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Modelling dialogues in agent societies

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ABSTRACT

Besides the simpler ability to interact, open multi-agent systems must include mechanisms for their agents to reach *agreements* by taking into account their social context. Argumentation provides multi-agent systems with a framework that assures a rational communication, which allows agents to reach agreements when conflicts of opinion arise. In this paper, we present the dialogue protocol that agents of a case-based argumentation framework can use to interact when they engage in argumentation dialogues. The syntax and semantics of the argumentation protocol are formalised and discussed. To illustrate our proposal, we have applied the protocol in the context of a water market. By using our dialogue protocol, agents represent water users that are able to explore different water allocations and justify their views about what is the best water distribution in a certain environment.

1. Introduction

Large scale computer systems can be viewed in terms of the entities that participate in them, offering and consuming services (Luck and McBurney, 2008). Open Multi-Agent Systems (MAS), whose software agents are able to interact with each other to solve complex tasks and reach agreements as the outcome of their interactions, have proven to be a very appropriate paradigm to implement these types of systems (Huhns et al., 2005; Ossowski, 2013; del Val et al., 2014). Furthermore, argumentation theory provides MAS with a framework that assures rational communication and allows agents to reach agreements when conflicts of opinion arise. However, agents that use an argumentation framework to argue also need a protocol to communicate, to interchange their arguments, and to be able to reach agreements.

Considerable research has been performed on the design of artificial agent communication languages, such as the *Knowledge Query and Manipulation Language (KQML)*[1] from DARPA, and the *Agent Communications Language (FIPA ACL)*[2] from the IEEE Foundation for Intelligent Physical Agents. These languages provide agents with high flexibility of expression. However, in a dialogue, agents can have too many choices of what to utter in each step of the conversation. Therefore, this flexibility can also be an important downside if it gives rise to a state-space explosion and leads agents to engage in never-ending dialogues (McBurney and Parsons, 2009, Chapter 13).

A possible solution for this problem consists of limiting the allowed set of utterances for each step of the dialogue by defining the agent communication protocol by means of a *dialogue game* (Hamblin, 1970; MacKenzie, 1979). Dialogue games are a concept from argumentation theory and game theory that has been applied in MAS to structure the dialogue between agents with different points of view. Formal dialogue games are interactions among several players (agents in our case) where each player moves by making utterances in accordance with a defined set of rules. A wide range of approaches that formalise interaction protocols by using different dialogue games have been published (McBurney and Parsons, 2002a).

However, to our knowledge no research has been done to propose a dialogue game that is based on case-based knowledge resources that agents can use to manage agreement processes in agent societies. Reasoning with cases is especially suitable where there is a weak (or even unknown) domain theory, but acquiring examples encountered in practice is easy. Many argumentation models for MAS produce arguments by applying a set of inference rules (Amgoud et al., 2000; Augusto and Simari, 2001; Verheij, 2009). Rule-based systems require eliciting an explicit model of the domain (Prakken, 2010). In open MAS, the domain is highly dynamic and the set of rules that model it is difficult to specify in advance, even if these rules are domain-specific inference rules that are intended to represent domain knowledge. However, tracking the arguments that agents put forward in argumentation processes can be relatively simple. Therefore, these arguments can be stored as cases that are codified in a specific case representation language such that different agents are able to understand (e.g., an ontological language, Jurisica et al., 2004). This approach makes possible to develop case-bases reducing the knowledge-acquisition bottleneck. With case-bases, agents are able to perform

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[1] www.cs.umbc.edu/research/kqml/
[2] www.fipa.org/repository/aclspecs.html

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0952-1976/

lazy learning processes on argumentation information. For complex and highly dynamic systems, this is easier than using a rule-based system.

Another important problem with rule-based systems arises when the knowledge-base must be updated (e.g., adding new knowledge that can invalidate the validity of a rule). Updates involve checking the knowledge-base for conflicting or redundant rules. Case-based systems are easier to maintain than rule-based systems since, in the worst case, the addition of new cases can give rise to updates in some previous cases, but it does not affect the correct operation of the system, even though it can have an impact on its performance.

Therefore, in this paper, we present a dialogue game protocol that agents can use in a case-based argumentation framework to interact with each other when they engage in dialogues. This protocol includes a syntax as the set of defined locutions that agents can use to engage in argumentation processes, the combinatorial properties of locutions, and the rules that govern the dialogue. We also provide the *operational* semantics of the locutions. This semantics views each locution as a transition in an abstract state-machine that represents the possible stages that can be reached during the dialogue.

The structure of this paper is as follows: Section 2 introduces a running example that clarifies the type of problems that we want to solve with our argumentation approach; Section 3 briefly introduces our case-based argumentation framework for agent societies; Section 4 shows the syntax and operational semantics of the protocol and provides a discussion on its properties; Section 5 develops the running example in a dialogue among several agents in a water market that is controlled by our protocol; Section 6 analyses related work and compares it with our proposal; and Section 7 summarises the contents of this paper.

2. The water market scenario

As in human societies, agents in agent societies have a social context that can impose on them a set of norms to obey, a preference order regarding a set of values that agents can promote with their actions, and a set of dependency relations that link them. By the mere fact of belonging to a group, an agent may have to comply with the norms of the group or to act in a way that promotes the values that the group prefers. Similarly, an agent that is under contract with another agent to provide it with a service is committed to accepting requests from the contracting party that it might never accept otherwise. To clarify this point, let us assume a real scenario where the social context of agents has a decisive influence on the agents' behaviour.

The example scenario consists of a water market where a society *S* of agents that represent different users must reach an agreement over a water-right transfer. This scenario was introduced in the *mWater* prototype (Botti et al., 2009a, 2009b, 2010; Garrido et al., 2009). Fresh water will be the “gold” of the 21st century (Honey-Roses, 2007). Only 3% of the Earth's water is salt free. Of that 3%, approximately 2.7% is frozen in polar ice caps or deep underground. This leaves only 0.3% of all the water on the planet available for human use (Schneider, 1996). Water scarcity is especially problematic in dry climates such as the Mediterranean. Spain already suffers from severe water shortages (Honey-Roses, 2007; Panayotou, 2007). During the last few years, a dramatic change in the Spanish Water Law has given rise to many water problems. Spain needs to improve its water management in order to meet the needs of different types of users (e.g., farmers, cities, and private companies) and to deal with its severe water scarcity problems.

In this scenario, agents are users of a river basin that can buy or sell their water rights to other agents. A water right is a contract with the basin administration authority that specifies the rights that a user has over the water of the basin (e.g., the maximum volume that the user can use, the price that the user must pay for the water, or the district where the water right is located[3]). For instance, a particular water right could allow its holder to pump up to 10 m^3 of water per day during the next cotton season. It is possible to consider both the seller and the buyer as grouped entities (instead of having only one member playing the role of seller/buyer, a set of members may join together to participate in the market on a larger scale). For instance, a given seller has a water right of 2 m^3 per day, which is clearly insufficient for a buyer who needs 10 m^3 of water. If more sellers are grouped together it would be possible to have water rights to fit the requirement of the buyer, which analogously can be grouped in a larger buyer entity. Now, the stakeholders of this scenario will need to take into consideration the seller/buyer entity and model the interactions among the particular members of each entity.

Our domain scenario assumes that several users are arguing to reach an agreement over a water-right transfer. In this scenario, agents can play the following roles (Giret et al., 2010):

- *Water user*: A water-right holder of the basin, for instance, a farmer.
- *Buyer*: A water user who wants to transfer its right and or buy a transportation resource.
- Seller: A water user who wants to purchase rights and or sell a transportation resource.
- *Third party*: A water user who can be affected by a water-right transfer agreement.
- *Basin regulating authority (Basin Administrator)*: The Basin Administration representative who can authorise a water-right transfer agreement.
- *Jury*: The referee entity for problems among the contracting parties and (possibly) third parties of a water-right transfer agreement.

Let us propose a concrete example for this scenario, where two agents that play the role of buyers and represent farmers ($F1$ and $F2$) in a group (the river basin RB) are arguing to decide over a water-right transfer agreement that will grant an offered water right of a farmer $F3$ playing the role of seller to another farmer. Fig. 1 shows a graphical representation of this scenario.

Here, a basin administrator (BA) controls the process and makes a final decision. The behaviour of the basin is controlled by a certain set of norms N_{RB}. The society commands a charity (Ch) dependency relation between two water users (farmers) ($Farmer <_{Ch} Farmer$) and a power (Pow) dependency relation between an administrator (basin administrator), and a buyer (farmer) ($Farmer <_{Pow} BasinAdministrator$). A power relation of an agent over another agent establishes a hierarchy for them, committing the second agent to accept the orders and requests of the first agent. A charity relation establishes a relationship of equality between two agents. Farmers usually prefer to reach an agreement before taking legal action in order to avoid the intervention of a jury (J). Also, $F1$ prefers to improve its economy (EC) over the intervention of a jury and this intervention over promoting the solidarity between users (SO) ($SO < J < EC$). F 2 prefers solidarity over the intervention of a jury and this over economy ($EC < J < SO$). By default, BA adopts the value preference order of the basin (which promotes saving money in each transfer over

[3] Following the Spanish Water Law, a water right is always associated with a district.