Argumentation about Exchanges Values in Multiagent Systems and Collaborative Environments

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Abstract. *This article shows how dialogue protocols can be used to support argumentation about the exchange values that may be involved in interactions that occur between agents, human or artificial. In consequence, the agents become able to influence each other's assignment of values to the results of interactions, and such valuative process becomes much more liable to be influenced by issues such as emotions and social power, which may arise between agents during their social lives.*

1. Introduction

An increasing number of computational systems has appeared in terms of interactions between autonomous agents. These agents have abilities to decide: i) which objectives must adopt; ii) which actions must be performed to reach determined objectives and; iii) when they must be performed.

In multiagent systems, the agents many times have different objectives to achieve. However, they are not always able to make a particular action to achieve their objectives. Thus, negotiation become fundamental in the interactions, allowing that groups of agents achieve an agreement regarding their mental attitudes .

In the approaches to negotiation based on argumentation [Sierra et al. 1997], [Kraus 2001], [McBurney et al. 2003], [Parsons et al. 2003b], [Rahwan et al. 2004], [Cogan et al. 2005], and [Franco and Costa 2007], an agent is allowed to argue with other agents about their beliefs and other mental attitudes, during the negotiation, with the intention to persuade the other agents of its own opinions.

We focus in this paper on the particular role that persuasive dialogues may have in social interactions. Concerning social interactions, we adopt Piaget's theory [Piaget 1995] of social relations, 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.

In the dialogues that they may establish during an exchange, the agents may argue about the realism of the values each other assigned to the services they exchanged. They may also present different personality traces at the moment they affirm or accept the various arguments. Such traces of personality and the strengths of the arguments can, thus, influence in the assignment of values to the services.

In this paper, we define dialogue protocols based on argumentation to allow agents to establish a consensus about the exchange values involved in the interactions between them through a persuasion process. We also show that the proposed model allows the agents to verify whether the exchanges occurred in an equilibrated way.

This paper is organized as follows. In Section 2 the Piaget's theory is summarized. Dialogues and argumentation are presented in Section 3. In Section 4 are presented: the definition of the model of service, the components of agents and its personalities, argumentation about exchange values, conditions for an equilibrated exchange, and the dialogue protocols. The conclusions and future work are presented in Section 5.

2. Theory of Exchange Values

The Piaget's theory [Piaget 1995] studies and formalizes the dynamics of social interactions as a system of exchanges of services between individuals (agents). All services that an individual 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 (e.g., time, money, emotions, etc) not all amenable to a quantitative evaluation.

Complete exchanges between individuals occur involving two kinds of stages. The first kind of stage - $I_{\alpha\beta}$ - consists of four steps:

i) α performs a service on behalf of β and associates with this action an *investment* (or renouncement) value $r_{\alpha\beta}$;
ii) β recognizes his satisfaction with the received action associating to it a *satisfaction* value $s_{\beta\alpha}$;
iii) β acknowledges the value of the received action by acknowledging the *debt* value $t_{\beta\alpha}$;
iv) α feels (personally or socially) valued with the realization of the service (and, possibly, with the acknowledgment of β) and associates to it a *credit* value $v_{\alpha\beta}$.

Later on, α can charge β for the credit which it accumulated, requesting that β performs some service in return, a service that benefits α. This gives rise to the second kind of stage - $II_{\alpha\beta}$:

i) α requests that β performs a return 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 $r_{\beta\alpha}$;
iv) α acknowledges his *satisfaction* $s_{\alpha\beta}$ with the service performed by β.

Piaget observes that situations in *disequilibrium* can occur during 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 (see [Piaget 1995], [Ribeiro et al. 2003] and [Dimuro et al. 2005], for further details).

The values involved in an exchange process are classified in two types: *material values* - values resulting from the evaluation of the real actions occurring during the interaction, and *virtual values* - values corresponding to debits and credits that are to be turned into material values in future interactions. The *material values* occur at moments (i) and (ii) in $I_{\alpha\beta}$, (iii) and (iv) in $II_{\alpha\beta}$, while the *virtual values* occur at moments (iii) and (iv) in $I_{\alpha\beta}$, (i) and (ii) in $II_{\alpha\beta}$.

We note that *exchange values* are not a kind of *utility values*: they do not serve the purpose of helping to choose between two alternative actions yet to be performed. They may be used in such way (see, e.g. [Ribeiro and Luck 2006]), but that is not their basic purpose. *Material values*, for instance, 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 which of the various 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. Dialogues and Argumentation

In approach based on argumentation [Sierra et al. 1997], [Kraus 2001] and [Rahwan et al. 2004], an agent is allowed to "argue" with other agents about their beliefs and other mental attitudes, with the intention to convince the other agents of its own opinions. Thus, the agents need to engage themselves in dialogues, in order to negotiate on the basis of argumentations.

Dialogues between agents have been the focus of study of diverse works [McBurney and Parsons 2002], [McBurney et al. 2003], [Parsons et al. 2003b], [Parsons et al. 2005], [Amgoud and Prade 2005] and [Franco and Costa 2007], mostly under the influence of [Walton and Krabbe 1995], who suggests six basic forms of dialogues, which can be variously combined: i) *Information Seeking Dialogue*: where one agent seeks the answer to some question(s), and interacts with another agent because it believes that the latter knows the answer(s); ii) *Inquiry Dialogue*: where agents collaborate to answer some question(s) whose answers are not known to any one of them; iii) *Persuasion Dialogue*: where one agent seeks to persuade another agent to adopt a belief or point-of-view that the latter does not currently hold; iv) *Negotiation Dialogue*: where the agents bargain over the division of some scarce resource; v) *Deliberation Dialogue*:

where agents collaborate to decide what course of action to take; and vi) *Eristic Dialogue*: where agents quarrel verbally as a substitute for physical fighting.

In [Parsons et al. 2003b] a formal system is presented for argumentation-based dialogues, where each agent involved in a dialogue 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.

Following [Parsons et al. 2003b], an argument is a pair $A = (H, h)$ where h is a formula of L and H a consistent subset of Σ such that $H \vdash h$; and no proper subset of H does so. H is called the support of A, written $H = Support(A)$ and h is the conclusion of A, written $h = Conclusion(A)$. We also write $H = support(h)$, when A is known.

In the formal system, two arguments may conflict. More precisely an argument may undercut another argument, where argument A_1 undercuts A_2 iff $\exists h \in Support(A_2)$ such that $Conclusion(A_1) \equiv \neg h$. A set of arguments H defends an argument A iff for each argument B that undercuts A, there is an argument in H that undercuts B.

An *acceptable argument* A is one that is not undercut, or for which there is an acceptable argument that undercuts each of the arguments that have been presented to undercut A. For further details, see [Parsons et al. 2003b] and [Cogan et al. 2005].

Dialogues are assumed to take place between two agents, α and β. Each agent has a knowledge base, Σ_α and Σ_β respectively, containing their beliefs. Each agent has a further knowledge base, accessible to both agents, containing commitments made in the dialogue.

For each move in a dialogue, the player that makes the move addresses the move to the other player. Each move involves a locution of one of the following kinds: i) $assert(p)$, where p is either a propositional formula or the special character U, which indicates that an agent cannot give a reply; ii) $assert(S)$, where S is a set of formulas representing the support of an argument[1]; iii) $accept(p)$, where p is a propositional formula; and iv) $accept(S)$, where S is a set of propositional formulas[2].

4. Proposed Model

In this section, we are going to present our proposed model for argumentation about exchange values, and some basic definitions that are necessary for understanding the model.

4.1. A Model of Service to Support Service Evaluations

Exchange values arise initially as the results of evaluations of services. We adopt [Almquist 1992] as our basis for the model of service that supports the task of service evaluations.

A *service* is a made "action". Each service is classified in: *gold* - high importance, *silver* - medium importance, or *bronze* - low importance. Services present attributes and parameters. The considered attributes are: *maximum*, *medium* and *minimum*. The parameters are: *time* - time to perform a service, and *quality* - whether the requested service

[1] An argument (H, h) can be asserted as a whole by a sequence of two assertions, $assert(H)$ and $assert(h)$.

[2] In [Cogan et al. 2005] and [Parsons et al. 2003b] other kinds of locutions are defined.

has been made completely. Type, attributes and parameters are defined as "*Quality of Service*" (QoS).

Each agent involved in the exchange defines the QoS that it wants of the service to be performed. During the realization of the service, the agents respectively assign values to the service actually performed and actually received, considering as a reference for such evaluation the terms stated in the QoS that they established.

The agents have a *scale of values* [Piaget 1995] formed by a set of elements. These elements are fundamental to agents to calculate the values that will be assigned to the services, calculated from the defined and the observed QoS. The elements that compose the *scale of values* are: i) the aspects of QoS that are evaluated - *type*, *time* and *quality*; ii) the values assignable to each aspect of QoS - *maximum = 3*, *medium = 2* and *minimum = 1*; and iii) the *weight* assigned to each aspect - 0 to 10.

The agents are assumed to use the same *scale of values* to calculate the values to be assigned to the performed and received services, but the importance (weight) given to the factors is subjective (each agent weights the factors in a different way, using different weights).

The the final value of a performed or received service is given by the equation:

$$\frac{((weight*value\_type)+(weight*value\_time)+(weight*value\_quality))}{TotalWeightSum} = Value$$

For example, β requests to the agent α the service of revising an article. The agent α assigns the cost value to the performed service considering: "type = 3" and "weight = 9", "time = 2" and "weight = 8", and "quality = 3" and "weight = 5". In this case, α assigns "type = 3", because α knows that β considers the service of the "type gold" and assigns "weight = 9", since α considers the "type" as being of great importance. The agent α considers that it spent an "average time" to perform the service "time = 2" and assigns "weight = 8", because α considers very important the "time". The agent α believes that the service was performed completely "quality = 3" and assigns "weight = 5" considering "quality" as not very important. The cost value assigned by α is[3]: $\frac{((9*3)+(8*2)+(5*3))}{30} = 1.94$

The *scale of values* allows the agent who requested the service to verify whether what was executed by the performer agent (observed QoS) is equal or not what was established (contracted).

4.2. Components of Agents

The agents involved in argumentation 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 Set: $V \subseteq V_r \times V_s \times V_t \times V_v$, 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 Set: $Prf = (V_r, \prec_r) \cup (V_s, \prec_s) \cup (V_t, \prec_t) \cup (V_v, \prec_v)$
- Obligations Set: $Ob \subseteq L$
- Goals Set: $Gls \subseteq L$

[3] An analogous calculus is also made by β to calculate the satisfaction and acknowledgment values.

- Plans Set: $Pln \subseteq L$

The *Beliefs Base* is composed by the information related to the environment and to other agents inserted in the environment. As each interaction occurs these beliefs can be modified. The *Values Set* 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 in accordance with the results of the argumentation process.

The *Preferences Set* contains the preferences of the agents with respect to the values that may appear in an exchange. In the *Obligations Set* are stored the obligations of the agents of making future actions that benefit other agents who had previously made services to it.

The *Objectives Set* is formed by the individual objectives of each agent. In the *Plans Set*, the agents plan their future actions (e.g., 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.

4.3. Personalities and Attitudes of Agents

Following [Parsons et al. 2003a], we assume that agents may have different personality traces, 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 (can not be undercut).

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.

The agents may also present different attitudes in the moment of assigning values to an exchange. Some of the attitudes we use in our model are based on [Dimuro et al. 2006]. Thus, during the exchange, in the moments that the agents calculate the acknowledgement and credit values, they may present one of the following attitudes: *egoism*, *altruism* and *realism*.

An *egoist* agent is always searching its own benefit. An egoist agent that receives a service calculates an acknowledgement value lower than the value that really represents for it. An egoist agent that performs a service assigns a credit value higher than the cost of performed service.

An *altruist* agent is always looking for the benefit of another agent. An altruist receiver agent assigns an acknowledgment value higher than the service represents, caus-

ing the benefit of the service performer agent. An altruist service performer agent, in the moment of express the credit value, assigns a lower value, to benefit the receiver agent that will have a lower debt with the performer agent.

A *realistic* agent assigns an acknowledgement value that is fair in relation to the benefits that the performed service really caused to it. On the other hand, a realistic performer agent expresses a value referring to how much the service really costed to it.

4.4. Argumentation about Exchange Values

During the exchange process, the agents can argue about the values assigned to the performed and received services. The 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 about 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 satisfaction value 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 acknowledgment value 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 credit value 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 equilibrium 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 persuade again, arguing about the proportion between the values assigned.

During the exchange each involved agent proposes 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 *decision rule* allows the agents to drop out of the dialogue if consensus is not achieved after a certain time or number of argument exchanges. The argumentation finishes after they achieve a consensus or after applying the decision rule.

The argumentation during the exchange may lead the agents to achieve an agreement that satisfies both of them. Such possibility allows the society (group formed by the agents involved in the exchange) to remain operational, through the continued interaction of agents.

4.5. Verifying Equilibrium

The conditions for an equilibrated exchange are formalized as follows:

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

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

It is fundamental that the credit value acquired for α ($v_{\alpha\beta}$) in stage $I_{\alpha\beta}$ is in equilibrium with the credit value charged for it ($v_{\alpha\beta}$) in stage $II_{\alpha\beta}$ - ($v_{I_{\alpha\beta}} = v_{II_{\alpha\beta}}$). The credit values will be argued in the beginning of stage $II_{\alpha\beta}$ for α and β, when they initiated the persuasion process with the objective to achieve an agreement about the credit and acknowledgment values.

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.

4.6. Dialogue Protocols

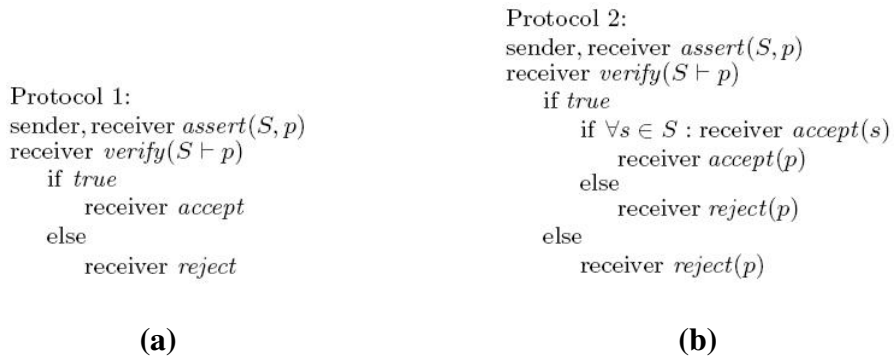
The proposed model presents four types of protocols (defined below), according to the different argumentation personalities of the involved agents. The definition of the protocols was strongly influenced by the protocol initially presented by [Parsons et al. 2003b] and extended by [Cogan et al. 2005].

Each argumentation protocol is mainly based on the *persuasion dialogue* [Walton and Krabbe 1995], where an agent tries to convince another agent to accept a particular argument. The agents argue in accordance with the information stored in their knowledge base Σ.

Protocol 1 (Figure 1a) 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 invalid (and the agent is lying) or because the argument is valid (and agent is confident and determined that $S \vdash p$). 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 (Figure 1b) considers that the agents involved in the exchange are either *liars* or *confident* to assert an argument, and *skeptical* to accept. The *sender agent* asserts an (valid or invalid) 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 3 (Figure 2a) 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 $s \in S$

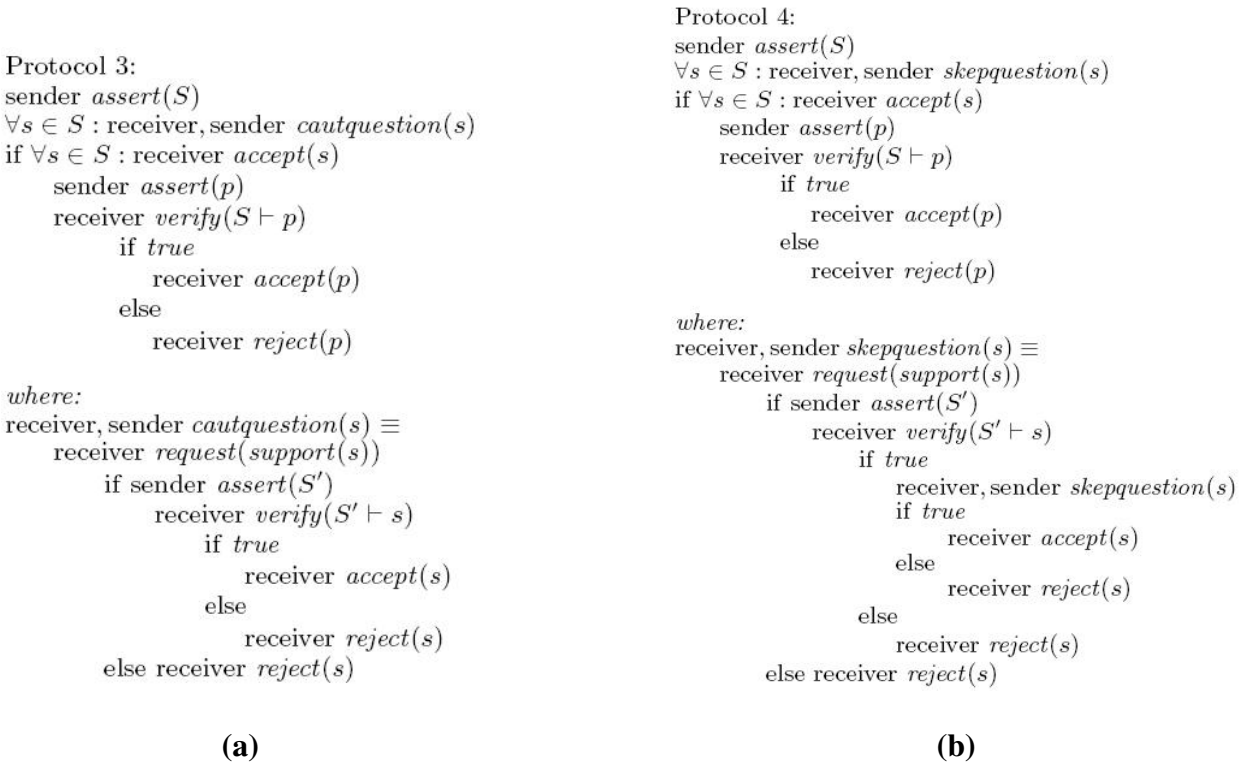


(a) **(b)**

Figure 1. Protocol 1 and Protocol 2

(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.

Protocol 4 (Figure 2b) 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.



(a) **(b)**

Figure 2. Protocol 3 and Protocol 4

Of course, the potential infinite recursion made possible by an agent being in-

finitely skeptic should be controlled.

For subjective reasons, the agents will can disagree about the cost, satisfaction, acknowledgment and credit values and will not reach consensus about equilibrium (even when there is equilibrium and objective calculations converge to a single value).

5. Conclusions and Future Work

This article proposed a model of dialogue protocols, concerned with the support for argumentation about the exchange values involved in the interactions between agents.

The model allows the agents to argue about the values involved in the exchange, allowing that they influence each other mental attitudes towards such exchange values and also allowing them reach a consensus about the values.

Argumentation about exchange values seem to have two main applications: i) 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); and ii) interactions with other agents may help an agent to decide which partners to choose at each moment.

The model supplies a social regulation tool that allows that the agents verify whether the exchange occurred in an equilibrated way, allowing the agents to choose with which social group they will interact and who will be their future partners.

Of course, the protocols would be to strict to be applied in case of argumentations between human agents in a collaborative environments, but some kind of protocol similar to the ones we presented seem mandatory if the argumentation is to involve artificial agents, besides human ones.

As future work, we plan: i) the definition of an on-line version of the presented protocol, which will allow the agents to negotiate and argumentation about the exchange values involved in a service while the service is being performed; ii) the analysis of the influence of the social power about the decisions of the agents; iii) the influence of the emotions in the assignment of the exchange values; and iv) the exploration of the proposed model in situations where various agents with different exchange personalities interact.

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