludes this paper with some perspectives for future works and roadmap.

2 Comprehensive View of Organisations in MAS

There is still no unanimously accepted definition of what is called "organisation" in MAS. Its meaning often varies between two basic views [30]: (i) a collective entity with an identity that is represented by (but not identical to) a group of agents exhibiting relatively highly formalised social structures [39], (ii) a stable pattern/structure of joint activity that may constrain or affect the actions and interactions of agents towards some purpose [6]. As we can see, organisation refers, in a general sense, to a *cooperation pattern* that can be more or less formalised. As in Sociology [2], it may concern the expression of a division of tasks, a distribution of roles, an authority system, a communication system, or also a contribution-retribution system. According to [18], this range of topics may also be extended to knowledge, culture, memory or history. This is what Parunak et al. express in different terms when they propose a definition of organisation, relatively to self-organisation, at three levels [35]: (i) an order (measure) on organisations, i.e. mapping from the set of organisations to the set of real numbers; (ii) a process in a single system in which the previous measure increases with time (from less organised to more organised); (iii) the structure resulting from the previous evolution.

Both views are generally not mutually exclusive and have led to different approaches in the domain. As in [3], we focus on a few features in order to build a comprehensive view of them. First, we will take into account the "definition process" of the agents' organisation (Sections 2.1) and then consider its "representation" within the agents' minds (Section 2.2). As what happens with every classification attempt, the one proposed here

has its limits and must be considered as an analysis grid of the different works and not as a definitive view on multi-agent organisations in MAS. The two dimensions of this grid are continuous, and it is completely possible to identify approaches that are at the boundary of two categories.

2.1 Agent-Centred View vs Organisation-Centred View

The first axis of the grid is an extension of the *agent-centred* and *organisation-centred* points of view initially proposed in [31].

The *agent-centred* point of view takes the agents as the "engine" for the organisation. Organisations only exist as observable emergent phenomena which state a unified bottom-up and objective global view of the pattern of cooperation between agents (see first row in Fig. 1-a-b). For instance (case (a)), in an ant colony [14], no organisational behaviour constraints are explicitly and directly defined inside the ants. The organisation is the result of the collective emergent behaviour due to how agents act their individual behaviours and interact in a common shared and dynamic environment. A similar point of view may be considered in the different reactive self-organisation approaches that exist in the literature [38]. In a more cognitive way (case (b)), the studies on coalition formation define mechanisms (within agents, e.g. social reasoning [40]), to build patterns of cooperation in a bottom-up process. In this view, the pattern of cooperation both structures and helps the agents in their collaborative activities.

The *organisation-centred* point of view sees the opposite direction: the organisation exists as an explicit entity of the system (see second row in Fig. 1-c-d). It stresses the importance of a supra-individual dimension [18] and the use of primitives that are different from the agents' ones. The pattern of cooperation is settled by designers (or by agents themselves) and is installed in a top-down manner in order to constrain or define the agent's behaviours. Note that the observer of the system can obtain a description of the system's organisation. For instance, in a school we have documents that state how it is organised. Of course, besides the explicit description of the organisation, the beholder can also observe the real school's organisation which is, possibly, different from the formal one.

2.2 Organisation Awareness vs Organisation Unawareness

From an agent architecture perspective, we can further refine these two points of view by considering an orthogonal axis regarding the agents' capabilities to represent and reason about its organisation.

In the first column of Fig. 1, the agents don't know anything about the organisation. In case (a) the agents don't represent the organisation, although the *observer* can see an emergent organisation. In some sense, they are not aware that they are part of an organisation. In case (c), the organisation exists as a specified and formalised schema, made by a designer but agents don't know anything about it and do not reason about it. They simply comply to it as if the organisational constraints were hard coded inside them (e.g. the MAS resulting from some AOSE, Agent-Oriented Software Engineering) methodologies where the agent's code is generated from an organisational specification [27, 1]).

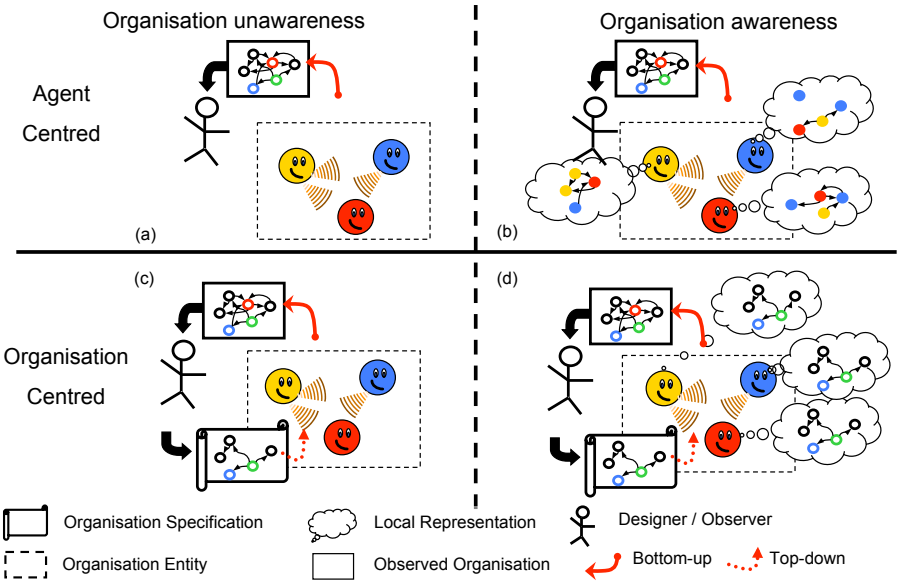

Fig. 1. Comprehensive view on organisations in MAS: (a) Emergent Organisation MAS; (b) Coalition Oriented MAS; (c) Agent Oriented Software Engineering; (d) Organisation Oriented MAS. The Designer/Observer may be the Developer/User (exogenous case) or a set of agents (endogenous case).

In the second column, we consider the cases where agents have some *representation of the organisation* in which they are executing. In case (b), each agent has an internal and local representation of cooperation patterns which it follows when deciding what to do (e.g. social networks for coalition formations [40]). This local representation is obtained either by perception, communication or explicit reasoning (e.g. social reasoning as in [40]) since, in an agent-centred view, there isn't, *a*-priori, any explicit global representation of the organisation which is available to the agents. In case (d), agents have an explicit representation of the organisation which has been defined (organisation-centred view). The agents are able to reason about it and to use it in order to initiate cooperation with other agents in the system.

In the literature, some agents' organisation approaches fit to a specific case shown in Fig. 1, others are based on multiple cases. For instance, proposals concerning reorganisation approaches for formal organisations may combine cases (b) and (d) in the sense that agents are using their internal mechanisms to adapt the organisation that was imposed on the system. The bottom-up or top-down manipulation of the organisation may be realised either *endogenously* (i.e. realised by the agents belonging to the organisation themselves) or *exogenously* (i.e. by an external designer, a human or agents outside of the organisation).

2.3 Applying this Comprehensive View to MAS

To be clearer, we can position some concrete existing systems and approaches within the grid.

1. *Emergent Organisation MAS (top-left)*: Here agents are unable to reason on the organisation since it is not modelled. Agents self-organise in a peer-to-peer fashion or using indirect communication via the environment. As example, we can cite swarms-based systems, adaptive multi-agent systems (AMAS) [20] and more generally all the works coming from the SASO community.
2. *Coalition Oriented MAS (top-right)*: Here agents are still unable to reason about the global organisation but can build inner models of the interactions/dependence relations with their neighbourhood with respect to predefined social rules and patterns. Common examples of such approaches are multi-agent coalitions [40] or more simply systems based on the contract net protocol [41].
3. *Agent-oriented software engineering (bottom-left)*: This category of approaches consider organisation at the design-time. Organisations are specified before encoding the agents. Agents can reason on the organisation at run-time but cannot be able of modifying it. Examples of such approaches are mainly found in the AOSE community which proposes several multi-agent oriented methodologies that focus on the organisational model such as MASE [11] and INGENIAS [36].
4. *Organisation Oriented MAS (bottom-right)*: These approaches are influenced by both AOSE and social reasoning, in the sense that organisation are used by designer to specify the system-to-be and by the agents that can perform organisational acts and possibly modify the organisation. Example of such approaches are AGR [16], TAEMS [32], STEAM [44], $\mathcal{M}$oise$^+$ [25] or ISLANDER[15].

2.4 Checkable vs Adaptive Organisations

Previous sections expounded the two dimensions of our comprehensive view grid, and some examples. Let us now come back to the main motivations of the existence of the two proposed points of view. On the one hand, SASO community aims at providing *adaptive* systems inspired by natural, biological and physical systems that display real adaptation and autonomy capabilities. However such properties also raise some design problems: how can we ensure that the system will converge towards a specified state and not continuously adapt and change? On the other hand, AOSE community, and to a lesser extent COIN community, firstly aimed at providing engineering tools to design systems using organisational concepts rather than classical object- or agent-oriented concepts. Such concepts and models enable a designer to *check* whether the system behaves as specified by the organisation specification. Thus, the specified cooperation patterns ensure certain properties on the system such as sanction triggering using formal commitments [17], or global states using Object-Z framework [23]. Nevertheless, such an *a priori* model of the organisation represents a limitation in terms of adaptation: how can we model all the possible organisation changes at design-time? Even if some works proposed reorganisation approaches to tackle this problem, it is not surprising that these two views often collide since they focus on two opposite extrema of the same spectrum from full adaptation to full checkability.

As we can see, these two points of view focus on two different extrema of the same spectrum, from complete adaptation to complete checking. Between these, midterms can be reached: systems in which partial checking and verification can be processed, and systems in which total checking is feasible under certain hypothesis. We will further aim at identifying complementarity in order to dress up perspectives for unifying self- and reorganisation approaches.

3 Where are Self- and Re- in the Adaptation of Organisations?

In this section we analyse several aspects regarding the two main approaches related to the organisation modification process –reorganisation and self-organisation– through the following questions: *what*, *when*, *why*, *who* and *how*.

3.1 What is Changed?

Changing the organisation may imply changes within the system at different levels and at different extents. These changes strongly depend on the chosen view (ACPV or OCVP) and on the organisational capabilities of agents (being or not aware of the organisation).

Considering the *emergence-based MAS*, the observed organisation of the agents may be changed along different dimensions: spatial configuration, neighbourhoods, differentiation/specialisation of the agents. In many approaches, the spatial configuration of the system strongly constrains the capabilities and the potential that the system can exhibit. Therefore, system adaptation expresses as changing this spatial configuration such that it can behave in a more adapted way to the new environmental pressure. For instance, in a self-constructed mechanical system [4], mechanical parts (agents) change by themselves their attachment to other parts as to optimise a trajectory function, which may change at runtime, without being aware of the global organisation (i.e. the whole mechanism configuration). The same kind of adaptation is also found in collective robotics [10] where the spatial position of all the agents is strongly related to the plans that they have to execute. The observed organisation may also be changed by changing the partners with which the agents of the system interact or the way they interact which each other. Several other self-organising mechanisms are also presented in [12, 22]. In other systems, adapting a system is visible as changes in the tasks and/or goals that agents achieve. For instance, in bio-inspired approaches the self-differentiation installs a bottom-up kind of implicit role allocation [14]. To conclude, such approaches often propose systems able to *explore the space of possible organisations*.

In the *coalition-oriented MAS*, the topology of the organisation is expressed in terms of local social configurations: agents belong to neighbourhoods, coalitions (agents know each other and cooperate together) expressed in terms of power relations, dependence relations or social commitments. For instance in [7], agents change their interactions depending on a *trust* evaluation, which is calculated using past experiences and opinions from other trusted agents. This represents a regulatory local mechanism that leads the system to a social order. Coalitions are also built and deleted using such mechanisms, in market places [9]. In distributed problem solvers like [34] coalition is defined/changed

from the election depending on the current state of the neighbourhood (e.g. the most constrained agent is elected to propose a solution) or the advance in the solving process.

Considering the *organisation-oriented MAS* approach, since there exists some explicit specification, the change of organisation may be considered at two levels: (i) change of the definition of the organisation itself and (ii) change of the allocation of roles to the agents, i.e. the way the multi-agent organisation itself is built. An example of the former is the work of Hübner et al. [26], in this work the agents are able to evaluate their organisation, identify that the problem is caused by the current definition (or specification) of the organisation, and then decide to change the specification. This kind of change usually implies changes in the role allocation, since the very set of available roles can be changed. Examples of the latter case of reorganisation include, for instance, the work of Kamboj et al. [28] where the reorganisation consists in the spawning and composition of agents in the system in order to reassign the roles the agents play. The reasons for changing the organisation consist in the wish to have a structure adapted to the environment and the task structure that has to be processed by the agents. Another example is the work of Glaser et al. [21] where the organisation is changed by the entrance of new agents in the system playing a particular role. The new agent is accepted only when it increases the utility of the overall system. Organisational structure generation has also been proposed as arising from local [19], global [8], and hybrid perspectives.

Concerning the *methodological viewpoint* (bottom-left), the designer may change the *model* of the system at several levels. At a low level, the agentification (i.e. the way model entities are specified as agents) may be changed, and therefore the organisation too. At an upper level, the organisation model may be changed by adding new roles, groups, tasks, etc.

3.2 When and Who Changes the Organisation?

Depending on the approach, the organisation can be changed at different times during the system life cycle. It can be initiated by different actors. The decision when to start the process can be either static or dynamic. In the first case the process is started according to a predefined criterion fixed within the definition of the organisation. In the second case, the reorganisation process is a consequence of the functioning of the system. It means that if agents do not meet one or several criteria (goal, performance etc.) the organisation is changed. In [13], Dignum defines the "when" to reorganise as linked to the utility of the organisation (interaction success, role success and structure success) and to the utility of the agent (different for each agent, depends on its goals, resource production and consumption).

The process is static when the adaptation of the system is performed by the designer, during the development of the system. Only designers (seen as Oracles) can detect, by using appropriate model checking, fast prototyping, or simulation tools like in IODA [29], which exhibit global undesired behaviours. Agents are not actors of the organisation adaptation process, but are only an implementation of the organisational model specified by the designer.

The process is dynamic when the organisation is modified at runtime. This modification can be performed by an external entity (designer, other systems, etc.) that acts on living agents, or autonomously by agents themselves. For instance, agents within a self-organising system change indirectly the organisation as a reaction to an *environmental change* detected at the agent level. So, in the example of self-constructed mechanics, mechanical components can change their weights (length, pressure, etc.) when they receive an external positive or negative feedback (by propagation), concerning the distance to the objective trajectory [4]. A coalition reacts also to changes detected at the coalition level, by *social pressure* (e.g. a coalition received a negative opinion concerning its leader), and therefore changes the organisation (e.g. by changing its leader) [33].

3.3 Why and How does the Organisation Change?

While we can identify different kinds of *changing objects* according to the organisation model being used, we can also identify some types of *changing processes* that will be detailed in the remainder of this section: (*i*) predefined changes, (*ii*) controlled changes and (*iii*) emergent changes. The general reason to trigger the change is that the organisation does not help in achieving the social purpose. In other words, the current organisation constrains the agents' behaviours to those which do not fit the behaviours that draw the social purpose. Such situations may happen, for instance, when the environment has changed, the MAS purpose has changed, the performance requirements are not satisfied, the agents are not capable of well playing their roles, a new task request arrives and the current organisation is not appropriate, etc.

Generic Organisation Process. Generally, in order to modify an organisation, we can identify a generic organisation process (or adaptation process) which will be differently implemented depending on the chosen adaptation approach. This process is usually composed of two main phases –monitoring and reparation. This last one, depending on the MAS type, can be decomposed into design, selection and execution phases [42] or selection and execution phases only. This adaptation process can be part of a more general environment-system life-cycle: perception, adaptation process, action, perception, and so on. Inherent problems of this process and the chosen approach are detailed in the remainder of this section.

1. The *monitoring* phase aims at detecting inadequacy problems between the system, the organisation or the agents, and the environment. Whatever is the entity responsible for the monitoring, and therefore whatever is the abstraction level of this detection (macro or micro), it is advisable to define the set of situations of non adaptation.
2. Once a need to adapt is detected, the *reparation* phase performs a process in order to find back an function as optimal as possible, at runtime.
   (a) For this, the *design* phase aims at defining and developing a set of possible alternatives for the current organisation, in a top-down or a bottom-up manner.
   (b) The *selection* phase determines one alternative to modify the organisation. The main problem is therefore the definition of *evaluation criteria* for evaluating the different alternatives.

(c) The *execution* corresponds to the implementation of the previously chosen alternative.

Predefined Change of Organisation. In this case we consider that changes are already planned and expressed by the designer to be performed at a precise moment [5]. For instance, a soccer team has previously accorded to change its formation at the 30 minutes of the match [43]. In this approach, the execution of the adaptation process is quite straightforward. Monitoring is performed by agents themselves or an external entity (e.g. the coach of the soccer team which consults a timer to know when to trigger the team change). The design phase, which determines all these trigger conditions, is not performed at runtime, but at design time. Selection and execution phase are immediate since trigger conditions are coupled with predefined actions, performed on the fly.

Controlled Change of Organisation. In this case, the system does not know when the organisation will change, but knows what are the conditions to trigger a change process, that will be implemented following a known procedure (e.g. a team has an expert that controls the reorganisation process). The main difference with the previous approach is that the designer des not know a priori when and how the organisation has to be changed. However he is able to define strategies for monitoring and repairing the organisation. These strategies can be used by agents to control and drive the organisation process. This process can be performed in two ways: either (*i*) an *endogenous* approach where a particular agent (centralisation) or agents themselves (coordinated decentralisation) will manage the reorganisation; or (*ii*) an *exogenous* approach where the user of the system, or an external system, controls the process. During the execution of an instance of the specified system, the entity responsible for the change (designer or agent) can detect the organisation is not adapted because of *inadequate performances*, and can therefore modify the model and the specification for improving the performances by *programming* a more adapted organisation.

The monitoring phase identifies a situation where the current *organisation is not adapted* and does not satisfy the needs of the MAS. The main problem this phase is *how to identify whether the social purpose is not being achieved because the current organisation does not allow it*. Many other reasons may cause the unaccomplishment of the MAS purpose (e.g. the social purpose is impossible to be achieved). In some cases to change the organisation is not helpful. Even in the case we know the problem can be solved by the reorganisation process, the new problem is to identify *which part of the organisation is causing the problem* in order to set the correct reorganisation level. The part of the organisation that is responsible for the problem can be either its specification (e.g. set of possible roles) or the current instantiation of that specification (e.g. who plays which role). The reparation phase requires then to execute the design, selection and execution phases. The design phase intends to develop a set of possible alternatives for the current organisation. The design of this set of alternatives can be based on (*i*) a search in a library of predefined organisations or (*ii*) their creation on demand. In the first case, the problem is to identify which predefined organisation is appropriate for the failure caught by the monitoring phase. In the second case, we have to deal with yet another problem: the hugeness of the search space for new organisational specifications

(this search space is defined by the organisational model). During the execution, means to change the current organisation must be defined without causing any failure. For example, how an agent will deal with the fact that the role it is playing was removed in the new organisation? What it will do with the commitments adopted under this extinguished role?

An example of controlled change of organisation is $\mathcal{M}$OISE$^+$ [26]. This work considers the organisational structure and functioning. They explicitly focus on controlling the reorganisation process for which they consider the four phases discussed above. In their view reorganisation is a cooperative process itself which is performed in an endogenous and decentralised way. This process may itself be the subject of a dedicated organisation composed of a hierarchy of roles specialised in the management of the reorganisation. Another example is [24], where a centralised reorganisation process is used, based on TAEMS (Task Analysis, Environment Modeling, and Simulation) modelling language and a diagnosis expert subsystem in charge of detecting deficiencies in the organisation and assisting in the creation of a solution. Its monitoring phase identifies failures when the system does not behave as expected by its functional model. Examples of controlled self-organisation can be found in some agent-based problem solvers, like [34] or [37], in which predefined roles are taken by agents depending on the state of the solving process. In a nominal situation, agents try to find a value by checking constraints shared with neighbours, but without knowing their values. If an agent detects that its neighbouring agents (sharing constraints) are blocked or over-constrained, it will take the *mediator* role [34] or will launch an *election process* [37] so as to force them to share their value as to set a new value minimising conflicts, for instance. Therefore, agents can play two different roles, predefined by the designer, at different times of the solving process.

Emergent Change of Organisation. In this last case, as for the controlled change of the organisation, the time to trigger the process is not predefined by the designer. The reasons to change are equivalent to the previous cases: the system behaviour is not adequate in its environment. The main characteristic of the process is that it is not led by an entity external from the system. Difference with other approaches is that the designer does not have global knowledge of strategies to monitor and repair the organisation. All the knowledge he has is local knowledge that is manipulated at the agent level, at a local level. Thus, the organisation which is defined comes from the interactions between the agents from their local perception and actions.

The monitoring phase is performed endogenously, by one or more agents. The designer equips them with capabilities to detect at local level that the organisation is no more globally adapted. For this, agents are able to know *they are not adapted*. Next, the agent that detects the problem will perform the reparation phase. It consists in the selection of one or more actions among the set of all possible actions, followed by the execution of this chosen action. In [38], the agent chooses and performs the action it judges as being the most appropriate with respect to a local evaluation criterion called cooperativeness. This action can be defined and implemented, or learned at runtime [14]. This phase is also realised during runtime. An agent *reacts* to change its position within the organisation/topology in order to adapt the system as a whole, or

to change its own behavioural specialisation [14]. An agent is able to autonomously decide the action that will change the organisation, by removing itself from the system for instance. An agent can also decide to act cooperatively, i.e. by taking into account its neighbours' states [38]. For instance, in a self-constructed mechanics, a component receiving a negative *feedback* from the environment must change its weights in order to change its function and its interactions with its neighbourhood as cooperatively as possible and therefore it reduces the negative feedback. Coalitions modify their organisation when *relations between agents are not adapted*. Such changes are the result of a *reasoning process* based on social concepts such as powers and dependencies. For instance, in a coalition of surveillance drones, agents change their leader after the current one has displayed some lack of computation or communication capabilities, in order to maintain the group adapted to the collective mission [33].

4 Discussion and Definitions

		Organisation Unawareness	**Organisation Awareness**
What?	**ACPV**	Topology Weights, Influence Differentiation Neighbourhood	Dependencies Commitments Powers
	OCPV	Design model Agentification	Organisation specification Role assignment
When?	**ACPV**	At runtime	At runtime
	OCPV	At design time	At runtime
Why?	**ACPV**	Agents are not adapted	Relations between agents are not adapted
	OCPV	Performances are not adequate	Organisation is not adapted
Who?	**ACPV**	Agents (environmental pressure)	Agents (social pressure)
	OCPV	Designer	Designer & Agents
How?	**ACPV**	Reacting indirectly on the organisation directly on the environment	Reasoning indirectly on the organisation directly on cooperation patterns
	OCPV	Programming directly the organisation directly the environment	Organising directly the organisation directly the cooperation patterns

Table 1. Aspects of organisation adaptation

Table 1 provides a synthetic view of the different points we analysed above. We can thus propose definitions of reorganisation and self-organisation concepts, in the context of Figure 1 and Table 1.

Definition 1. Reorganisation *is a process, endogenous or exogenous, concerning systems in which organisation is explicitly manipulated through specifications, constraints*

or other means, in order to ensure an adequate global behaviour, when the organisation is not adapted. Agents being aware of the organisation state and structure, they are capable of manipulating primitives to modify their social environment. This process can be both initiated by an external entity or by agents themselves, by reasoning directly on the organisation (roles, organisational specification) and the cooperation patterns (dependencies, commitments, powers).

This process thus appears on the right side of the grid, and mainly concerns organisation-oriented systems and, to a lesser extent, coalition-based systems.

Definition 2. Self-organisation *is an endogenous and bottom-up process concerning systems in which only local information and representations are manipulated by agents unaware of the organisation as a whole, in order to adapt the system to the environmental pressure by modifying indirectly the organisation, therefore by changing directly the system configuration (topology, neighbourhoods, influences, differentiation), or the environment of the system, by local interactions and propagation, by avoiding predefined model biases.*

This process appears on the top row of the grid, and therefore concerns emergent organisations and, to a lesser extent, coalition-based-systems. So, we can identify a continuum between self-organising systems and reorganising ones, via coalition-based systems. Reorganisation and self-organisation are also two different implementations of the same generic process of adaptation of organisations: detection and reparation. In a self-organising system, this process is decentralised, implicit and endogenous, giving the responsibility to agents and often initiated by an environmental change. In a reorganising system, this process can be decentralised or not, but always explicit and directly performed by entities (designer or agents) manipulating organisational primitives.

5 Conclusion

In this paper we presented a comprehensive view of the organisational aspects in multi-agents systems from agent-centred and organisation-centred points of view. We also underlined the main differences between the reorganisation and self-organisation processes by analysing the reasons and scope of organisation changes (what, when, who, why, how). Following this analysis, we proposed definitions of reorganisation and self-organisation, with respect to the organisation-centred and agent-centred points of view. However, these two points of view are not incompatible if we consider them at different moments of the life time: for instance, emergence at the beginning, capitalisation and injection of the capitalised organisation in the functioning of the system, change of this organisation (reorganisation), and self-organisation once the set of known possible organisations is no more sufficient.

Once we have dressed up a comprehensive view of the organisation adaptation context, in future works we will aim at defining a formal framework capturing the notions of both views as to make them cooperate. We can imagine using self-organising mechanisms at the organisation model level to explore the space of possible organisations, and to propose more adequate organisations and norms. From the opposite viewpoint,

we can imagine using organisational specification to set boundaries for the emergent behaviours of self-organising systems, by defining, for instance, regimented constraints that agents cannot violate and enforced constraints that agents may violate to explore new organisational configurations.

References

1. F. Bergenti, M.P. Gleizes, and F. Zambonelli. *Methodologies and Software Engineering for Agent Systems*. Kluwer, 2004.
2. P. Bernoux. *La sociologie des organisations*. Seuil, 3ème edition, October 1985.
3. O. Boissier, J. F. Hübner, and J. S. Sichman. Organization oriented programming from closed to open organizations. In Gregory O'Hare, Michael O'Grady, Oguz Dikenelli, and Alessandro Ricci, editors, *Engineering Societies in the Agents World VII (ESAW 06)*, volume 4457 of *LNCS*, pages 86–105. Springer-Verlag, 2007.
4. D. Capera, M.-P. Gleizes, and P. Glize. Mechanism Type Synthesis based on Self-Assembling Agents. *Journal of Applied Artificial Intelligence*, 18(9-10):921–936, 2004.
5. T. Carron and O. Boissier. Towards a temporal organizational structure language for dynamic multi-agent systems. In *Pre-Proceeding of the 10th European Workshop on Modeling Autonomous Agents in a Multi-Agent World (MAAMAW'2001)*, 2001.
6. C. Castelfranchi. Modeling social action for AI agents. *Artificial Intelligence*, (103):157–182, 1998.
7. C. Castelfranchi. Engineering Social Order. In *ESAW '00: Proceedings of the First International Workshop on Engineering Societies in the Agent World*, pages 1–18. Springer-Verlag, 2000.
8. D. D. Corkill and V. R. Lesser. The use of meta-level control for coordination in distributed problem solving network. In Alan Bundy, editor, *Proceedings of the 8th International Joint Conference on Artificial Intelligence (IJCAI'83)*, pages 748–756, Los Altos, CA, 1983. William Kaufmann.
9. D. Cornforth, M. Kirley, and T. Bossomaier. Agent Heterogeneity and Coalition Formation: Investigating Market-Based Cooperative Problem Solving. *Autonomous Agents and Multiagent Systems, International Joint Conference on*, 2:556–563, 2004.
10. M. M. de Weerdt and B. J. Clement. Introduction to planning in multiagent systems. *Multiagent and Grid Systems An International Journal*, 5(4), 2009.
11. S.A. DeLoach. *Methodologies and Software Engineering for Agent Systems. The Agent-Oriented Software Engineering Handbook Series : Multiagent Systems, Artificial Societies, and Simulated Organizations*, volume 11, chapter The MaSE Methodology. Kluwer Academic Publishing (available via Springer), 2004.
12. G. Di Marzo Serugendo, M.-P. Gleizes, and A. Karageorgos. Self-Organisation and Emergence in Multi-Agent Systems: An Overview. *Informatica*, 30(1):45–54, 2006.
13. V. Dignum, F. Dignum, and L. Sonenberg. Towards dynamic organization of agent societies. In G. Vouros, editor, *Workshop on Coordination in Emergent Agent Societies*, pages 70–78, 2004.
14. A. Drogoul, B. Corbara, and S. Lalande. MANTA: New experimental results on the emergence of (artificial) ant societies. In Nigel Gilbert and Rosaria Conte, editors, *Artificial Societies: the Computer Simulation of Social Life*, pages 119–221. UCL Press, London, 1995.
15. M. Esteva, J.A. Rodriguez-Aguiar, C. Sierra, P. Garcia, and J.L Arcos. On the formal specification of electronic institutions. In Frank Dignum and Carles Sierra, editors, *Proceedings of the Agent-mediated Electronic Commerce*, LNAI 1191, pages 126–147, Berlin, 2001. Springer.

16. Jacques Ferber and Olivier 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'98)*, pages 128–135. IEEE Press, 1998.
17. N. Fornara and M Colombetti. Specifying and enforcing norms in artificial institutions. In *7th International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS 2008), Estoril, Portugal, May 12-16, 2008, Volume 3*, pages 1481–1484, 2008.
18. L. Gasser. Organizations in multi-agent systems. In *Pre-Proceeding of the 10th European Worshop on Modeling Autonomous Agents in a Multi-Agent World (MAAMAW'2001)*, Annecy, 2001.
19. L. Gasser and T. Ishida. A dynamic organization architecture for adaptive problem solving. In *Proceedings Ninth National Conference on Artificial Intelligence (AAAI'91)*, pages 185–90. The MIT Press & AAAI Press, 1991.
20. J.-P. Georgé, B. Edmonds, and P. Glize. Making Self-Organizing Adaptive Multi-Agent Systems Work - Towards the engineering of emergent multi-agent systems (chapter 8). In *Methodologies and Software Engineering for Agent Systems*, pages 319–338. Kluwer, 2004.
21. N. Glaser and P. Morignot. The reorganization of societies of autonomous agents. In Magnus Boman and Walter Van de Velde, editors, *Multi-Agent Rationality*, LNAI 1237, pages 98–111, Berlin, 1997. Springer.
22. S. Hassas, G. Di Marzo-Serugendo, A. Karageorgos, and C. Castelfranchi. On self-organising mechanisms from social, business and economic domains. *Informatica*, 30(1):63–71, 2006.
23. V. Hilaire, P. Gruer, A. Koukam, and O. Simonin. Formal driven prototyping approach for multiagent systems. *International Journal of Agent-Oriented Software Engineering*, 2(2):246–266, 2008.
24. Bryan Horling, Brett Benyo, and Victor Lesser. Using self-diagnosis to adapt organizational structures. In *Proceedings of the 5th International Conference on Autonomous Agentes (Agents' 01)*, 2001.
25. J.F. Hübner, J.S. Sichman, and O. Boissier. $\mathcal{M}$oise$^+$: Towards a structural, functional, and deontic model for MAS organization. In Cristiano Castelfranchi and W. Lewis Johnson, editors, *Proceedings of the First International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS'2002)*, pages 501–502. ACM Press, 2002.
26. Jomi Fred Hübner, Jaime Simão Sichman, and Olivier Boissier. Using the $\mathcal{M}$oise$^+$ for a cooperative framework of MAS reorganisation. In Ana L. C. Bazzan and Sofiane Labidi, editors, *Proceedings of the 17th Brazilian Symposium on Artificial Intelligence (SBIA'04)*, volume 3171 of *LNAI*, pages 506–515, Berlin, 2004. Springer.
27. C. Iglesias, M. Garrijo, and J. Gonzalez. A survey of agent-oriented methodologies. In *Proceedings of the 5th International Workshop on Intelligent Agents V : Agent Theories*, pages 317–330, Heidelberg, 1999. Springer-Verlag.
28. S. Kamboj and K.S. Decker. Organizational self-design in semi-dynamic environments. In *AAMAS '07: Proceedings of the 6th international joint conference on Autonomous agents and multiagent systems*, pages 1–8, New York, NY, USA, 2007. ACM.
29. Y. Kubera, P. Mathieu, and S. Picault. Interaction-oriented agent simulations : From theory to implementation. In *Proceedings of the 18th European Conference on Artificial Intelligence (ECAI'08)*, pages 383–387. IOS Press, 2008.
30. O. Boissier L. Coutinho, J.S. Sichman. Modeling dimensions for multi-agent systems organizations. In V. Dignum, F. Dignum, B. Edmonds, and E. Matson, editors, *Agent Organizations: Models and Simulations (AOMS), Workshop held at IJCAI 07*, 2007.
31. C. Lemaître and C.B. Excelente. Multi-agent organization approach. In Francisco J. Garijo and Christian Lemaître, editors, *Proceedings of II Iberoamerican Workshop on DAI and MAS*, 1998.

32. V. Lesser, K. Decker, T. Wagner, N. Carver, A. Garvey, B. Horling, D. Neiman, R. Podorozhny, M. NagendraPrasad, A. Raja, R. Vincent, P. Xuan, and X.Q.. Zhang. Evolution of the gpgp/taems domain-independent coordination framework. *Autonomous Agents and Multi-Agent Systems*, 9(1):87–143, July 2004. Kluwer Academic Publishers.
33. M. T. Long, R. R. Murphy, and J. Hicinbothom. Social roles for taskability in robot teams. In *International Conference on Intelligent Robots and Systems (IROS'07)*, pages 2338–2344. IEEE, 2007.
34. R. Mailler and V. Lesser. Solving Distributed Constraint Optimization Problems Using Cooperative Mediation. In *Proceedings of Third International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS'04)*, pages 438–445. IEEE Computer Society, 2004.
35. H. V. D. Parunak and S. A. Brueckner. Engineering swarming systems. In *Methodologies and Software Engineering for Agent Systems*, pages 341–376. Kluwer, 2004.
36. Juan Pavón and Jorge J. Gómez-Sanz. Agent oriented software engineering with ingenias. In Vladimír Marík, Jörg P. Müller, and Michal Pechoucek, editors, *CEEMAS*, volume 2691 of *Lecture Notes in Computer Science*, pages 394–403. Springer, 2003.
37. G. Picard, M.-P. Gleizes, and P. Glize. Distributed Frequency Assignment Using Cooperative Self-Organization. In *Self-Adaptive and Self-Organizing Systems, 2007. SASO '07. First International Conference on*, pages 183–192. ACM Press, 2007.
38. G. Picard and P. Glize. Model and Analysis of Local Decision Based on Cooperative Self-Organization for Problem Solving . *Multiagent and Grid Systems*, 2(3):253–265, septembre 2006.
39. W. R. Scott. *Organizations: rational, natural and open systems*. Prentice Hall, 4 edition, 1998.
40. 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*, pages 188–192, 1994.
41. R.G. Smith. The contract net protocol: High-level communication and control in a distributed problem solver. *IEEE Transaction on Computers*, 29(12):1104–1113, 1980.
42. Y. So and E.H. Durfee. An organizational self-design model for organizational change. In *Proceedings of AAAI93 Workshop on AI and Theories of Groups and Organizations*, 1993.
43. P. Stone and M.M. Veloso. Task decomposition and dynamic role assignment for real-time strategic teamwork. In Jörg P. Müller, Munindar P. Singh, and Anand S. Rao, editors, *Proceedings of the 5th International Workshop Agent Theories, Architectures, and Languages (ATAL-98)*, LNCS 1555, pages 293–308, Berlin, 1999. Springer.
44. M. Tambe. Towards flexible teamwork. *Journal of Artificial Intelligence Reseearch*, 7:83–124, 1997.