Strategical Considerations for Negotiating Agents

Leila Amgoud
IRIT - CNRS
118, route de Narbonne
Toulouse, France
amgoud@irit.fr

Souhila Kaci
CRIL - CNRS
Rue de l'Université SP 16
62307 Lens, France
kaci@cril.univ-artois.fr

ABSTRACT

The choice of the offer to propose at a given step in a negotiation dialogue is a *strategic* matter and depends broadly on the *profile* of the agent and its *mental states*. The aim of this paper is to propose some negotiation strategies which are based not only on the *goals* of the agents but also on their *rejections*. A three-layered setting is proposed for defining and analyzing strategies.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Intelligent agents

General Terms

Human Factors, Theory

Keywords

Negotiation, Strategies

1. INTRODUCTION

Negotiation consists of an exchange of offers between agents until a compromise is reached. As argued in [2, 3], the choice of the offer to propose at a given step is a *strategic* matter. Indeed, that choice depends broadly on the *agent profile* and its *mental states*, namely its goals and beliefs. As discussed in recent cognitive psychology studies [1], we claim that taking into account what an agent rejects, in addition to its goals and beliefs, in the offer selection enables a more refined selection, and allows to discard rejected offers. Thus, we propose different strategies following a three-layered setting. We will show that the way in which an offer is selected influences the result of the negotiation.

2. MENTAL STATES OF THE AGENTS

$\mathcal{L}$ denotes a first order propositional language. X stands for the set of offers. Each agent has got a set $\mathcal{B}$ of *beliefs*, a set $\mathcal{G}$ of *goals*, and a set $\mathcal{R}$ of *rejections*. Beliefs are pervaded with uncertainty i.e., they are more or less certain while rejections and goals may not have equal priorities.

AAMAS'05, July 25-29, 2005, Utrecht, Netherlands.

DEFINITION 1 (MENTAL STATES OF AN AGENT). *The* mental states *of an agent are:* $\mathcal{B} = \{(b_i, \alpha_i), i = 1, \ldots, n\}$, $\mathcal{R} = \{(r_j, \beta_j), j = 1, \ldots, m\}$, *and* $\mathcal{G} = \{(g_k, \lambda_k), k = 1, \ldots, p\}$ *where* b_i, r_j, g_k *are formulas of* $\mathcal{L}$ *and* α_i, β_j, $\lambda_k \in (0, 1]$.

The sets of beliefs and rejections are supposed to be *consistent*. Beliefs play a key role in delimiting the set of *feasible* offers.

DEFINITION 2 (FEASIBLE OFFERS). *Let* $x \in X$. *An offer* x *is* feasible *if it satisfies the set of beliefs.*

Each rejection (r_j, β_j), which should not be satisfied, induces by complementation an integrity constraint $(\neg r_j, \beta_j)$ which should be respected. $\mathcal{R}'$ denotes the set of induced integrity constraints from $\mathcal{R}$. The offers which respect the induced integrity constraints will be *acceptable* for the agent.

DEFINITION 3 (ACCEPTABLE OFFERS). *Let* $x \in X$. *An offer* x *is* acceptable *iff it satisfies the integrity constraints w.r.t. a criterion* c_a*, denoted* $\mathcal{R}' \Vdash_{c_a} x$.

The acceptability of an offer depends on a criterion c_a. For instance, one may accept an offer which respects all the integrity constraints or respects the most important of them. The offers which satisfy the goals of an agent according to some criterion will be *satisfactory* for that agent. For instance, one may accept the offers which satisfy all its goals, or the offers which satisfy at least its most important goals.

DEFINITION 4 (SATISFACTORY OFFERS). *Let* $x \in X$. *An offer* x *is* satisfactory *iff* x *satisfies the goals of the agent w.r.t. a criterion* c_s*, denoted* $\mathcal{G} \Vdash_{c_s} x$.

Let T be a weighted base. $T_{>\alpha} = \{t_j \mid (t_j, \alpha_j) \in T \text{ and } \alpha_j > \alpha\}$, $T_{=\alpha} = \{t_j \mid (t_j, \alpha) \in T\}$, $\bigvee(T_{=\alpha}) = \bigvee\{t_j \mid (t_j, \alpha) \in T\}$.

3. A SETTING FOR OFFER SELECTION

Selecting offers follows a three steps process: i) defining a relation $\succeq$ between $\mathcal{B}$, $\mathcal{R}$ and $\mathcal{G}$. Indeed, one may not have the same set of candidate offers when $\mathcal{G} \succeq \mathcal{R}$ or $\mathcal{R} \succeq \mathcal{G}$. In order to avoid any wishful thinking, it holds that: $\mathcal{B} \succ \mathcal{G}, \mathcal{R}$. The ordering between $\mathcal{G}$ and $\mathcal{R}$ is more difficult to guess. ii) defining *criteria* for selecting acceptable offers. iii) defining *criteria* for selecting satisfactory offers.

DEFINITION 5 (STRATEGY). *Let* $\mathcal{B}$, $\mathcal{R}$ *and* $\mathcal{G}$ *be the agent's bases and* X *the set of offers. A* strategy *is a triple* $<\succeq, \Vdash_{c_a}, \Vdash_{c_s}>$. *This system will return a set* $\underline{\mathcal{S}} \subseteq X$ *of* candidate *offers.*

If $\mathcal{R} \approx \mathcal{G}$, the acceptable offers and the satisfactory ones are computed separately from the feasible offers. The candidate offers are those which are both acceptable and satisfactory.

DEFINITION 6. *If $\mathcal{R} \approx \mathcal{G}$, then the set of* candidate *offers $\underline{\mathcal{S}}$ = $\mathcal{S}_1 \cap \mathcal{S}_2$ such that: 1) $\mathcal{S}_1, \mathcal{S}_2 \subseteq X$, and 2) $\forall\, x \in \mathcal{S}_1$, x is feasible and acceptable, and 3) $\forall\, x \in \mathcal{S}_2$, x is feasible and satisfactory.*

This approach is too requiring since it may lead to an empty set of *candidate* offers. When $\mathcal{R} \succ \mathcal{G}$, one starts by selecting the acceptable offers among the feasible ones, then selecting the satisfactory ones (w.r.t. some criteria) among the acceptable offers. Formally:

DEFINITION 7. *If $\mathcal{R} \succ \mathcal{G}$, the set of* candidate *offers is $\underline{\mathcal{S}}$ = $\{x \in S'$ such that x is satisfactory$\}$, where 1) $\mathcal{S}'$ = $\{x \in X$ such that x is feasible and acceptable$\}$. 2) $\mathcal{S}'$ is maximal for ($\subseteq$) among the sets satisfying the first condition.*

This approach is cautious since the agent prefers to select acceptable offers, among feasible ones, even if none of them satisfies any goal. When $\mathcal{G} \succ \mathcal{R}$, one selects first satisfactory offers among feasible ones, then among the offers it gets, it chooses those which are acceptable w.r.t. some criteria.

DEFINITION 8. *If $\mathcal{G} \succ \mathcal{R}$, then the set of* candidate *offers is $\underline{\mathcal{S}}$ = $\{x \in S'$ such that x is acceptable$\}$, where 1) $\mathcal{S}'$ = $\{x \in X$ such that x is feasible and satisfactory$\}$. 2) $\mathcal{S}'$ is maximal for ($\subseteq$) among the sets satisfying the first condition.*

This approach is too adventurous since it may lead the agent to select offers which are not acceptable at all.

4. ACCEPTABILITY OF OFFERS

An offer is acceptable if it respects the integrity constraints induced by rejections. In some situations, one cannot find an offer which satisfies all the constraints, and the set of candidate offers is empty. To relax this criterion, an agent may accept the offers which respects the constraints at a certain level, called *acceptability level*. Indeed, the acceptability level is the complement to 1 of the degree of the less important constraint that should be respected by offers. The acceptable offers are the ones with a greater acceptability level.

DEFINITION 9 (ACCEPTABILITY CRITERION). *Let $x \in X$. The offer x is* acceptable *iff $Level(x)_A \geq Level_A(x')$, $\forall$ x' $\in X$ with $Level_A(x)$ = 1 - min$\{\beta$ such that x satisfies $\mathcal{R}'_{>\beta}\}$. If x falsifies $\mathcal{R}'_{>\beta}$ for all β then $Level_A(x) = 0$.*

5. SATISFIABILITY OF OFFERS

It is natural that an agent aims to satisfy all its goals. When this is not possible, it may try to satisfy as much as possible prioritized goals. A *cardinality*-based selection mode seems appropriate in this case. Before defining this criterion, let's first introduce some notations.

Let $\beta_1, \cdots, \beta_m$ be the weights appearing in $\mathcal{G}$ s.t. $1 \geq \beta_1 > \cdots > \beta_m > 0$. Let $\mathcal{G}'$ = $\mathcal{G}_1 \cup \ldots \cup \mathcal{G}_m$ be the representation of $\mathcal{G}$ in its well ordered partition. Each $\mathcal{G}_j$, called *layer*, contains formulas of $\mathcal{G}$ having the weight β_j. Let x be an offer and $\mathcal{S}_x$ = $\mathcal{S}_x^1 \cup \ldots \cup \mathcal{S}_x^m$ where $\mathcal{S}_x^j$ is a subset of $\mathcal{G}_j$ containing the goals of $\mathcal{G}_j$ satisfied by x.

DEFINITION 10 (CARDINALITY-BASED CRITERION). *Let $x \in X$. $\mathcal{G} \Vdash_{Card} x$ iff $\forall x' \in X$: i) $\exists\, k$ s.t. $\forall\, j = 1, \ldots, k-1$;$|\mathcal{S}_x^j|$ = $|\mathcal{S}_{x'}^j|$ and $|\mathcal{S}_x^k| > |\mathcal{S}_{x'}^k|$, or ii) $|\mathcal{S}_x^j| = |\mathcal{S}_{x'}^j|$ for $j = 1, \cdots, m$, where $|\mathcal{S}_x^j|$ is the number of formulas in $\mathcal{S}_x^j$.*

The cardinality-based criterion gives priority to the offers which satisfy a maximum of prioritized goals. A weaker version of this criterion consists of choosing the offers which satisfy at least one prioritized goal.

	$\Vdash_{Level}$, $\Vdash_{Conj}$	$\Vdash_{Level}$, $\Vdash_{Disj}$	$\Vdash_{Level}$, $\Vdash_{Card}$
$(\mathcal{R} \approx \mathcal{G})$			
$(\mathcal{R} \succ \mathcal{G})$			
$(\mathcal{G} \succ \mathcal{R})$			

Table 1: Different strategies

DEFINITION 11 (DISJUNCTIVE-BASED CRITERION). *Let $x \in X$. $\mathcal{G} \Vdash_{Disj} x$, iff $Level_{DS} \geq Level_{DS}(x')$, $\forall\, x' \in X$, where $Level_{DS}(x)$ = $max\{\lambda$ such that x satisfies $\bigvee(\mathcal{G}_{=\lambda})\}$. If x falsifies all formulas of $\mathcal{G}$ then $Level_{DS}(x) = 0$.*

Another refinement of the cardinality-based criterion consists of accepting the offers which satisfy as many prioritized goals as possible.

DEFINITION 12 (CONJUNCTIVE-BASED SELECTION). *Let $x \in X$. $\mathcal{G} \Vdash_{Conj} x$ iff $Level_{CS} \geq Level_{CS}(x')$, $\forall\, x' \in X$, where $Level_{CS}(x)$ = $1 - min\{\lambda$ such that x satisfies $\mathcal{G}_{>\lambda}\}$. If x falsifies $\mathcal{G}_{>\lambda}$ for all λ then $Level_{CS}(x) = 0$.*

PROPOSITION 1. *Let $x \in X$.*

$$(\mathcal{G} \Vdash_{Card} x) \Rightarrow (\mathcal{G} \Vdash_{Conj} x) \Rightarrow (\mathcal{G} \Vdash_{Disj} x).$$

A strategy for selecting the offers to propose during a negotiation dialogue has three parameters: an ordering between $\mathcal{R}$ and $\mathcal{G}$, an acceptability criterion and finally a satisfaisability criterion. Different systems can then be defined using the criteria suggested in the previous sections. Table 1 summarizes these systems (strategies).

6. CONCLUSION

This paper studies the notion of strategy for selecting offers during a negotiation dialogue. We have proposed a general setting for defining a strategy, which consists of fixing three parameters: i) the agent's profile by choosing the ordering between the set of goals and the set of rejections, ii) a criterion for defining acceptable offers and finally, iii) another criterion for defining satisfactory offers. The three parameters are defined on the basis of three mental states of an agent: its beliefs, its goals and its rejections. We have proposed different agent's profiles and different criteria for the notions of acceptability and satisfiability of offers. A combination of an agent's profile, a criterion for selecting acceptable offers and a criterion for selecting the satisfactory ones gives birth to different strategies which are more or less restrictive. At the best of our knowledge, very few works have addressed the problem of offer selection. Moreover all existing works only consider goals in this process. We claim that rejections play also a key role in this problem since they allow to discard rejected offers.

7. REFERENCES

[1] J.T. Cacioppo, W.L. Gardner, and G.G. Bernston. Beyond bipolar conceptualizations and measures: The case of attitudes and evaluative space. *Personality and Social Psychology Review*, 1, 1:3–25, 1997.

[2] A. Kakas, N. Maudet, and P. Moraitis. Layered strategies and protocols for argumentation based agent interaction. In *Proc. AAMAS'04 1st International Workshop on Argumentation in Multi-Agent Systems, (ArgMAS'04)*, 2004.

[3] S. Kraus, K. Sycara, and A. Evenchik. *Reaching agreements through argumentation: a logical model and implementation*, volume 104. Journal of Artificial Intelligence, 1998.