Towards a Protocol for Negotiations about Exchange Values Involved in Multiagent Interactions

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Abstract

This article presents an argumentation protocol to support negotiations about the exchange values involved in interactions between agents of a multiagent system. The agents using the protocol argue about the values assigned to the services they perform to each other during the interaction. The argumentation-based negotiation protocol supplies a regulation tool that allows the agents to influence the temporal evolution of the social groups in which they participate, in the direction of either social equilibrium or social disequilibrium.

1 Introduction

In multiagent systems, negotiation is often considered to be essential for productive interaction, because it allows groups of agents to achieve better agreement regarding mutual beliefs, goals and plans.

To allow agents to influence each others point of view during the negotiation process, some form of argumentation dialogues has to be introduced in the negotiation protocol [Cogan *et al.*, 2005] [Amgoud and Prade, 2005] [McBurney *et al.*, 2003] [Parsons *et al.*, 2002].

In this paper, we define a negotiation protocol based on argumentation to allow agents to establish negotiations about the exchange values involved in the interactions between them. We show how agents can negotiate the exchange values involved in social exchanges.

We adopt Jean Piaget's [Piaget, 1973] theory, which follows the so-called *social exchanges* approach: an interaction is an exchange of services (actions and/or objects) between agents, such that the agents assign some values (called *exchange values*) to the actions and objects that they exchange during the interaction.

Exchange values have often an important function in interactions and in social systems in general. They constitute a regulation tool which the set of agents can use in an effort to guarantee the stability of their social interactions, because agents are assumed to tend to keep an interaction that they jointly evaluate positively. Exchange values can also be used in the agents' processes of social reasoning, helping them to select better partners for their interactions.

The article is organized as follows: In Section 2 the theory of exchange values by Piaget is summarized. Section 3 describes agents that need to negotiate exchange values. Negotiations about exchange values are introduced in Section 4. Section 5 presents the protocol for argumentation-based negotiation about exchange values. The conclusions and future works are presented in Section 6.

2 Theory of Exchange Values

The theory of Piaget [Piaget, 1973] studies and formalizes the dynamics of social interactions as a system of exchanges of services between agents. All services that an individual agent performs for others, or which it receives from others, constitute values for him, either costs or benefits.

Such values can generate debts (obligations to perform new services in compensation for previously received services) and credits (rights to demand the realization of a new service in compensation for services previously executed).

Exchanges can, thus, be understood from two different points of view. On one side, exchanges are related to the objectives of the individuals and/or of the society as a whole. On the other side, exchanges involve investments, benefits and profits of many different kinds of elements (time, money, emotions, etc.) not all amenable to a quantitative evaluation.

For each one of these points of view, it is possible to assign a different type of value, resulting from the evaluation of the exchange: final values or performance values. Final values (or goal values) are associated with the exchanges to represent their contribution to the accomplishment of the objectives of the individuals and/or the society. Performance values are assigned to exchanges to represent the variation in their motivational and affective aspects.

In the latter sense, a value is the result of a qualitative mental evaluation of the elements involved in interactions (e.g., actions, emotions, objectives, etc.). Each resultant value is mentally associated with one of these elements and its assessment can, therefore, influence the behavior of the individual in relation to the interactions.

Complete exchanges between individuals occur involving two kinds of stages. The first kind of stage consists of four steps: i) α performs a service on behalf of β and associates with this action an *investment* value $r_{\alpha\beta}$; ii) β expresses his satisfaction with the received action associating to it a *satisfaction* value $s_{\beta\alpha}$; iii) β acknowledges the value of the re-

ceived action by acknowledging the *debt* value $t_{\beta\alpha}$; and iv) α feels (personally or socially) valued with the acknowledgment of β and associates to it a *credit* value $v_{\alpha\beta}$.

Later on, α can charge his credit with β by requesting that β performs some service in return, a service that benefits α. This gives rise to the second kind of stages: i) α requests that β performs an action on behalf of α, based on the *credit* $v_{\alpha\beta}$ it has in relation to β; ii) β acknowledges the *debt* $t_{\beta\alpha}$; iii) β performs a service with an *investment* value $r_{\beta\alpha}$; and iv) α acknowledges his *satisfaction* $s_{\alpha\beta}$ with the service performed by β.

Piaget observes that situations in *disequilibrium* can occur at any point of an exchange, and for various reasons. For example, when the investment of α is greater than the satisfaction of β, or when β does not recognize the whole value of the work of α (for further details, see [Ribeiro *et al.*, 2003] [Dimuro *et al.*, 2005]).

The values involved in an exchange process are classified in two types: *material values* and *virtual values*. In stages of the kind $I_{\alpha\beta}$, the material values occur at moments (i) e (ii), while the virtual values occur at moments (iii) e (iv).

Definitions of the theory of exchange values, briefly described in this section, are used in the argumentation-based negotiation protocol that we proposed, in order to show how agents can negotiate the exchange values.

We note that material exchange values are not a kind of utility values: they do not serve the purpose of deciding between two alternative actions yet to be performed. On the contrary, material exchange values just register the costs and benefits of services already performed, and that were chosen to be performed for whatever reason. Virtual values, too, although referring to future services, just register the costs and benefits that such services will have to have when and if performed, but they do not serve the purpose of helping agents to decide if such services should effectively be performed. The utility values that may help the decision on the realization or not of a service, may take exchange values (or, better, their balances) into account, but are clearly of a different nature then the exchange values themselves.

3 Agents that Negotiate Exchange Values

The agents involved in negotiations about exchange values need to have a special structure. At each time, each agent needs the following databases (components of Σ):

- Beliefs Base: $Bel \subseteq L$
- Values Base: $V \subseteq V_r \times V_s \times V_t \times V_v$, where
  $V_r = \{r_1, r_2, ..., r_n\}$, $V_s = \{s_1, s_2, ..., s_n\}$,
  $V_t = \{t_1, t_2, ..., t_n\}$ and $V_v = \{v_1, v_2, ..., v_n\}$
- Preferences Base:
  $Prf = (V_r, \prec_r) \cup (V_s, \prec_s) \cup (V_t, \prec_t) \cup (V_v, \prec_v)$
- Obligations Base: $Ob \subseteq L$
- Goals Base: $Gls \subseteq L$
- Plans Base: Pln

The *beliefs base* (Bel) of each agent is composed by the information related to the environment and to other agents inserted in the environment. As each interaction occurs (exchange of service or negotiation) these beliefs can be modified.

The *values base* (V) records the material values assigned to each action received or performed by the agent, along with the virtual values generated in connection to them. These values can be modified by the agent in accordance with the results of the negotiation, by the strength of the arguments. But they are assumed to be private to the agents, so that the only way an agent has to have access to the values base of another agent is by the latter communicating such information to the former.

The *preferences base* (Prf) contains the preferences of the agents with respect to the values that may appear in an exchange. So, the preferences base implements the *scale of values* required from each agent by Piaget (see [Piaget, 1973], for further information).

In the *obligations base* (Ob) are stored the obligations of the agents of making future actions that benefit other agents who had previously made services to it.

The *objectives base* (Obj) is formed by the individual objectives of each agent.

In the *plans base* (Pln), the agents plan their future actions (delegation of actions, formation of coalitions, etc.). We leave open the structure of such plans.

In our model, the agents have a *common knowledge base* about the exchange process. That is, they all know the costs of the performed services and the values of satisfaction that the services generated for the agents that received them.

Following [Parsons *et al.*, 2002], we assume that agents involved in the exchange values process may have different personalities[1], inducing different *attitudes* towards either the *assertion of propositions* or the *acceptance of propositions*.

We take that agents must present one of three attitudes towards the assertion of an argument (*assertion attitudes*): liar, confident or cautious. A *liar* agent makes assertions and delivers supports for them without any concern about their truth. A *confident agent* is able to assert a proposition p whenever it can build an argument (S, p) that supports it. A *cautious agent* is able to assert a proposition p whenever it can build an argument (S, p) for it, and the agent can verify that such argument is acceptable[2].

Also, we take that agents must present one of two attitudes towards the acceptance of an argument (*acceptance attitudes*): credulous or skeptical. A *credulous agent* accepts any proposition p whenever there is an argument (S, p) that supports it. A *skeptical agent* accepts a proposition p only if there is an argument (S, p) that supports it, and the agent can verify that such argument is acceptable.

4 Negotiations about Exchange Values

During the exchange process, the agents can argue about the values assigned to the performed and received services. The

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[1] Among some related works about personalities of agents are: [Castelfranchi *et al.*, 1998] [Talman *et al.*, 2005] [Dimuro and Costa, 2006]

[2] An acceptable argument is one that can't be undercut by the opponent – for further information, see [Parsons *et al.*, 2003]

agents argue with the intention to influence each other about the assignment of the *material values* $(r_{\alpha\beta}, s_{\beta\alpha})$ and *virtual values* $(t_{\beta\alpha}, v_{\alpha\beta})$ involved in the exchange.

Agents argue by the exchange values by exchanging arguments about such values. In connection to exchange stages of the kind $I_{\alpha\beta}$, the exchange of arguments can occur in four moments during the stage and at one moment after the stage finished.

- The four moments during the stage $I_{\alpha\beta}$ at which the *exchange of arguments* can occur are:

  1. $Dialogue_1$: After agent α performed a service to agent β and before β assigned a value to received service. The dialogue occurs to allow the agents to establish a consensus about the cost (investment) to be assigned to the service performed by α.

  2. $Dialogue_2$: After β used the service performed by α and before β assigned a value to the received service. The dialogue occurs to allow the agents to establish a consensus about the value of satisfaction to be assigned by β to the received service.

  3. $Dialogue_3$: After β assigned a satisfaction value to the received service and before β assigned an acknowledgment value. The dialogue occurs to allow the agents to establish a consensus about the value of acknowledgment to be assigned by β for the received service.

  4. $Dialogue_4$: After β assigned an acknowledgment value for the serviced received and before α assigned a credit value for the service it performed. The dialogue occurs to allow the agents to achieve a consensus about the value of credit to be assigned by α for having performed the service to β.

- At the moment after stage $I_{\alpha\beta}$ finished:

  If one of the agents, after the stage of exchange, is not satisfied with the balance of the exchange (so that it is not satisfied with one or more of the values assigned to the service – investment value and debt), the agents can start to negotiate again, arguing about the proportion between the values assigned.

During the negotiation each involved agent propose to the other the value that it would like to establish.

If, during this process, the agents do not achieve a consensus, a decision rule is used. The negotiation finishes after they achieve a consensus or after applying the decision rule.

The simplest decision rule is to allow the agents to drop out of the dialogue if consensus is not achieved after a certain time or number of argument exchanges, and assign values independently of each other.

The negotiation during the stage $I_{\alpha\beta}$ may lead the agents to achieve an agreement that satisfies both of them. Such possibility may allow the society (group formed by the involved agents in the exchange) to remain operational, through the continued interaction of agents.

The conditions for an equilibrated exchange are as follows. First, the cost of the service should be equal to the satisfaction value ($r_{\alpha\beta} = s_{\beta\alpha}$). In case these values are equal, it can be

concluded that the material values are in equilibrium. If the acknowledgment and credit values are equal ($t_{\beta\alpha} = v_{\alpha\beta}$), the virtual values are in equilibrium. This is formalized as follows[3]:

$$(r_{\alpha\beta} = s_{\beta\alpha}) \wedge (s_{\beta\alpha} = t_{\beta\alpha}) \wedge (t_{\beta\alpha} = v_{\alpha\beta}) \wedge (v_{\alpha\beta} = r_{\alpha\beta})$$

In case the group is in disequilibrium, the injured agents may not want to exchange services with their usual partners anymore, and may start to look for new partners, thus raising risks for the integrity of the group.

5 A Model for Argumentation-based Negotiations about Exchange Values

Any negotiation of exchange value between agents follows the model proposed here by occurring through one of the types of argumentation protocols (defined below).

The proposed model presents four types of argumentation protocols, according to the different argumentation personalities of the involved agents. The definition of the argumentation protocols was strongly influenced by the protocol initially presented by [Parsons *et al.*, 2003] and extended by [Cogan *et al.*, 2005].

Each argumentation protocol is mainly based on the Persuasion Dialogue of [Walton and Krabbe, 1995], where an agent tries to convince another agent to accept a particular argument. Each agent has a data base Σ, which contains formulas of a propositional language L. In the formalization, $\vdash$ stands for classical inference and $\equiv$ for logical equivalence. The agents argue in accordance with the information stored in their knowledge base Σ.

The protocols are defined considering the following notation:

$$\text{sender, receiver } assert(S, p) \quad \equiv \quad \begin{array}{l} \text{sender } assert(p) \\ \text{receiver } request(S) \\ \text{sender } assert(S) \end{array}$$

where, an argument is a pair $A = (S, p)$ where p is a formula of L and S a consistent subset of Σ such that $S \vdash p$; and no proper subset of S does so. S is called the support of A, written $S = Support(A)$ and p is the conclusion of A, written $p = Conclusion(A)$. We also write $S = support(p)$, when A is obvious in the context (for further information, see [Parsons *et al.*, 2003]).

Protocol 1 considers that the agent asserting the argument is either a *liar* or *confident* to assert it, and that the agent receiving the argument is *credulous*. The *sender agent* asserts an argument (S, p), either because the argument is valid [4] (and agent is confident and has determined that $S \vdash p$) or because the argument is invalid (and the agent is lying). The *receiver agent* tries to verify if $S \vdash p$. If the receiver finds that p is supported by S, it accepts the argument asserted by sender.

Protocol 2 considers that the agents involved in the exchange are either *liars* or *confident* to assert an argument, and

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[3]Similar conditions apply to exchange stages of the kind $II_{\alpha\beta}$ (not looked at in this paper, see [Piaget, 1973] [Dimuro *et al.*, 2005] [Ribeiro *et al.*, 2003])

[4]An argument is valid if $S \vdash p$.

skeptical to accept. The *sender agent* asserts an argument (S, p). The *receiver agent* verifies whether $S \vdash p$. If false, the receiver agent rejects the argument. If true, it tries to see if the argument is acceptable. To each $s \in S$ the receiver agent accepts it or questions it (based on its beliefs base). If the receiver agent accepts all $s \in S$, the receiver accepts the proposition p asserted by the sender. Otherwise, the receiver agent rejects it.

Protocol 1:
sender, receiver $assert(S, p)$
receiver $verify(S \vdash p)$
    if *true*
        receiver *accept*
    else
        receiver *reject*

Protocol 2:
sender, receiver $assert(S, p)$
receiver $verify(S \vdash p)$
    if *true*
        if $\forall s \in S$: receiver $accept(s)$
            receiver $accept(p)$
        else
            receiver $reject(p)$
    else
        receiver $reject(p)$

Protocol 3 considers that the agents involved in the exchange are *cautious* to assert an argument and *credulous* to accept it. The *sender agent* asserts a support S. The *receiver agent* questions (cautiously) each $s \in S$. If the receiver accepts all $s \in S$ (i.e., if receiver accepts S), sender asserts p. Then, receiver verifies whether $S \vdash p$. If true, receiver accepts p. Otherwise, receiver rejects p. Questioning s means requesting a support S' for s, verifying that $S' \vdash s$ and, if that is true accepting s, otherwise rejecting s.

Protocol 4 considers that the agents involved in the exchange are *cautious* to assert an argument and *skeptical* to accept it. The *sender agent* asserts a support S. The receiver agent (skeptically) questions each $s \in S$. If receiver accepts each $s \in S$, the sender asserts p. The receiver, then, verifies whether $S \vdash p$. If true, the receiver accepts p. Otherwise, the receiver rejects p.

Of course, the potential infinite recursion made possible by an agent being infinitely skeptic should be controlled.

The dialogues do not guarantee that the process of exchange finish in equilibrium, because α and β may not come to a consensus about the costs and satisfactions of the exchanged services, and thus may end by assigning values that do not agree with each other.

6   Conclusion

The argumentation in the proposed model makes possible that the agents argue about the performed services and thus that they may influence each other in the establishment of the exchange values involved in the service exchanges.

Protocol 3:
sender $assert(S)$
$\forall s \in S$: receiver, sender $cautquestion(s)$
if $\forall s \in S$: receiver $accept(s)$
    sender $assert(p)$
    receiver $verify(S \vdash p)$
        if *true*
            receiver $accept(p)$
        else
            receiver $reject(p)$

where:
receiver, sender $cautquestion(s) \equiv$
    receiver $request(support(s))$
        if sender $assert(S')$
            receiver $verify(S' \vdash s)$
                if *true*
                    receiver $accept(s)$
                else
                    receiver $reject(s)$
        else receiver $reject(s)$

Protocol 4:
sender $assert(S)$
$\forall s \in S$: receiver, sender $skepquestion(s)$
if $\forall s \in S$: receiver $accept(s)$
    sender $assert(p)$
    receiver $verify(S \vdash p)$
        if *true*
            receiver $accept(p)$
        else
            receiver $reject(p)$

where:
receiver, sender $skepquestion(s) \equiv$
    receiver $request(support(s))$
        if sender $assert(S')$
            receiver $verify(S' \vdash s)$
                if *true*
                receiver, sender $skepquestion(s)$
                if *true*
                    receiver $accept(s)$
                else
                    receiver $reject(s)$
            else
                receiver $reject(s)$
        else receiver $reject(s)$

Negotiations about exchange values allow the agents to have a higher level of certainty when deciding to continue or discontinue some interaction (because it is becoming less profitable then expected).

The history of the exchanges performed with other agents may help an agent to decide which partners to choose at each moment. The more such exchanges were discussed between the agents, the more confidence an agent may have while choosing one such partner.

For future work, we plan: 1) the systematic exploration of

the proposed model in situations where various agents with different exchange personalities interact; and 2) the definition of an on-line version of the presented protocol (will allow the agents to negotiate about the exchange values involved in a service while the service is being performed).

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