Adaptive Agents in Argumentation-Based Negotiation

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Abstract. The paper presents a multi-agent system that comprises a society of self-interested agents that use argumentation-based negotiation to reach agreements regarding cooperation and goal satisfaction. The system is a generalization of some argumentation-based multi-agent systems proposed in the literature in which better cooperation agreements are reached through the use of human-like arguments. We then shows how this type of negotiation can be adapted according to evolved models of other agents in the system. Negotiation is performed using different types of arguments varying from quantitative ones, such as money or trade objects, to qualitative arguments, such as promises, appeal to past promises, and past examples. The models of the other agents are built and refined incrementally during negotiation; these models are then used to adapt the negotiation strategy according to other agents' desires, preferences and behavioral characteristics during interactions.

1 Introduction

In a multi-agent system, an agent exists and performs its activity in a society in which other agents exist and act. Therefore, coordination among agents is essential for achieving their goals and acting in a coherent manner, for both self-interested and collectively motivated agents. The paper presents a multi-agent system in which self-interested agents are aiming to reach agreements through argumentation-based negotiation while developing models of the other agents in the system. In this way, agents will be able to evolve their negotiation strategy and adapt themselves according past negotiation experiences.

The paper is organized as follows. Section 2 presents the agent model and the architecture of the multi-agent system we propose. Section 3 describes the communication and negotiation mechanisms, and the types of arguments that are used in negotiations. Section 4 describes how agents can adapt themselves by evolving models of other agents in the system, while Section 5 draws conclusions and traces directions for future work.

2 The Multi-agent System

The system comprises a society of self-interested agents that use argumentation-based negotiation to reach agreements regarding cooperation and goal satisfaction. The system is a generalization of some argumentation-based multi-agent systems proposed in the literature [2] in which better cooperation agreements are reached through the use of human-like arguments and considers how this type of negotiation can be adapted according to evolved models of other agents in the system. As opposed to the existing few such systems, our agents extend the possible types of argumentation so as to include both qualitative arguments, such as the ones proposed in [2] and arguments that are drawn from conventional negotiations based on costs and gain [1].

Each agent is endowed with a set of abilities or actions he is able to perform, has a set of desires, a set of beliefs about other agents (quite close to the BDI model), and has in its possession several physical objects and an amount of money. An agent's desire can be the execution of an action or the wish to posses a physical object. Each desire has its own preference, the main goal of an agent being to satisfy its most important desires. To satisfy its desires, an agent may need to persuade some other agents to give it an object or to perform an action on its behalf. Alternately, an agent may want to change the set of desires of some other agents in order to obtain the fulfillment of its own desires. Therefore, the agents can try to trade virtual objects which may be physical objects, actions performed on their behalf, desires of other agents, other agents' preferences, or money.

The system is open: an agent can enter or leave the system anytime and has no a priori information related to the state of other agents. A special agent, the facilitator, is responsible for keeping track of agents entering and leaving the system, of the public information that each agent declared about itself (some of the virtual objects it possesses), and of the market evolution, namely a history of the negotiated virtual objects and results of the corresponding negotiations (Fig. 1).

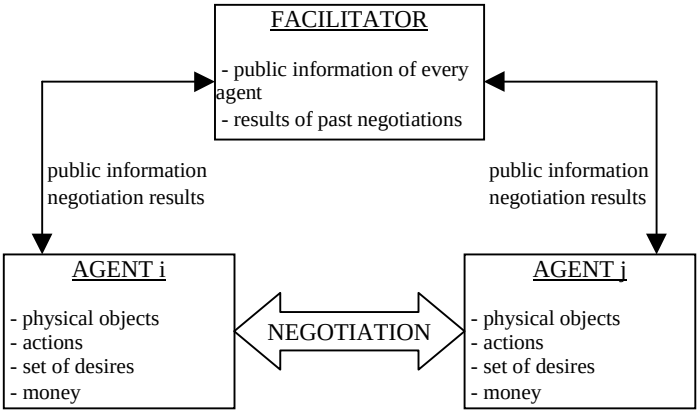

Fig. 1. The Multi Agent System

In each life cycle, an agent selects a desire to fulfil which represents its current goal. It may ask the facilitator about the agents able to satisfy its goal and then choose

one of them to negotiate with, or it can make this decision based on its own beliefs about the other agents in the system. It then negotiates with the selected agent and the negotiation result is sent to the facilitator, along with an updated list of public virtual objects.

For the time being, all information known by the facilitator is free so that each agent in the system may use it at its convenience. In a future development of the system, some of the facilitator information, e.g. negotiation history, will have an associated cost and agents will have to trade this information with the facilitator. This implies to endow the facilitator with a subset of agent negotiation capabilities.

3 Communication and Negotiation

Negotiation is an iterative process between two agents called the persuader and the persuadee, the first trying to convince the second to do one of the following: give a physical object, change its desires (or the preferences of some of them), perform an action on its behalf. This can be generalized by saying that the negotiation's objects are virtual objects.

The agents have a planning module, which allows them to build negotiation plans by choosing the arguments to use in a negotiation. As a result of interactions, an agent builds models of the agents with which it has negotiated. These models are updated after each completion of a negotiation and, sometimes, depending on the relevance of gathered information, also during one negotiation. In the latter case, the agents need to enter a re-planning phase during which the negotiation plan is updated according to the modified model of the other.

3.1 Communication Language

In order to negotiate, an agent must be able to communicate with the other agents in the system. One of the most influential agent communication languages is KQML [3], as it has been used in many systems and it has served as a model for other many agent languages, like the one in [1]. Our proposed system uses a KQML-type of language, but modified to allow the use of different types of arguments. We have assumed that every agent understands this language and that all agents have access at common argument ontology, so that the semantics of a message is the same for all agents.

The agents communicate using the following communication primitives:

Request(Source, Destination, Item, Argument).
Accept(Source, Destination).
Reject(Source, Destination, Motivation).
ModifyRequest(Source, Destination, Item, Argument, Motivation).
CloseNegotiation(Source, Destination, Motivation).

where:
- *Source* – is the agent sending the message;
- *Destination* – is the agent receiving the message;
- *Item* – is the virtual object of negotiation;
- *Argument* – is the argument proposed by an agent in exchange for *Item* (may be absent);
- *Motivation* is an optional explanation for a Reject or ModifyRequest message.

3.2 Argument Ontology

Negotiation is an intensively studied area in multi-agent systems, but most of the existing work focuses on cost-based negotiation, with little work emphasizing the use of arguments in negotiation. Several types of arguments have been proposed in [2], where argumentation is represented like an iterative process emerging from exchanges between agents to persuade each other and bring about changes in their intentions. The types of arguments used in [2] are the ones identified to be most commonly used in daily human interactions, like threats, promises, appeals to past promises, examples of similar situations or appeals to self-interest. We may call these arguments qualitative ones, to oppose them to what we consider being quantitative arguments, namely cost or money. In real life, good human negotiators may use both categories of arguments, qualitative and quantitative, as means to persuade or trade something with other humans. Our agents are using both categories of arguments, namely *Money* and *Trade*, and a subset of the qualitative arguments mentioned above: *Promises*, *Appeal to past promises* and *Past examples*, but in the future more arguments will be added.

For each of these types of arguments, there is a set of possible justifications to use in the *Reject* and *ModifyRequest* messages. For example, if the argument used by the persuader is a *Promise*, the persuadee can reply with a *Reject* message with no justification or a justification such as *don't trust you* or *not interested* (in the object of the promise).

If *Money* is used as an argument, the agent will propose to pay the negotiated virtual object with a certain the sum of money. The subject of the *Trade* argument is a physical object that the persuader offers for the required negotiation item or an action it is willing to perform provided it gets that item. The subject of a *Promise* argument is one of the persuadee's desires. The persuader "promises" that this desire will become one of its own. If an agent makes a promise to another agent, it is likely that the second agent will require the fulfillment of that promise, sometimes in the future. Therefore, the agents must have a memory of the past negotiations where to keep track their promises or to search past successful negotiations in order to use past examples as arguments.

An agent assigns a value to every physical object or action it cares about. This value is not measured in money, it represents instead how much that item worthies in the agent's opinion. For example, the value of an action represents how much it costs the agent to perform it. The agents are using the assigned values in order evaluate proposals received from other agents

3.3 Negotiation

The persuader chooses an argument by evaluating the presumed effect of that argument on the persuadee. The most accurate the model of the persuadee is, the most accurate is the evaluation. When receiving an argument, the persuadee has to evaluate it, considering both its current goal and its model of the persuader. If the evaluation results in a good enough value, the persuadee accepts the proposal, if not, it can make a counter-proposal or close the negotiation. The choice of arguments and responses to arguments is also affected by the agent desires to establish analogues of human notions such as credibility and reputation, during interactions with other agents in the system. The negotiation process between agent A and an agent B can be described as a state space, as shown in Fig. 2.

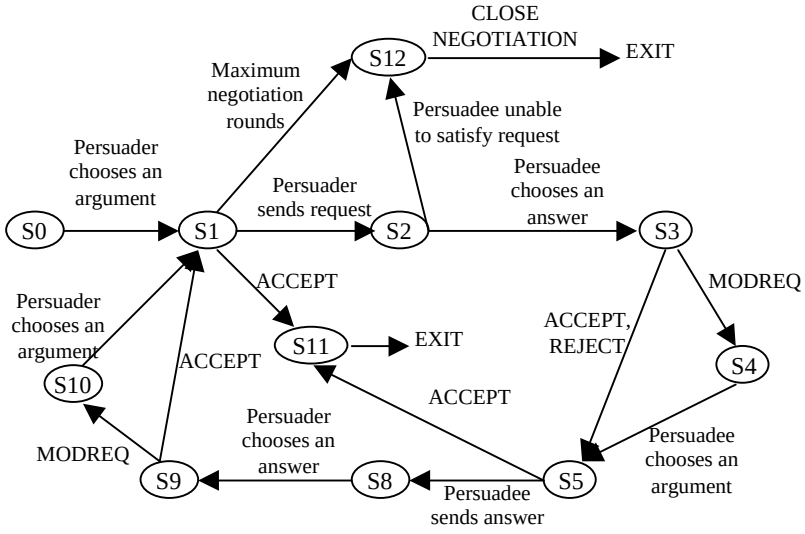

Fig. 2. The process of negotiation between two agents

In order to quantify the effect of a negotiation, we have introduced the notion of negotiation balance (NB), which is the ratio between the value of the item being negotiated and the value of the item being traded for it. Ideally, this rapport should be 1, meaning that the agent offers something with the same value in exchange, but in reality the persuader will try to raise the balance (the value of obtained item being bigger that the value of the given one), while the persuadee will try to lower it.

While evaluating an argument, the value of the NB is compared with some agent predefined values in order to make a decision. Examples of these values are the maximum limit of the NB for which the persuadee accepts the argument, the maximum limit of the NB for which the persuadee doesn't accept the argument but proposes a new one, the minimum limit of NB for which the persuader agrees with the argument, etc. These limits vary around 1 (the ideal value of the NB) depending on several parameters, e.g., how much an agent likes the other (*LAg*), how much an agent likes the type of the argument (*LArg*), or if there is a desire opposing that argument.

The value of some limit also depends of the type of the virtual object being negotiated: physical object, action, change of desire.

When the persuader has to choose an argument, it creates a list of possible arguments from which it will choose the one that minimizes NB for the persuadee, keeping its NB greater that the lower acceptance limit. When the persuadee will face the same choice, the criteria should change so that the argument will be in its area of acceptance and will maximize the negotiation balance for the persuader.

As both agents must have the possibility to choose a response and an associated argument at different moments of negotiation process, a set of rules has been proposed for developing negotiation plans. This set of rules takes in consideration various aspects like negotiation balance, characteristics of other agents, convincing power of the argument (Fig. 3).

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1. if it hasn't a desire for the object (action) offered
   then Reject(Not_Interested)
2. if its NB is less than the upper limit for acceptance
   and there is another object (action) X that would lower its
       NB, but it will not lower the persuader's NB
   then ModifyRequest(X, More_interested)
3. if its NB is less than the upper limit for acceptance
   then Accept
4. if its NB is less than the upper limit for new proposal
   and there is another object (action) X that would lower its
      NB
   then ModifyRequest(X, No_justification)
5. if its NB is less than the upper limit for new proposal
   then choose a new type of argument TA
   and ModifyRequest(TA)
6. if its NB is not less than the upper limit for new proposal
   then Reject.
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Fig. 3. Rules used to choose the answer if the argument received by the persuadee is a trade.

4 Adaptive Agents

An agent must build and refine models of other agents in order to obtain better results in negotiation. It can then use these models to adapt its negotiation to the other agent characteristics and to develop negotiation plans based on presumed reactions of these agents. The models are refined based on what the agent knows about past negotiations or on what it finds out during a particular negotiation. This includes the trace of its own previous negotiations or the results of negotiations performed by other agents in the past, which are accessible through the facilitator. The evolving models are based on the ideas of the "ideal modeling system" described in [4]. One important feature of the model is that it is built incrementally. Therefore, an agent doesn't always have to memorize all the acquired information about other agents, as this information will be used to refined the model only once. The proposed model an agent *X* develops to model an unknown agent *Y* includes several characteristics:

- how much *X* likes the other agent (*Y*);
- how much the agent *Y* likes different types of arguments;
- how much the agent *Y* wants/uses to keep its promises;
- the set of *Y*'s desires.

One important characteristic is the "what are the arguments preferred by another agent". Although a persuader has a preference for a certain argument, it may change this argument with another one if it believes that the persuadee prefers this other type of argument. It is possible that an agent will believe another agent likes an argument only because that agent has used it or has accepted this type of argument many times before. But this acceptance may be triggered by the fact that the other agent is adapting to this one too, thus a convergence of the proposed arguments may occur. This convergence may be avoided by developing 2-level modeling agents [5] that are building models of other agents as agents building simple models of the others. In this way, an agent is able to distinguish if another agent is using an argument because it really likes it or because it just believes it will have a greater impact on it.

In order to learn how wilingful an agent is to keep its promises, an agent must monitor the answers given by that agent at requests for past promises. When an agent evaluates a proposal of a *promise* from another, its behavior is strongly related to how much it trusts the other. Because an agent knows about other agents only what they have declared as public virtual objects, it is very important that it has information on the desires of others, helping it to evaluate more accurate the arguments received from them. An agent may have beliefs based on the model he has previously built about some virtual objects of another agent, even if this information was not declared as public. Then, it will change its behavior, adapting to what the other desires, in order to fulfil its goal.

5 Conclusions and Future Work

We have presented a multi-agent system in which agents are able to negotiate in order to satisfy their goals and desires. The system is open, the agents in the system are self-interested and are using argument-based negotiation to reach agreements regarding cooperation and goal satisfaction. Negotiation is performed using different types of arguments varying from quantitative ones, such as money or trade objects, to qualitative arguments, such as promises, appeal to past promises and past examples.

The basic contributions of this paper are the following: the objects being negotiated are virtual objects which may represent physical objects, actions performed on their behalf, desires of other agents, other agents' preferences, or money; the argument-based negotiations are covering both economic type negotiations and symbolic daily life ones; the agents are adapting their negotiation plans according to an evolved model of the other agents in the system. The current set of arguments proposed in this paper include some of the most relevant and frequently used arguments in human interactions. More arguments are to be considered, among them being threats, counter-examples and appeal to common interest. Also, a combination of arguments will be allowed, an agent being able to use a cumulation of two or more basic arguments to persuade another.

Another future extension is the investigation of how different planning strategies influence the negotiation performances. In particular, we are aiming to construct

agents that are building meta-negotiation plans based on the 2-level modeling. Alternately, an agent will be able to perform some fake negotiations to make the others evolve a false model of itself and then use this induced belief to obtain better results in future interactions. The 2-level modeling may detect such kind of false behavior.

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