ESSLLI08: Deontic Logic in Computer Science Part 2b/5: Normative Multi-Agent Systems

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Normative multiagent systems as a research area can be defined as the intersection of normative systems and multiagent systems [2]. With 'normative' we mean 'conforming to or based on norms', as in normative behavior or normative judgments. Other meanings of normative not considered here are 'of, relating to, or determining norms or standards', as in normative tests, or 'prescribing norms', as in normative rules of ethics or normative grammar. With 'norm' we mean 'a principle of right action binding upon the members of a group and serving to guide, control, or regulate proper and acceptable behavior'. Other meanings of 'norm' not considered here are 'an authoritative standard or model', 'an average like a standard, typical pattern, widespread practice or rule in a group', and various definitions used in mathematics.

1 Definition (2005): norm change

The Agentlink Roadmap [4, Fig. 7.1.] observes that norms must be introduced in agent technology in the medium term for the infrastructure for open communities, reasoning in open environments and trust and reputation. The first workshop on normative multiagent systems held in 2005 as a symposium of the Artificial Intelligence and Simulation of Behaviour convention (AISB) in Hatfield, United Kingdom defined it as follows.

> **"A normative multiagent system** is a multiagent system together with normative systems in which agents on the one hand can decide whether to follow the explicitly represented norms, and on the other the normative systems specify how and in which extent the agents can modify the norms." [2]

Since norms are explicitly represented, according to the definition of a normative multi-agent system, the question should be raised how norms are represented. Norms can be interpreted as a special kind of constraint, and represented depending on the domain in which they occur. However, the representation of norms by domain dependent constraints runs into the questions of what happens when norms are violated, how to represent permissive norms and their relation to obligations, and how norms evolve.

Deontic logic studies logical relations among obligations and permissions, and more in particular violations and contrary-to-duty obligations, permissions and their relation to obligations, and the dynamics of obligations over time. Therefore, insights from deontic logic can be used to represent and reason with norms in multi-agent systems. Deontic logic also offers representations of norms as rules or conditionals. However, there are several aspects of norms which are not covered by constraints nor by deontic logic, such as the relation among the cognitive abilities of agents and the global properties of norms.

Agent architectures like BOID explain agent decision making in normative systems, the relation between desires and obligations, how agents can acquire norms, how agents can violate norms, and how an agent can be autonomous. However, they do not explain where norms come from, how they are enforced, how norms structure organizations, how norms coordinate groups and societies, the relation between legal courts, how one system can authorize access in another system, or how global policies can be defined to regulate these local policies.

2 Definition (2007): mechanism design

After four days of discussion, the participants of the second workshop on normative multiagent systems held as a Dagstuhl seminar in 2007 agreed to the following consensus definition:

> **"A normative multiagent system** is a multiagent system organized by means of mechanisms to represent, communicate, distribute, detect, create, modify, and enforce norms, and mechanisms to deliberate about norms and detect norm violation and fulfilment." [3]

The emphasis has shifted from representation issues to the mechanisms used by agents to coordinate themselves. For example, there are norms in social systems like multi-agent systems, because a norm is a mechanism to obtain desired multi-agent system behavior [1]. Norms have for long been considered as one of the possible incentives to motivate agents in economics, which is, at root, the study of incentives: how people get what they want, or need, especially when other people want or need the same thing. There are three basic flavors of incentive: economic, social, and moral. Very often a single incentive scheme will include all three varieties. Think about the anti-smoking campaign of recent years. The addition of $3-per-pack "sin tax" is a strong economic incentive against buying cigarettes. The banning of cigarettes in restaurants and bars is a powerful social incentive. And when the U.S. government asserts that terrorists raise money by selling black-market cigarettes, that acts as a moral incentive.

More generally, there are norms in multi-agent systems to organize them. Norms are communicated, for example, since agents in open systems can join a multiagent system whose norms are not known. Norms are distributed among agents, for example, since when new norms emerge the agent could find a new coalition to achieve its goals. Norm violations and norm compliance are detected, for example, since spontaneous emergence norms of among agents implies that norm enforcement cannot be delegated to the multiagent infrastructure.

3 Norm classifications

There are many classifications of norms, but the most important one for normative multiagent systems is taken from legal theory and highlights the multiagent structure of normative systems. Substantive norms define the legal relationships of people with other people and the state in terms of regulative and constitutive norms, where regulative norms are obligations, prohibitions and permissions, and constitutive norms state what counts as institutional facts in a normative system. Procedural norms are instrumental norms, addressed to agents playing roles in the normative system, which aim at achieving the social order specified in terms of substantive norms. Procedural law encompasses legal rules governing the process for settlement of disputes (criminal and civil). Procedural and substantive law are complementary. Procedural law brings substantive law to life and enables rights and duties to be enforced and defended. For example, procedural norms explain how a trial should be carried out and which are the duties, rights and powers of judges, lawyers and defendants.

4 Ten research challenges

Boella *et al.* [3] take the perspective from an agent programmer, and consider which kinds of tools like programming primitives, infrastructures, protocols, and mechanisms she needs to deal with norms in the example scenario. Similar needs exist at the requirements analysis level, or the design level, but they have chosen for the programming level since it makes the discussion more concrete, and this level is often ignored when norms are discussed. They observe that the list is not exhaustive, and there is some overlap between the challenges. Their aim is to illustrate the range of topics which have to be studied, and they therefore do not attempt to be complete.

1. Tools for agents supporting communities in their task of recognizing, creating, and communicating norms to agents. Even if social norms emerge informally, e.g., when a community becomes more complex and more open, an explicit representation of norms becomes necessary. The new problem is the role of the agents and humans involved in the interaction with the multiagent system.
2. Tools for agents to simplify normative systems, recognize when norms have become redundant, and to remove norms. Challenge 2 is the counterpart of Challenge 1, because the natural tendency of overregulation creates the need for a counterbalance.
3. Tools for agents to enforce norms. In a distributed approach, roles should be defined for agents in charge of monitoring and sanctioning. The virtual environment can offer new opportunities for norm enforcement not found in the usual environments. For example, evidence about agent behaviors can be collected via the logfiles of the system.
4. Tools for agents to preserve their autonomy. Challenge 4 is the counterpart of Challenge 3, because there is a natural tendency to enforce norms by regimenting them into the system.
5. Tools for agents to construct organizations. E-institutions as proposed in multiagent systems can be a starting point, but they are often too flat - i.e., not hierarchically organized - and they usually do not support the dynamics of the underlying normative systems by allowing the creation of new norms.
6. Tools for agents to create intermediate concepts and normative ontology, for example to decide about normative gaps. The solution in real normative system is to endow some agents with powers to decide whether a new concept is subsumed by another one. The role of agents in the logical reasoning of a normative system is something which is still missing in the state of the art of the field.
7. Tools for agents to decide about norm conflicts. This challenge is related to Challenge 6 since norms do not cover all possible cases and conflicts between norms are possible. Thus agents need a mechanism to take decisions in situations of conflicting norms.
8. Tools for agents to voluntarily give up some norm autonomy by allowing automated norm processing in agent acting and decision making. In many examples, the autonomy of the agent must be adjusted to the context.
9. Tools for conviviality. Since scenarios like Second Life are aiming at people having pleasant social interactions, and norms may interfere with the goals of the players, the impact of norms on this dimension must be considered.
10. Tools for legal responsibility of the agents and their principals. Nowadays, agents become subjects of human legislation.

5 Five development levels

To put this shift from legal to interactionist view into perspective, Boella *et al.* [3] identify five levels in the development of normative multiagent systems.

1. **[Norm design]** At level 1 of off-line norm design, norms are imposed by the designer and automatically enforced, and agents cannot organize themselves by means of norms.
2. **[Norm representation]** At level 2 of norm representation, norms are explicitly represented, they can be used in agent communication and negotiation, and a simple kind of organizations and institutions can be created.
3. **[Legal reality (Norm manipulation)]** At level 3 of norm manipulation, a legal reality is created in which agents can add and remove norms following the rules of the normative system.
4. **[Social reality]** Whereas existing normative multiagent systems are still at one of these first three levels of norm autonomy (for an introduction to norm autonomy in multiagent systems, multiagent system research is now moving to level 4 of social reality, and is concerned with the ten challenges discussed in Section 4 above. We believe that there is at least one more level to be dealt with in the future.
5. **[Moral reality]** At level 5, the norms create a new moral reality. This goes beyond present studies in machine ethics, which seems more concerned with agent decision making in the context of norms dealt with at each level of normative multiagent systems, than with creating a new ethics.

Clearly, for each level the development of the normative multiagent system will take a much larger effort than the development of similar systems at lower levels.

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