Formalizing Argument-based Agent Interaction in Electronic Institutions

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1. Introduction, motivations and goals

During the last decade the notion of *agent* has gained acceptance within the AI community, mainly due to its adequacy to formalize complex environments. Agents can be thought as active software objects, which may be autonomous and able to perceive, reason, act, and interact with other agents. When agents interact with each other, a multi-agent system (MAS) arises.

Recently there has been growing interest in incorporating concepts based on the notion of *organization* as part of MAS. Organizational approaches come along with a number of issues to be coped with when dealing with *open* MAS, such as *heterogeneity* of the agents involved, *trust*, *exception handling*, adaptability to social and structural changes, etc.

In order to cope with this situation human societies have created *institutions* that set and enforce laws, monitor and respond to emergencies, prevent and recover from disasters, etc. Recent work [SSPJ99, NS96 , PSJ98b, ER+00] has been focused on the adoption of a similar approach for the realization of open multi-agent systems based on the development of *electronic institutions*.

According to [NS96,ER+00], the notion of electronic institution is founded on three basic concepts: **dialogical framework, performative structure** and **rules of behavior.** The dialogical framework provides a context or environment for agent interaction. In dialog-based institutions, agents interact among each other by means of *illocutions*, which convey the meaning of the agents' intentions and desires. The performative structure stipulates the communication protocol under which these interactions will take place. Dialogical actions of agents will have consequences, normally as *commitments* that impose constraints on actions these agents might carry out in the future. Finally, behavior rules regulate and delimitate the agents' behavior.

The notion of interaction among agents can be seen as the kernel of an electronic institution. Interactions that can typically be identified as observable part of the agents' behavior are *cooperation*, *coordination*, *collaboration* and *negotiation* among agents. Recent research [PSJ98b, NS96] has highlighted the role of argumentation as a process which underlies different kinds of interaction among agents. In many settings, the exchange of illocutions between two agents that cooperate, coordinate, collaborate, or negotiate can be conceptualized as the presentation of offers and counter-offers (equivalently, arguments and counter-arguments) in order to determine whether an

original proposal (thesis) is accepted or rejected. The dialogical framework has a natural analogy with a logical framework for *defeasible argumentation* [SL92, Vre93, PraVre99, CML00]. Protocols for defeasible argumentation correspond on its turn with the notion of performative structure in an electronic institution, and dialectical constraints (e.g. consistency, avoidance of fallacious argumentation, etc.) have a natural correspondence with the notion of behavior rules.

In this context, our research work is oriented towards a formalization of argument-based interaction in electronic institutions by applying different logical models for defeasible argumentation. Formalizing complex social structures in these institutions is crucial for a complete understanding of many features, such as hierarchies between agents, temporal constraints, computation with limited resources, etc. Such a model would allow to study and analyze the emerging behavior of intelligent, autonomous agents which may interact asynchronously with each other. A useful formalization tool is provided by so-called *context-based* reasoning, which will be briefly discussed in the next section.

2. Context-based reasoning in electronic institutions

Most cognitive processes carried out by human beings are *context-dependant*, i.e. they depend on the environment or *context* within which they are carried out. In AI, the importance of the notion of context was first postulated by John McCarthy in 1987 as an alternative for formalizing the well-known qualification problem. Later research provided several formal theories for context-based reasoning, which contributed to the development of new and more powerful ontologies.

Developing a framework for defining electronic institutions is clearly a complex task, in which several separate issues (the role of the agents involved, hierarchies among agents, communication capabilities, etc.) are intertwined. Thus, context-based approaches provide a natural tool for formalizing electronic institutions.

Two major approaches related to formalizing context-based reasoning were *multi-context systems* (MCS) and *labelled deductive systems* (LDS). Multi-context systems [GS94] allow to define and relate different formal theories, which interact with each other by means of so-called *bridge rules*. On the other hand, LDS [Gab96] offer also an attractive approach to formalizing complex logical systems, since they allow to characterize the different components involved by using different sorts of *labels*. These two approaches complement each other (both of them are based on the idea of labeled formulas: in MCS, the labels denote *contexts*, whereas in LDS the label is a wff in a labeling language).

In recent work [PSJ98b] a MCS-based approach was developed for characterizing an argument-based agent architecture. In this setting, different contexts are used to represent different components of the agent. This approaches enforces a modular structure with well-defined interfaces, and thus accords well with good software engineering practice. Later work [SSPJ99] showed that actual implementations could be developed based on this formal model.

3. Ongoing research

Currently we are trying to relate existing research on argumentation in electronic institutions to SDE_{AR} , an LDS-based formal approach developed in [Che01]. SDE_{AR} provides a logical framework for modeling argumentative reasoning for a single agent.

One of our aims is to extend these ideas for a multi-agent setting, formalizing this situation under a dialogical framework as the one described in [NS96, ER+00]. We contend that a formalization of different kind of interactions among agents can be achieved by applying an LDS-based approach. Research in this direction is currently being pursued.

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