Propositional-Logic Approach to One-Shot Multi Issue Bilateral Negotiation

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Semantic-based e-marketplaces have emerged in recent years, to ease the initial phase of transaction in e-marketplaces, where demand/supply descriptions can be complex and expressive.

With the - long term - aim of building an e-marketplace fully exploiting rich semantic descriptions in all stages of a transaction, in this paper we propose a semantic-oriented approach to multi issue bilateral negotiation, which exploits a simple propositional logic. We present the theoretical setting, the negotiation protocol, whose outcome is Pareto-efficient, and illustrate the behavior with a simple example.

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1. INTRODUCTION

Automated negotiation among agents is one of the most challenging issues both in AI and in microeconomics research communities. Rubinstein [Rubinstein 1982] defined the *Bargaining Problem* as the situation in which "Two individuals have before them several possible contractual agreements. Both have interests in reaching agreement but their interests are not entirely identical. What 'will be' the agreed contract, assuming that both parties behave rationally?" Obviously, in several real situations, individuals have not only a limited set of possibilities, because they can work, during the negotiation process, in order to create additional possible agreements. Also Nash [Nash 1950] defined: "a TWO-PERSON bargaining situation involves two individuals who have the opportunity to collaborate for mutual benefit in more than one way." Usually, not all possible agreements are known to both

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partners at the beginning of the negotiation. However, an electronic facilitator, as the one we hypothesize in this paper, may automatically explore the negotiation space, and discover Pareto-efficient agreements[1] to be proposed to both parties. In game theory, bargaining is considered a type of game, and two types of games are analyzed that can model the bargaining problem: *cooperative* and *non-cooperative* games [Gerding et al. 2000]. The former, given a set of axioms and a coalition, determines how to split the surplus among the participants; so the aim is finding a solution given a set of possible outcomes. Instead, in non-cooperative games there are a well-defined set of rules and strategies; in such a game it is possible to define an *equilibrium* strategy, which ensures the rational outcomes of a game: no player could benefit by unilaterally deviating from her strategy, given the other players follow their own strategies [Li et al. 2003].

In most bilateral negotiation models, two opponents negotiate using alternate-offers protocol [Rubinstein 1982], sending offers and counteroffers back and forth. At each step an agent can accept or reject the received offer, propose a new offer or quit the negotiation process. *Single-shot* bargaining [Raiffa 1982] also has been studied, like *ultimatum game* where one player proposes a deal and the other player may only accept or refuse it [Binmore 1992]. In the *monotonic concession* protocol a deal, from the space of possible deals, is proposed simultaneously. An agreement is reached if one of the player matches or exceeds what the other one asks for in terms of utility [J.S. Rosenschein and G. Zlotkin 1994]. If no agreement is reached, both the players make an offer in the next round. Obviously, the offer has to be "monotonic", as it cannot have a lower utility than the last counter player offer. In each round a player can concede or make the same offer; if neither player concedes in the same round the negotiation ends and the agreement reached is the so-called *conflict deal*, both players receive their disagreement payoffs [Nash 1950].

If a single item is involved in a bilateral bargaining, the negotiation is *distributive*(zero-sum game), also called Win-Lose negotiation [Raiffa et al. 2002]: the bargainers have opposite interests and if one gets more the other part gets less. Instead *integrative* negotiation (Win-Win negotiation) concerns several issues negotiated simultaneously, where each issue has a different utility (or score) for each player. The players have different preferences on the issues; clearly both sides will be more interested to achieve agreement on the items most important to them and get into a trade off on items less important [Lai et al. 2004]. Differently from the distributive case, the players are not strict competitors: they can cooperate and if one gets more, the other player does not necessarily gets less.

Finally it is possible to have *many issues* to be negotiated among *many parties*; handling this situation is not easy because of the interplay among shifting coalitions: parties can join and act against other parties involved [Raiffa 1982].

In a more general case, in a bilateral negotiation scenario, participants are self-interested and have incomplete information about the opponents, that is no knowledge about preference ranking of possible offers and about opponent's reservation

[1] An agreement is Pareto-efficient if there is no other agreement that will make at least one participant better off without making at least one other participant worse off. If a negotiation outcome is not Pareto efficient, then there is another outcome that will make at least one participant happier while keeping everyone else at least as happy [Jennings et al. 2001].

value. [2]

Recently, there has been a growing interest toward multi-issue negotiation, but issues are described only as uncorrelated terms, without considering any underlying semantics, which could instead be exploited, among other reasons, to perform a pre-selection of candidate deals.

Here, we propose a theoretical framework for one-shot multi-issue negotiation in a logic based framework, where the issues involved in the process are related with each other via a theory $\mathcal{T}$ formulated using a logical language. Applications for such framework are all the scenarios where demands and supplies have to be identified using rich descriptions and not uniquely, as it is the case *e.g.*, of P2P e-marketplaces.

Notice that in this paper, although several other negotiation protocols exist in the e-commerce area, we focus our initial investigation on a one-shot protocol.

2. A NEGOTIATION SCENARIO

In order to define a negotiation mechanism we have to outline the following [J.S. Rosenschein and G. Zlotkin 1994] items:

. ***Space of possible deals***: the set of candidate deals, that is the set of all possible agreements.

. ***Negotiation Protocol***: the set of rules that specifies how an agreement will be reached, that is, the protocol giving the rules of the conversation between the supplier and the demander.

. ***Negotiation Strategy***: the actions that an agent adopts given an explicit set of rules specified in the negotiation protocol. The negotiation outcome will depend on the particular strategy adopted by each agent.

In some negotiations the parties cannot reach an agreement without some external help, that is without the intervention of a mediator. Usually they may not want to disclose their preference or utility function to the other party, but they are ready to reveal this information to a "third-party intervenor" helping negotiating parties to achieve efficient and equitable outcomes [Raiffa et al. 2002]. However what is the role played by the external helper in a negotiation process? She may "impose" or "suggest" a solution, find an acceptable solution selecting a point on the efficient frontier [3], or ask each participant to make a final offer choosing at last one of these offers. The third-party can be defined as a *facilitator*, *mediator* or *arbitrator*, depending on her influence and power in the negotiations, that is depending on her role: the more the role is evaluative, more appropriate is to define the third-party intervention as arbitration rather than facilitation or mediation.

In our framework the *space of possible deals* is computed with the aid of propositional logic [Russell and Norvig 2003]. The *protocol* exploited is a one-shot protocol with the intervention of a *facilitator* with a proactive behavior, so it suggests to

[2] The reservation value is the bottom line [Raiffa et al. 2002], the minimum value that will be acceptable in negotiation by both of participant.

[3] "The efficient frontier - sometimes called the Pareto Optimal Frontier, after the economist Vilfredo Pareto - is defined as the locus of achievable joint evaluations from which no joint gains are possible"[Raiffa 1982].

each participant the solution which is efficient, that is, the solution which maximizes the product of utilities, see Section 4. For what concerns *strategy*, the players can choose to accept or refuse the solution proposed by facilitator; they refuse if they think possible to reach a better agreement looking for another partner, or another shot, or for a different set of bidding rules. In this preliminary approach we do not consider the influence of the *outside options* in the negotiation strategy [Li et al. 2004; Muthoo 1995; Chatterjee and Lee 1998; Cunyat 1998; Gantner 2002], but in a e-marketplace scenario, both buyer and seller know that the opponent is probably not the only partner available for negotiating with and that there might be more than one single e-marketplace. Furthermore buyer and seller might not be willing to reveal their true utilities.

3. A LOGIC-BASED APPROACH FOR MULTI-ISSUE BILATERAL NEGOTIATION

The approach we propose here copes with multi-issue negotiation processes, where the involved issues are related with each other via logical constraints, *e.g.*, an implication or disjoint relation. Let us consider a car marketplace; if a demander is looking for a car with an audio CD reader and the seller is offering cars with stereo able to play CD with MP3 files, then we expect the supply satisfies the demand. In fact if a car has an MP3 CD reader then it is able to play audio CD, too[4]. On the other hand, if the the demander is looking for a car with leather seats and the supplier is able to offer only cars with cloth seats, then we (equivalently mediators) want to catch the incompatibility issue between the demand and the supply. In the proposed approach we model the relations among issues using a set $\mathcal{T}$ – for Theory – of propositional formulas[Russell and Norvig 2003].

Before proceeding with the approach we note here main assumptions we make:

—**Participants reveal their preferences to a third party**. Therefore the utility functions are private, as each participant does not need to know anything about the opposite preferences, but participants reveal their preferences to the facilitator and only the facilitator needs to know informations about the utility function of the opponents, as we will show in the following. Although the hypothesis that agents reveal their true preferences to the counterpart is usually unrealistic, both agents might agree to reveal their preferences to a trusted (automated) facilitator, see [Raiffa et al. 2002].

—**Utility of each issue mutually independent**. We assume only positive values for utilities and issues mutually utility independent. That is, for any two items the utility of the union of the two items is the sum of the utilities of each of the individual item. This assumption is the most common in the literature, although other assumptions are possible, see [Berliant and Dunz 2004; Berliant et al. 1992; Maccheroni and Marinacci 2003].

—**One-shot protocol with the intervention of a facilitator**. The presence of a facilitator and the one-shot protocol is an incentive for the two parties to reveal the true preferences, because they can trust in the facilitator and they have a single possibility to reach the agreement with that counterpart. We admit that this assumption is controversial and should be further investigated.

[4]Without claim of completeness on the audio/MP3 CD readers domain. This is just a toy example.

3.1 Space of Possible Deals

Possible deals in our framework, are all those "states of the world" where $\mathcal{T}$ is true. In logical terms, we are looking among all the models for $\mathcal{T}$.

Definition 1. *Let $\mathcal{A} = \{A_1, \ldots, A_n\}$ be the set of propositional terms (Issues), and $\mathcal{T}$ be a propositional theory whose symbols are in $\mathcal{A}$. We use $\mathcal{M} = \{m_i\}$, with* i=1...n*, where* n *is the cardinality of all possible agreements, to denote the set of all models for $\mathcal{T}$. Given two propositional formulas $\mathcal{D}$ (for Demand) and $\mathcal{S}$ (for Supply) whose symbols are in $\mathcal{A}$, we say that m is a* ***possible deal*** *between $\mathcal{D}$ and $\mathcal{S}$ iff $m \models \mathcal{T}$, that is m is a model for $\mathcal{T}$.*

From the previous definition, each possible successful negotiation outcome - the final deal - has to be a model of $\mathcal{T}$.

3.2 Logic-based Utility Functions

In a negotiation process, each participant has a private utility function indicating her utility with respect to each possible model.

Definition 2. *Given a theory $\mathcal{T}$ and its set of models $\mathcal{M}$, a logical multi-issue utility function u_d for the buyer (respectively u_s for the seller) is a function $u_d : \mathcal{M} \rightarrow \Re^+$ (respectively $u_s : \mathcal{M} \rightarrow \Re^+$).*

That is such functions have to take into account the information represented in $\mathcal{D}$ – utility function of the buyer u_d – and in $\mathcal{S}$ – utility function of the seller u_s. Considering a multi-issue bilateral negotiation, a way to model utility functions is considering the weight of each issue in $\mathcal{D}$ for u_d and each issue in $\mathcal{S}$ for u_s.

In our logical framework, we formalize buyer's demand and seller's supply as follows:

$\mathcal{D} = A_1^d \wedge A_2^d \wedge \ldots \wedge A_p^d$ *with* $p \leq n$.
$\mathcal{S} = A_1^s \wedge A_2^s \wedge \ldots \wedge A_q^s$ *with* $q \leq n$.

i.e., as a conjunction of positive propositional symbols/issues[5] from the set $\overline{\mathcal{A}} = \mathcal{A}_d \cup \mathcal{A}_s \subseteq \mathcal{A}$, where $\mathcal{A}_d = \{A_1^d, A_2^d. \ldots, A_p^d\}$ and $\mathcal{A}_s = \{A_1^s, A_2^s, \ldots, A_q^s\}$.

We consider each term both in $\mathcal{D}$ and $\mathcal{S}$ as a request expressed from the buyer, as well as from the seller, to find an optimal deal m_{opt} where all the specified issues are set true.

Definition 3. *Given a possible deal m and the set $\mathcal{A}' = \{A'_j\} \subseteq \mathcal{A}$ the weight of each A'_j w.r.t. m, from now on $\omega_{\mathcal{A}'}(A'_j, m)$, is such that:*

$$\omega_{\mathcal{A}'}(A'_j, m) = \begin{cases} 0, \text{ if } A'_j = \texttt{false} \text{ in } m \\ w_{A'_j} > 0, \text{ if } A'_j = \texttt{true} \text{ in } m \end{cases}$$

In the rest of the paper we write $\omega_{\mathcal{A}'}(A'_j)$ instead of $\omega_{\mathcal{A}'}(A'_j, m)$ when the dependency on a specific $m \in \mathcal{M}$ does not need to be noted.

[5]For the sake of simplicity here we consider both $\mathcal{D}$ and $\mathcal{S}$ as a conjunction of propositional terms. Negation operator never occurs in $\mathcal{D}$ and $\mathcal{S}$, but only in $\mathcal{T}$. The approach can be easily extended considering generic formulas F. Anyway the two approaches are equivalents as long as $\mathcal{T}$ can contain axioms of the form $A \Leftrightarrow F$.

Based on the above definition, now we can formalize both u_d and u_s with respect to a possible deal m in a logic based multi-issue negotiation process.

DEFINITION 4. *Given a demand $\mathcal{D}$, a supply $\mathcal{S}$and a possible deal m, logical multi-issue utility functions u_d for the buyer and u_s for the seller w.r.t. m are:*

$$u_d(m) = \sum_{A_j^d \in \mathcal{A}_d} \omega_{\mathcal{A}_d}(A_j^d)$$
$$u_s(m) = \sum_{A_j^s \in \mathcal{A}_s} \omega_{\mathcal{A}_s}(A_j^s)$$

PROPERTY 1. *Given a possible deal m, for both u_d and u_s the following conditions hold:*

. *if $m_{opt} \models \mathcal{D}$, $u_d(m_{opt}) > 0$*
. *if $m_{opt} \models \mathcal{S}$, $u_s(m_{opt}) > 0$*

As an example, consider two models $m_1 = \{a = \texttt{true}, b = \texttt{true}, c = \texttt{false}\}$ and $m_2 = \{a = \texttt{false}, b = \texttt{true}, c = \texttt{true}\}$, $\mathcal{A}_d = \{b, c\}$ with $\omega_{\mathcal{A}_d}(b) = x$ and $\omega_{\mathcal{A}_d}(c) = y$, $\mathcal{A}_s = \{a, b\}$ with $\omega_{\mathcal{A}_s}(a) = z$ and $\omega_{\mathcal{A}_s}(b) = t$. In this case $u_d(m_1) = x$, $u_d(m_2) = x + y$ and $u_s(m_1) = z + t$, $u_s(m_2) = t$.

Notice that we assume only positive values for utilities and issues mutually utility independent, hence the global utility over a model m is an additive linear polynomial.

3.3 Setting Reservation Values

Usually, in a negotiation process it is possible to determine for both the buyer and the seller a reservation value, that is a lower bound for the expected utility.

How to compute a reservation value in the proposed logical framework? The seller and buyer specify the *strict* issues in their supply and demand respectively; this will be useful in order to settle a *reservation requirements set* $\mathcal{R}_d$ in order to compute a *reservation value* ρ_d for the buyer, respectively for the seller $\mathcal{R}_s$ and ρ_s. The *reservation requirements sets* $\mathcal{R}_d$ and $\mathcal{R}_s$ represent the positive propositional terms/issues, respectively in $\mathcal{D}$ and $\mathcal{S}$, both the buyer and the seller necessarily want to be true in the final agreement. Formally we can say:

$\mathcal{R}_d = \{A_k^d\}$ *with* $k \in \{1, \ldots, p\}$, *then* $\mathcal{R}_d \subseteq \mathcal{A}_d$.
$\mathcal{R}_s = \{A_h^s\}$ *with* $h \in \{1, \ldots, q\}$, *then* $\mathcal{R}_s \subseteq \mathcal{A}_s$.

Since both $\mathcal{R}_d$ and $\mathcal{R}_s$ represent the propositional terms that must be set true in m, in order to continue the negotiation process, possible agreements have to be selected in the subset of $\mathcal{M}$ such that the above condition holds true.

For instance, with respect to the previous example (Section 3.2), if $\mathcal{R}_d = \{c\}$ and $\mathcal{R}_s = \{b\}$ then m_1 is not a possible agreement because in m_1 we have $c = \texttt{false}$; m_2 is a possible agreement because in m_2 both c and b are set $\texttt{true}$.

DEFINITION 5. *Let $\mathcal{T}$ be a set of propositional formulas whose symbols are in $\mathcal{A} = \{A_1, \ldots, A_n\}$ and let $\mathcal{R}_d = \{A_k^d\}$ and $\mathcal{R}_s = \{A_h^s\}$ be the reservation sets for respectively the buyer and the seller. We call* ***reservation models*** *a set $\mathcal{M}_\mathcal{R} = \{m_j\} \subseteq \mathcal{M}$ such that $m_j \models \mathcal{T} \bigcup_k A_k^d \bigcup_h A_h^s$.*

If seller and buyer have settled *strict* issues that are in conflict with each other, that is there is no model in $\mathcal{M}$such that all the strict items are true, then $\mathcal{M}_\mathcal{R} = \emptyset$

and the negotiation ends immediately because, "*sic stantibus rebus*", it is impossible to reach an agreement. If the participants are willing to avoid the *conflict deal* [J.S. Rosenschein and G. Zlotkin 1994], and continue the negotiation, it will be necessary they revise their preferences about *strict* issues modifying the content of $\mathcal{R}_d$ and $\mathcal{R}_s$.

Considering the *reservation requirements sets* $\mathcal{R}_d$ and $\mathcal{R}_s$ it is possible to compute the reservation value for both the buyer and the seller.

DEFINITION 6. *Given the reservation requirements sets $\mathcal{R}_d$ and $\mathcal{R}_s$, the reservation values for the buyer and the seller, respectively ρ_d and ρ_s are:*

$$\rho_d. = \sum_{A_k^d \in \mathcal{R}_d} \omega_{\mathcal{A}_d}(A_k^d, m_R)$$
$$\rho_s. = \sum_{A_h^s \in \mathcal{R}_s} \omega_{\mathcal{A}_s}(A_h^s, m_R)$$

The reservation value is hence the sum of the weights for all the issues in the reservation requirements set. It is easy to show that if the reservation requirements set is an empty set, then the reservation value is 0.

PROPERTY 2. *Given a possible agreement $m \in \mathcal{M}_{\mathcal{R}}$ the following conditions hold:*

$$u_d(m) \geq \rho_d$$
$$u_s(m) \geq \rho_s$$

In other words, the global utility of the final agreement for the buyer (respectively for the seller) cannot be lower than the utility computed considering only issues in the reservation requirements sets.

Based on the previous definitions, we can give a formal definition of the bargaining problem.

DEFINITION 7. *Given a demand $\mathcal{D}$, a supply $\mathcal{S}$ and a propositional theory $\mathcal{T}$ and two rationale thresholds ρ_d, ρ_s, a **M**ulti-issue **B**ilateral **N**egotiation problem – MBN – is finding a model m (agreement) such that $m \models \mathcal{T}$ and both $u_d(m) \geq \rho_d$ and $u_s(m) \geq \rho_s$.*

Traditionally among all possible models that we can compute given a theory $\mathcal{T}$, we are interested in agreements that are Pareto-efficient, so we define:

DEFINITION 8. *A Pareto agreement for an MBN is an agreement m, such that for no agreement m' both $u_d(m') > u_d(m)$ and $u_s(m') > u_s(m)$ hold.*

4. THE BARGAINING PROCESS

From an operative point of view, the bargaining process covers the following phases:

Preliminary Phase. the buyer defines both $\mathcal{D}$ and $\mathcal{R}_d$, the seller defines both $\mathcal{S}$ and $\mathcal{R}_s$. They inform the facilitator about these specifications and the $\mathcal{T}$ they refer to.

Initial phase. The facilitator computes $\mathcal{M}_{\mathcal{R}}$. If $\mathcal{M}_{\mathcal{R}} = \emptyset$ the facilitator asks the buyer and the seller to refine respectively their $\mathcal{R}_d$ and $\mathcal{R}_s$ and recompute $\mathcal{M}_{\mathcal{R}}$. Once/If buyer and seller solve any conflicts about reservation requirements, the negotiation can start.

If $\mathcal{M}_{\mathcal{R}} \neq \emptyset$, for each issue in $\mathcal{A}_d$ and $\mathcal{A}_s$ a weight is settled. For the purpose of this paper we are not interested on how to compute weights. The weight determination process can use direct assignment methods, like Ordering, Simple Assessing or Ratio Comparison, and pairwise comparison methods, like AHP and Geometric Mean, see [Pomerol and Barba-Romero 2000].

Negotiation-Core phase. The facilitator proposes an agreement mutually beneficial for both the buyer and the seller. It is a *take-it-or-leave-it* offer, because the participants can either accept or reject it [Jennings et al. 2001]. Notice that, as it is better explain later on, the proposed deal is Pareto-efficient, hence although the participants can move from the proposed deal, they might end in a less (not Pareto) efficient agreement. Once it computes the space of all possible deals $\mathcal{M}_{\mathcal{R}}$, the facilitator evaluates the utility of each model $m \in \mathcal{M}_{\mathcal{R}}$, both for the buyer – $u_d(m)$ – and for the supplier – $u_s(m)$.

Among all possible models, it chooses $\overline{m}$ maximizing the product $u_d(m) * u_s(m)$ and proposes such solution to the opponents[6]. If there is more than one model maximizing the above product, the facilitator chooses the one which maximizes the sum of utilities. "If there is more than one such sum-maximizing product maximizer, the arbitrator will choose among those deals with some arbitrary probability" [J.S. Rosenschein and G. Zlotkin 1994]. Notice that any deal maximizing the product of utilities, is also a Pareto agreement. Because if there was a model m' such that both $u_d(m') > u_d(m)$ and $u_s(m') > u_s(m)$ hold, the model m' would have a larger product. If one of the opponents, or both of them, refuse the deal proposed by the facilitator, they reach a *conflict deal* although they know that the proposed deal is the best deal they can reach, under these rules and assumptions, as it maximizes the product of utilities.

5. AN ILLUSTRATIVE EXAMPLE

In the following we will show our logic based approach to automate negotiation process with the aid of a simple example with respect to the phases outlined in the previous Section.

5.1 Preliminary phase

Let us suppose to be in an e-marketplace related to Autos and Vehicles, and the buyer's demand and seller's supply expressed as:

$\mathcal{D} = \mathit{Sedan} \wedge \mathit{MP3\_player} \wedge \mathit{Leather\_seats} \wedge \mathit{Automatic\_transmission}$.

$\mathcal{S} = \mathit{Sedan} \wedge \mathit{CD\_player} \wedge \mathit{Cloth\_seats} \wedge \mathit{Manual\_transmission}$.

Let $\mathcal{T}$ be the theory[7]:

$\mathit{Cloth\_seats} \Leftrightarrow \neg \mathit{Leather\_seats}$.

$\mathit{Manual\_transmission} \Leftrightarrow \neg \mathit{Automatic\_transmission}$.

$\mathit{CD\_player} \Rightarrow \neg \mathit{MP3\_player}$.

[6]All the mechanisms in the class PMMs (*Product Maximizing Mechanisms*) are efficient [J.S. Rosenschein and G. Zlotkin 1994].

[7]For the sake of conciseness we omit axioms only introducing propositional terms such as (Sedan $\vee$ $\neg$ Sedan)

	CD	MP3	Cloth	Leather	Mantran.	Autotran.	Sedan
D	0.068	0.159	0.091	0.136	0.136	0.182	0.227
S	0.163	0.116	0.163	0.070	0.209	0.047	0.233

Table I. Utility assigned to each attribute involved in the negotiation process

Models	CD	MP3	Cloth	Leather	Mantran.	Autotran.	Sedan	u_d	u_s	$u_d * u_s$	$u_d + u_s$
$m1$	true	false	true	false	false	true	true	0.568	0.605	0.344	1.173
$m2$	true	false	false	true	false	true	true	0.614	0.512	0.314	1.125
$m3$	false	true	true	false	false	true	true	0.659	0.558	0.368	1.217
$m4$	false	true	false	true	false	true	true	0.705	0.465	0.328	1.170
$m5$	false	false	true	false	false	true	true	0.500	0.442	0.221	0.942
$m6$	false	false	false	true	false	true	true	0.545	0.349	0.190	0.894

Table II. $\mathcal{M}_{\mathcal{R}}$ and the utility associated to each model

Notice that while the first two formulas model that in a car there cannot be cloth and leather seats (in the same way for manual and automatic transmission) at the same time, the latter formula states that if the car has exclusively a CD player then it is not possible to play MP3 files.

The buyer and the seller settle reservation requirements:

$\mathcal{R}_d$ $=\{$*Sedan*, *Automatic_transmission*$\}$.

$\mathcal{R}_s$ $=$ *Sedan*.

5.2 Initial phase

The facilitator computes $\mathcal{M}_{\mathcal{R}}$ evaluating all the models for $\mathcal{T} \bigcup_k A^d_k \bigcup_h A^s_h$, that is for:

Cloth_seats $\Leftrightarrow \neg$*Leather_seats*.

Manual_transmission $\Leftrightarrow \neg$*Automatic_transmission*.

CD_player $\Rightarrow \neg$*MP3_player*.

Sedan.

Automatic_transmission.

Table II shows a row for each model in $\mathcal{M}_{\mathcal{R}}$. Columns 2 to 8 represent the value of each issue in the related model. Since $\mathcal{M}_{\mathcal{R}} \neq \emptyset$, it is possible to continue the process. Using values in Table I, $u_d(m)$ and $u_s(m)$ are computed for each $m \in \mathcal{M}_{\mathcal{R}}$ (as shown in Table II columns 9 and 10).

5.3 Negotiation phase

The facilitator chooses m maximizing the product of utilities, see Section 4, and proposes the deal to the players, who can refuse or accept.

In this case the deal that maximizes the product of utility is:
m_3=$\{$`Sedan`, `MP3_player`, `Cloth_seats`, `Automatic_transmission`$\}$[8]
$u_d(m_3) = \omega($`Sedan`$)+\omega($`MP3_player`$)+\omega($`Cloth_seats`$)+\omega($`Automatic_transmission`$)=$ 0,659
$u_s(m_3) = \omega($`Sedan`$)+\omega($`MP3_player`$)+\omega($`Cloth_seats`$)+\omega($`Automatic_transmission`$)$=0,558
$u_d(m_3)$*$u_s(m_3)$=0,368

[8]Here we represent only attributes set `true` in the model.

6. CONCLUSION AND FUTURE WORK

In this paper we proposed a one-shot multi issue bilateral negotiation approach, which is Pareto-efficient, based on a logic formalization of the relations among issues. We showed, modeling such relations with a subset of propositional logic, how to exploit the formal semantics of both a demand and a supply. The theoretical setting we presented takes into account elements from classical negotiation theory and uses them into a more expressive setting.

We are investigating an extension of the approach, exploiting other logic languages –namely Description Logic– which can cope with greater expressiveness in demand/supply descriptions, and also the application of logics to other bilateral negotiation protocols, also different from one-shot ones, suitable for P-2-P E-marketplaces.

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