

Chapter 19

Organisational Reasoning Agents

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19.1 Introduction

In a MAS, agents are situated in a common environment, and are capable of flexible and autonomous behaviour. They make use of different cognitive elements and processes in order to control their behaviour (e.g. beliefs, desires, goals, capacities of situation assessment, of planning). Their autonomy is among the most important characteristics of the concept of agency. However, this autonomy can lead the overall system to exhibit undesired behaviour, since each agent may do what it wants. This problem may be solved by assigning an organisation to the system, as it is done in human societies. Roles, as they are defined in organisational models, are generally used to flag the participation of an agent to the organisation and to express what the expected behaviour is of that agent in the organisation. In the literature, more or less formal specifications of the requirements of a role exist (see for instance [Boella et al. 2005](#) on the different notions of roles and [Coutinho et al. 2009](#)). Combined with the different dimensions that are expressed in the organisational models supporting the organisation specification, this leads to different sets of constraints that can be imposed on the agent's behaviour while participating in an organisation (constraints on beliefs, on goals, on the interaction protocols that it can use while cooperating with other agents, on the agents to communicate with, etc).

From this global picture at the macro level (i.e. organisation perspective), let's have a look at the micro level, i.e. agent perspective. Taking an agent's architecture perspective and analysing the reasoning capabilities with respect to organisation,

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different cases may be considered (Boissier 2001; Hübner 2003): first, agents may or may not have an explicit representation of the organisation, and second, they may or may not be able to reason about it. In this section, we mainly consider agents that, internally, have the capability to represent the organisation and that are able to reason about it. They could consider the organisation as an aid to deciding what to do (e.g., coalition formations Sichman et al. 1994), and/or as a set of constraints that aim to reduce their autonomy or, on the contrary may help them to gain certain powers.

From what precedes, one could ask why it would be worth having such kind of agents in a multi-agent organisation. From the analysis drawn in Boissier et al. (2005), mainly from human societies, it clearly appears that when an agent plays a role, its behaviour and its cognitive elements and processes change. Correspondingly, one may want to *recreate* these kinds of processes when artificial agents also play roles in artificial organisations.

Moreover, agents that are able to reason about organisations are needed in order to realize *open systems* (Boissier et al. 2007; Dignum et al. 2008). Increasingly, it is recognized that the Internet (including latest developments into sensor networks and the ‘Internet of things’) can form an open interaction space where many heterogeneous software agents co-exist and act on behalf of their users. Such open systems need to be regulated. However, such regulation is only effective if agents can understand the imposed regulations and adapt their behaviour accordingly, i.e., if agents are capable of organisational reasoning.

Finally, organisational reasoning agents facilitate engineering multi-agent systems adhering to the principle of *separation of concerns*. That is, when agents can reason about an organisation, the agents and the organisation can be developed separately. When the system designer changes parts of the organisation, e.g., norms that agent playing a certain role should adhere to, one does not need to change the agents as they will be able to adapt (within reasonable limits) to the changed organisation.

There are different ways in which an agent’s cognitive elements or behaviour can change because of the role it plays. It may adopt the role’s goals, desires or beliefs, it may acquire knowledge or new powers. It may also acquire or lose some powers and finally it may decide to do what’s best for the organisation, putting aside (for the moment) its own goals. Any agent playing a role is faced with the problem of integrating the cognitive elements of the role with its own. Moreover, when the internal motors of the agent change, its behaviour is likely to change too. An agent should also change its way of reasoning, to cope with the new dimensions of its behaviour, i.e., its mental processes are different when it plays a role. Besides the changes on the individual dimension of an agent, playing a role also affects the agent’s relationships with other agents: a change of the agent’s status by interpreting all of the agent’s physical actions, communications, beliefs, etc. as being the ones of its role, acquisition/loss of powers, dependence relationships with respect to other agents, trust relationship by being more (or less) trusted by others, etc.

After this brief introduction sketching the motivations for having organisation aware agents, we will first present in Sect. 19.2 some fundamental mechanisms for reasoning about organisations, identifying how and what kind of organisation-

primitives agents may have. We will then present some approaches proposed by the literature that illustrate the use of reasoning about organisation. The adaptation of organisations being addressed in the following chapter (cf. Chap. 20), we focus here on the kind of reasoning that an agent should develop for the entry/exit in/of an organisation (cf. In Sect. 19.3) considering both the ability and desirability points of view.

19.2 Mechanisms for Reasoning About Organisations

In order to be able to develop reasoning behaviours on the organisation, an agent must be equipped with fundamental mechanisms as described in a very abstract way in Fig. 19.1 (van Riemsdijk et al. 2009). The agent must be equipped with a basic set of primitives to act on the organisation and, the dual aspect, the capabilities to acquire the organisation description and represent it internally. Then it should be able to reason with this representation, affecting the agent's cognitive reasoning (reasoning about how to achieve goals and react to events).

These capabilities must be included in an agent architecture for reasoning about the different constructs induced by the participation of the agent to an organisation. Different concrete architectures have been proposed (e.g. Castelfranchi et al. (2000), Broersen et al. (2001), Kollingbaum and Norman (2003) and Hübner et al. (2007)). Each of these allows agents to represent and reason about various treatments of norms and organisations.

19.2.1 Mechanisms for Making Agents Aware of the Organisation

Several proposals have been made in the literature, dealing with the way agents are connected to the organisation, i.e. how agents acquire the description of the organisation (either an abstract specification of it or a concrete one in terms of

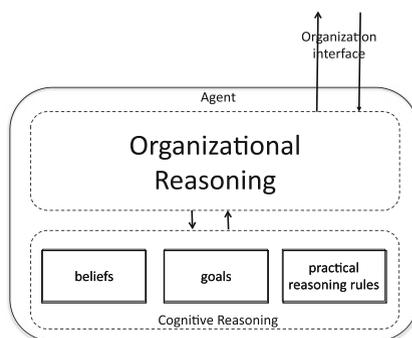


Fig. 19.1 Abstract Description of organisational reasoning agent architecture (van Riemsdijk et al. 2009)

which agent plays what, etc). To illustrate this more clearly, let's consider the *Moise* organisational model (explained in Sect. 17.2 of this book) for which there is available an extension of the Jason language (Bordini et al. 2007) to develop reasoning plans and strategies on the organisation. This extension allows developers to use this high-level BDI language to program agents able to reason about the organisation, by making them able to acquire organisational descriptions, especially its changes (e.g., a new group is created, an agent has adopted a role), and to act upon it (e.g., create a group, adopt a role). In this model, the way it is done is strongly connected to the set of organisational artifacts (Hübner et al. 2010) that instruments the MAS environment to support the management of the organisations expressed with the *Moise* organisation model.

These different concrete computational entities aimed at managing, outside the agents, the current state of the organisation in terms of groups, social schemes, and normative state encapsulate and enact the organisation behaviour as described by the organisation specifications.

From an agent point of view, such organisational artifacts provide the actions that can be used to proactively take part in an organisation (for example, to adopt and leave particular roles, to commit to missions, to signal to the organisation that some social goal has been achieved, etc.). They dynamically also provide specific observable properties to make the state of an organisation perceivable to the agents along with its evolution, directly mapped into agents' percepts (leading to beliefs and triggering events). So as soon as the observable properties values change, new percepts are generated for the agent that are then automatically processed (within the agent reasoning cycle) and the belief base updated. Besides, they provide actions that can be used by agents to manage the organisation itself (sanctioning, giving incentives, reorganising). They provide the operations and the observable properties for agents so that they can interact with the organisation. This means that, at runtime, an agent can perform an action α if there is (at least) one artifact providing α as operation – if more than one such artifact exist, the agent may contextualise the action explicitly specifying the target artifact. We refer the interested reader to Hübner et al. (2007, 2010) to have a look at the available repertoire of actions and observable properties.

So in programming an agent it is possible to write down plans that directly react to changes in the observable state of an artifact or that are selected based on contextual conditions that include the observable state of possibly multiple artifacts.

19.2.2 Mechanisms for Organisational Reasoning

Development of mechanisms for full-fledged organisational reasoning is still in its early stages. Nevertheless, several approaches have been proposed, some of which we briefly describe below.

The following papers address role enactment. In Dastani et al. (2003) an approach is proposed in the context of agent programming that defines when an agent and a

role match or are conflicting. An agent can enact a role if they are not conflicting. Enactment is then, broadly speaking, specified as taking up the goals of the role, and defining a preference relation over the agent's own goals and the role's goals. In (Dastani et al. 2004) the authors propose programming constructs that allow an agent to enact and deact a role. The semantics of the constructs is defined by specifying how the agent's mental attitudes change when a role is enacted/deacted. In van Riemsdijk et al. (2011) it is investigated how agents can reason about their capabilities in order to determine whether they can play a role (see also Sect. 19.3.1). It is shown how reasoning about capabilities can be integrated in an agent programming language.

Once an agent enacts a role, it should take into account the norms and regulations that come with the role in its reasoning. In Meneguzzi and Luck (2009), an approach is proposed on how AgentSpeak(L) agents can adapt their behaviour to comply with norms. Algorithms are provided that allow an AgentSpeak(L) agent to adopt goals upon activation of obligations, or remove plans upon activation of prohibitions. Even if an agent participates in an organisation, it may still decide to violate some of the corresponding norms. In Meneguzzi et al. (2010) it is investigated how to extend plans with normative constraints that are used to customize plans in order to comply with norms. In Broersen et al. (2002) an approach based on prioritized default logic is proposed, that allows it to express whether an agent prioritizes obligations, desires or intentions. Based on this prioritization, the agent generates the goals that it will pursue. In Castelfranchi et al. (2000) an architecture is proposed by means of which norms can be communicated, adopted and used as meta-goals on the agent's own processes. As such they have impact on deliberation about goal generation, goal selection, plan generation and plan selection. The architecture allows agents to deliberately follow or violate a norm, e.g., because it has a more important personal goal. Another proposal for deliberation about norms is put forward in Criado et al. (2010). It investigates the usage of coherence theory in order to determine what it means to follow or violate a norm according to the agent's mental state and making a decision about norm compliance. Moreover, consistency notions are used for updating agent mental state in response to these normative decisions. In Corkill et al. (2011), an extended BDI reasoning architecture is proposed for 'organisationally adept agents' that balances organisational, social, and agent-centric interests and that can adjust this balance when appropriate. Agent organisations specify guidelines that should influence individual agents to work together in the expected environment. However, if the environment deviates from expectations, such detailed organisational guidelines can mislead agents into counterproductive or even catastrophic behaviours. The proposed architecture allows agents to reason about organisational expectations, and adjust their behaviours when the nominal guidelines misalign with those expectations. In Panagiotidi and Vázquez-Salceda (2011) norms are taken into account during an agent's plan generation phase. Norms can be obligations or prohibitions which can be violated, and are accompanied by repair norms in case they are breached. Norm operational semantics is expressed as an extension/on top of STRIPS semantics, acting as a form of temporal restrictions over the trajectories (plans) computed by the planner.

19.3 Reasoning About the Participation in an Organisation

In this section we will see different approaches related to entering an organisation, playing a role in the organisation and leaving the organisation. Agents should be able to decide whether to enter an organisation, consider whether they are able to participate and whether they really desire to participate; and we will also analyse how roles affect agents, i.e., how playing a role affects directly an individual and how playing a role affects an individual's relationships with others.

19.3.1 *Am I Able to Participate in an Organisation?*

An important aspect that organisational reasoning agents should be able to reason about is whether they are able to play a role in an organisation, i.e., about whether it has the required *capabilities* (van Riemsdijk et al. 2011).

This is important as it allows an agent to decide, e.g., only to apply for roles for which it has (some of) the capabilities. Also, an agent may have to communicate the capabilities that it has. For example, consider organisations in which a dedicated agent (a *gatekeeper*) is responsible for admitting agents to the organisation. An example of an organisational modelling language in which such a gatekeeper is present, is OperA (Dignum 2004). The idea is then that the gatekeeper asks agents who want to join whether they have the necessary capabilities for playing the desired role in the organisation (similar to a job interview), and assigns roles to agents on the basis of this. In order to be able to answer the gatekeeper's questions, the agent needs to know what its capabilities are.

In order to develop general techniques that allow agents to determine what their capabilities are, it is important to make precise what kind of capabilities are considered. One may consider various capability types, like capabilities to execute *actions*, to *perceive* aspects of the environment in which the agents operate, to *communicate* information, questions or requests, and to achieve *goals* (van Riemsdijk et al. 2011).

Once it is precisely defined which capability types are considered, the agent should be endowed with mechanisms that allow it to *reflect on its own capabilities*. Reflection can in general be seen as an agent's introspective abilities. Reflection is also a technical term in programming. It allows a program to refer to itself at run-time (see, e.g., Java and Maude Clavel et al. 1996), which facilitates a modification of its run-time behaviour based on these reflections. Reflection in the latter sense can be a way to implement an agent's introspective abilities. In van Riemsdijk et al. (2011) it was proposed to allow an agent to derive beliefs about its capabilities, in this way integrating reflection in a natural way in its BDI reasoning mechanisms.

19.3.2 Do I Desire to Participate in an Organisation?

Besides being able to detect if it is able to play a role in an organisation, it is also necessary for an agent to detect if it is worth being part of an organisation.

For instance, in [Carabelea et al. \(2005\)](#), social commitments and social policies have been used to express what an agent is expected to do when entering an organisation. As in [Vazquez-Salceda \(2004\)](#) where playing a role is considered as a contract, it is considered that an agent playing a role in an organisation implies a set of commitments towards the organisation in which it plays this role. A role is thus defined by the social commitments it implies, but also by the resources put at the disposal in order to fulfil the social commitments that come with the role. We can classify the constraints imposed to an agent playing a role in an organisation into several categories:

- Goals to achieve: when it accepts to play a role, an agent accepts to try to achieve several goals, the role's goals.
- Authority relations: a role can have authority over another goal for something.
- Context-dependent obligations: when playing a role, an agent might have to fulfil several obligations towards the organisations.
- Permissions and prohibitions: when it accepts the playing a role, an agent receives permissions to perform some tasks and prohibitions to perform others.

From that understanding, the agent translated these commitments into power relations on which it was able to install social-power reasoning mechanisms that it used before deciding whether to adopt a role or not in order to assess the implications of this decision, i.e. what it will gain or lose by playing the role, what changes are likely to occur in his reasoning or behaviour.

This analysis and classification on the playing of a role may be conducted along two main directions: how playing a role directly affects an individual, how playing a role affects an individual's relationships with others.

19.3.2.1 How Playing a Role Directly Affects an Individual

There are different ways in which an agent's cognitive elements or behaviour change because of the role it plays. It may adopt the role's goals, desires or beliefs, it may acquire knowledge or new powers. It may also acquire or lose some powers and finally it may decide to do what's best for the organisation.

Adoption of the role's goals, desires, beliefs: Most related work in MAS focuses on the need for an agent to adopt the desires or goals of its role: most formal organisations divide the global goal of the organisation into subgoals delegated to its members, which are identified by the roles they play. Since the role's goals can

facilitate or hinder the achievement of the agents' own set of goals (Dastani et al. 2003), agent adoption of the role's goals may depend on:

- Degree of autonomy, internal motivations. If there is no conflict between the role's and the agent's goals, then an agent will adopt its role's goals and will try to pursue them. If there is a conflict and the goals cannot be satisfied together, an agent should choose what to do: (i) it could either not adopt the role's goals, (ii) it could adopt them and discard its own contradicting goals, (iii) it could adopt all the goals and make a decision later which of its currently contradicting goals it will pursue
- Organisational incentives, etc.

Acquisition of knowledge, of new powers: In order to ensure that its members are able to achieve their roles' goals, an organisation usually: gives these members access to sources of information or knowledge, trains them to better perform their tasks, gives them physical resources (money, a house, a car, etc.) or permissions to access and use organisation's resources. Autonomous agents accept the taking of a role because of the acquisition of: knowledge, access to information, new powers (Castelfranchi 2002) (using the resources coming with role and associated permissions). However, agents might use knowledge/power for their own interest or they can take advantage of an information source (e.g., a library) or power to satisfy their own personal goals.

Losing powers: When an agent agrees to take a role in a group, it signs a more or less formal or explicit contract with the group: what powers will be given to the agent (resources, permissions) and lost by the agent (prohibitions, obligations), which of his powers an agent puts at the disposal of the group.

The role's prohibitions are one of the reasons for losing powers: If an agent was able to satisfy a goal, it will not be able anymore if there is a prohibition to pursue that goal or to execute a key action in the plan to achieve that goal. playing a role might imply the agent loses the physical access to a resource.

The role's obligations hinder an agent's powers in a more subtle way: by obliging the agent to consume resources needed for other goals.

Putting powers at the disposal of a group means that the agent's decision process is no longer autonomous: his decision process is influenced (or even controlled) by an external entity. He thus loses other powers because he is no longer free to decide to use them.

Desire the best for the group: Agents, even if self-interested, usually desire the best for the organisation they belong to: this is often implicit in an agent (especially in the case of MAS), but it is behind many decisions made by the agent when playing a role in that group. Therefore, it is important in multi-agent organisations to make explicit not only a role's goals and norms, but also this desire. Agent behaviour is affected in many ways when playing these roles, e.g. by using their personal powers for the best of the organisation enabling a functional violation of norms (i.e. to violate norms if it's in the organisation's best interest) (Castelfranchi 2005).

This desire to ensure the best of the group should be present in all roles and agents should adopt it when playing these roles. It might affect agents' behaviour in many ways, like using their personal powers for the best of the organisation, but also by enabling a functional violation of norms (Castelfranchi 2005). Agents could decide to disobey the norms imposed on their roles if they believe that by doing this they increase the well-being of the organisation. We believe that is important in multi-agent organisations to make explicit not only a role's goals and norms, but only this desire with its high importance, thus enabling agents to violate norms if it's in the organisation's best interest.

19.3.2.2 How Playing a Role Affects an Individual's Relationships with Others

Playing a role may impact the relationships an agent develops with other agents in different ways, in term of status, powers, dependence relationships and/or trust.

Count-as effect: playing a role changes the agent's status: all of its physical actions, communications, beliefs, etc. are interpreted as being the ones of its role, e.g. other agents interpret executed actions/communication as being the role that executed the action/communication, and not the agent (e.g. command has a different meaning coming from a role with authority or from a simple agent). Importance for agents to have a means to express whether their actions, communications, . . . count as the actions, communications, . . . of their role or not. Agents should be aware of this and act accordingly. This limits the ways they can behave.

Acquisition/losing powers: Roles in an organisation belong to a rich network of relationships that are inherited by the agents playing the roles. e.g. authority relationship: a "superior" role has authority over an "inferior" role for something, meaning that whenever an agent playing the superior role delegates a goal (or an action, etc.) to an agent playing an inferior role, the latter must adopt and achieve it. These relationships modify the powers of an agent playing a role: an agent playing a role with authority over another gains a power over the agent playing the inferior role, i.e. the first agent disposes whenever it wants of one of the powers of the second agent (the power for which it has authority). The first agent thus gains an indirect power, while the second agent loses its power, by losing the possibility of deciding about it. The higher the role of an agent in the role hierarchy, the more indirect powers it gains: however, due to the relative nature of authority, an agent could have power over others for something, while the others will have power over it for something else.

Dependence relationships: Even in a non-organisational context, when not playing any role, agents depend on each other for one power and not for another power (Sichman et al. 1994): lack of power of achieving goals, lack of the needed resources or know-how. Not only do agents have dependence networks, but also roles in organisations (Hannoun et al. 1998): agents playing the roles inherit these relationships and usually must use the role's dependence network instead of their own.

An agent should not solve only conflicts between his goals, beliefs, etc., and the ones of his role, but also conflicts between his personal dependences and those of his role. An interesting situation occurs when an agent takes several roles at the same time and combine and use several dependence networks, a situation from which an agent might benefit sometimes.

Being more (or less) trusted by others: Trust relationships (Sabater 2004) between agents change when they take roles (see Part VI). Institutional trust (Castelfranchi and Falcone 1998): An agent can be trusted by others simply because it plays a role in an institution. The others' trust in it comes from their beliefs in the characteristics of the role inherited by the agent. Another reason to trust an agent playing a role in a group more, is because the group acts as an enforcer: there are incentives for an agent to obey the role's specifications.

19.4 Conclusions

Organisations represent an effective mechanism for activity coordination, not only for humans but also for agents. Nowadays, the organisation concept has become a relevant issue in the multi-agent system area, as it enables the analysis and design of coordination and collaboration mechanisms in an easier way, especially for open systems. In this section we have presented some work aimed at endowing the agents with capabilities for reasoning about organisations. We have focused on the kind of reasoning that agents should develop about whether to enter an agent organisation or not. In the current landscape of agreement technologies this is an important issue in the sense that the systems that are considered are large scale and open systems. We can also add to this kind of reasoning, all the different reasoning methods developed for organisation adaptation (described in the next chapter), for norm compliance, given the fact that norms are often considered in the context of organisations (see Part III). Besides these different reasoning mechanisms, we have also described basic and fundamental mechanisms that make agents able to develop these different kinds of reasoning.

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