An argumentation-based approach for dialog move selection

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Abstract. Modeling different types of dialog between autonomous agents is becoming an important research issue. Several proposals exist with a clear definition of the dialog protocol, which is the set of rules governing the high level behavior of the dialog. However, things seem different with the notion of strategy. There is no consensus on the definition of a strategy and on the parameters necessary for its definition. Consequently, there are no methodology and no formal models for strategies.

This paper argues that a strategy is a *decision* problem that consists of: i) selecting the type of act to utter at a given step of a dialog, and ii) selecting the content that will accompany the act. The first kind of decision amounts to select among all the acts allowed by the protocol, the best option which according to some *strategic beliefs* of the agent will at least satisfy the most important *strategic goals* of the agent. The second kind of decision consists of selecting among different alternatives (eg. different offers), the best one that, according to some *basic beliefs* of the agent, will satisfy the *functional goals* of the agent. The paper proposes then a formal model based on argumentation for computing on the basis of the above kinds of mental states, the best move (act + content) to play at a given step of the dialog. The model is illustrated through an example of auctions.

1 Introduction

An increasing number of software applications are being conceived, designed, and implemented using the notion of autonomous agents. These applications vary from email filtering [10], through electronic commerce [12, 16], to large industrial applications [6]. In all of these disparate cases, however, the agents are *autonomous* in the sense that they have the ability to decide for themselves which goals they should adopt and how these goals should be achieved [17]. In most agent applications, the autonomous components need to interact with one another because of the inherent interdependencies which exist between them. They need to communicate in order to resolve differences of opinion and conflicts of interest that result from differences in preferences, work together to find solutions to dilemmas and to construct proofs that they cannot manage alone, or simply to inform each other of pertinent facts. Many of these communication requirements cannot be fulfilled by the exchange of single messages. Instead, the agents concerned need to be able to exchange a *sequence of messages* which all bear upon the same subject. In other words they need the ability to engage in *dialogs*. In [15] different categories of dialogs have been distinguished including persuasion and negotiation. Work in the literature has focused on defining formal models for these dialog types. Generally, a dialog system contains the following three components: the agents involved in the dialog (i.e their *mental states*), a dialog *protocol* and a set of *strategies*. The dialog protocol is the set of *rules of encounter* governing the high-level behavior of interacting agents. A protocol defines among other things:

- the set of permissible acts (eg. asking questions, making offers, presenting arguments, etc.);
- the legal replies for each act.

A dialog protocol identifies the different possible replies after a given act. However, the exact act to utter at a given step of the dialog is a *strategy* matter. While the protocol is a public notion, strategy is crucially an individualistic matter. A strategy can be seen as a two steps *decision process*:

1. among all the possible replies allowed by the protocol, to choose the move to play. For instance, in a negotiation dialog, the protocol may allow after an offer act the following moves: accepting/rejecting the offer or making a new offer.
2. to choose the content of the move if any. In the above example, if the agent chooses to make a new offer, it may decide among different alternatives the best one to propose.

In most works on modeling dialogs, the definition of a protocol poses no problems. However, the situation is different for dialog strategies. There is no methodology and no formal models for defining them. There is even no consensus on the different ingredients involved when defining a strategy. Regarding persuasion dialogs, there are very few works devoted to the notion of strategy in the literature if we except the work done in [2, 7]. In these works, different criteria have been proposed for the argument selection. As for negotiation dialogs, it has been argued that the game-theoretic approaches characterize correctly optimal strategies [8, 13]. However, another line of research [5, 9, 11, 14] has emphasized the limits of game-theoretic approaches for negotiation, and has shown the interest of arguing during a negotiation. Consequently, the optimal strategies given by game theory are no longer valid and not suitable. In [3], the authors have studied the problem of choosing the best offer to propose during a dialog and several criteria have been suggested. However, in that framework, the act offer is supposed to be chosen by the agent. Thus, this work has focused only on the second step of the decision process.

This paper argues that the strategy is a decision problem in which an agent tries to choose among different *alternatives* the best option, which according to its beliefs, will satisfy at least its most important goals. Two kinds of goals (resp. of beliefs) are distinguished: the *strategic* and the *functional* goals (resp. the *strategic* and *basic* beliefs).

The strategic goals are the meta level goals of the agent. Such goals will help an agent, on the basis of the strategic beliefs, to select the type of act to utter. Regarding functional goals, they will help an agent to select, on the basis of the basic beliefs to select the content of a move.

We propose a formal model for defining strategies. The model takes as input two sets of goals: the strategic and the functional goals together with the strategic and basic beliefs and returns among the possible replies allowed by the protocol after a given act, the next move (act + its content) to play. The model is an extension of the argument-based decision framework proposed in [1]. The basic idea behind this model is to construct for each alternative the different arguments (reasons) supporting it, then to compare pairs of alternatives on the basis of the quality of their supporting arguments.

The paper is organized as follows: Section 2 presents the different classes of goals and beliefs maintained by an agent. Section 3 introduces the logical language which will be used throughout the paper. Section 4 introduces an abstract argumentation-based decision model which forms the backbone of our approach. Section 5 presents an instantiation of that abstract model for computing the best move to play among the different replies allowed by the protocol. Section 6 introduces a second instantiation of the abstract model for computing the content of the move selected by the first instantiation. The whole framework is then illustrated in section 8. Section 9 is devoted to some concluding remarks and some perspectives.

2 Agents' mental states

During a dialog, an agent makes two decisions: it first selects the type of act to utter, for instance making a new offer, asking a question or arguing. Once the act chosen, the agent should select the content of the act if necessary. We say if necessary because some acts such as "withdrawal" from a dialog does not need a content. However, for an act "offer", it is important to accompany the act with an appropriate content. If the agents are negotiating the "price" of a car, then the act offer should contain a given price. The two above decision problems involve two different kinds of goals:

Strategic goals: For choosing the type of act to utter, an agent refers to what we call *strategic goals*. By strategic goals we mean the meta-level goals of the agent such as "minimizing the dialog time", "selling at the end of the dialog", etc. Suppose that at a given step of a negotiation dialog, an agent has to choose between making an offer and asking a question. If the agent wants to minimize the dialog time then it would choose to make an offer instead of spending more time in questions. However, if the agent wants to get a maximum of information about the wishes of the other agent, then the agent would decide to ask a question.
Strategic goals are generally independent of the *subject* of the dialog. If the agents are negotiating the place of a next meeting, then those goals are not related to the place.

Functional goals: The goals of the agent which are directly related to the subject of the dialog are called *functional goals*. They represent what an agent wants to achieve or to get regarding the subject of the dialog. Let us take the example of the agent negotiation the place of a meeting. The agent may prefer a place which is not warm and not expensive. The agent may also prefer a place with an international airport. These functional goals are involved when selecting the content of a move. In a negotiation, an agent proposes offers that satisfy such goals.

As for goals, the beliefs involved in the two decision problems are also of different nature:

Strategic beliefs that are the meta-level beliefs of the agent. They may represent the beliefs of the agent about the dialog, and about the other agents involved in the dialog. In negotiation dialogs where agents are trying to find a common agreement, agents may intend to simulate the reasoning of the other agents. Thus it is important for each agent to consider the beliefs that it has on the other agents'goals and beliefs. Indeed, a common agreement can be more easily reached if the agents check that their offers may be consistent with what they believe are the goals of the others.

Basic beliefs represent the beliefs of the agent about the environment and the subject of the dialog. Let us consider again the example of the agent negotiating the place of a meeting. Basic beliefs of the agent may include for instance the fact that "London is not warm", "Tunisia is hot", "London is very expensive", etc. This base may also contain some integrity constraints related to the dialog subject such as "the meeting cannot be at the same time in London and in Algeria".

3 The logical language

Let $\mathcal{L}$ be a propositional language, and $Wff(\mathcal{L})$ be the set of well-formed formulas built from $\mathcal{L}$. Each agent has the following bases:

$\mathcal{B}_b$ = $\{(k_p, \rho_p), p = 1, \ldots, s\}$, where $k_p \in Wff(\mathcal{L})$, is the basic beliefs base. The beliefs can be less or more certain. They are associated with certainty levels ρ_p. A pair (k_p, ρ_p) means that k_p is at least certain at a degree ρ_p.

$\mathcal{B}_s$ = $\{(l_j, \delta_j), j = 1, \ldots, m\}$, where $l_j \in Wff(\mathcal{L})$, is the strategic beliefs base. Each of these beliefs has a certainty level δ_j.

$\mathcal{G}_s$ = $\{(g_q, \lambda_q), q = 1, \ldots, t\}$, where $g_q \in Wff(\mathcal{L})$, is a base of strategic goals. The strategic goals can have different priority degrees, represented by λ_q. A pair (g_q, λ_q) means that the goal g_q is important for the agent at least to a degree λ_q.

$\mathcal{G}_f$ = $\{(go_r, \gamma_r), r = 1, \ldots, v\}$, where $go_r \in Wff(\mathcal{L})$, is the base of the functional goals of the agent. Each functional goal has a degree of importance denoted by γ_r.

The different certainty levels and priority degrees are assumed to belong to a unique linearly ordered scale T with maximal element denoted by 1 (corresponding to total certainty and full priority) and a minimal element denoted by 0 corresponding to the complete absence of certainty or priority.
We shall denote by $\mathcal{B}_b^*$, $\mathcal{B}_s^*$, $\mathcal{G}_s^*$ and $\mathcal{G}_f^*$ the corresponding sets of propositional formulas when weights are ignored.

Let $\mathcal{S}$ be the set of speech acts allowed by the protocol. $\mathcal{S}$ may contain acts such as

“’Offer’ for making offers in negotiation dialogs, “Question” for asking questions, “Assert” for asserting information such as “the weather is beautiful”, “Argue” for presenting arguments in persuasion dialogs, etc. The protocol precises for each act the possible replies to it. Let us suppose that the function `Replies` returns for each act, all the legal replies to it.

$$\texttt{Replies:}\ \mathcal{S} \longmapsto 2^{\mathcal{S}}$$

Some acts may have a content. For instance, an act “Offer” should be accompanied with a content such as a price, a town, etc. However, the act “Withdraw” does not need any content. Such acts will then have an empty content, denoted by the symbol “?”. In what follows, the function `Content` returns for a given act, the set of its possible contents. Formally:

$$\texttt{Content:}\ \mathcal{S} \longmapsto 2^{Wff(\mathcal{L}) \cup \{?\}}$$

For instance, $\texttt{Content}(Withdraw) = \{?\}$, $\texttt{Content}(Offer) = \{London, Algeria\}$.

During a dialog, agents exchange *moves* which are pairs: a *speech act* and its *content*. Formally:

Definition 1 (Moves). *A* move *is a pair (a, x), where $a \in \mathcal{S}$ and $x \in \texttt{Content}(a)$.*

The strategy problem is formalized as follows:

Definition 2 (The strategy problem). *Let (a, x) be the current move in a dialog. What is the next move (a', x') to utter such that $a' \in \texttt{Replies}(a)$?*

To answer this question, one should find both a' and x'. Indeed, a' is the “best” element in $\texttt{Replies}(a)$ that satisfies $\mathcal{G}_s^*$ according to $\mathcal{B}_s^*$. This will be denoted by: $\mathcal{B}_s^*$, $a' \rightarrow \mathcal{G}_s^*$. Here by “best” we mean the act that satisfies as much important goals as possible.

Concerning x', this is also the “best” element among $X \subseteq Wff(\mathcal{L})$ that satisfies $\mathcal{G}_f^*$ according to $\mathcal{B}_b^*$. This will be denoted by: $\mathcal{B}_b^*$, $x' \rightarrow \mathcal{G}_f^*$. Here the set X is exactly the set of different alternatives concerning the content of a move. This set may contain different offers (eg. different town) if we have to choose the content of the act “offer”, it may contain a set of formulas if we have to choose the content of the act “Assert”, it may also contain a set of arguments if one has to select the content of the move “Argue”, etc.

The solution to the strategy problem is the pair (a', x') such that ($\mathcal{B}_s^*$, $a' \rightarrow \mathcal{G}_s^*$) $\wedge$ ($\mathcal{B}_b^*$, $x' \rightarrow \mathcal{G}_f^*$).

4 The abstract argumentation-based decision model

Recently, Amgoud [1] has proposed a formal framework for making decisions under uncertainty on the basis of arguments that can be built in favor of and against a possible choice. Such an approach has two obvious merits. First, decisions can be more easily explained. Moreover, argumentation-based decision is maybe closer to the way humans make decisions than approaches requiring explicit utility functions and uncertainty distributions.

Solving a decision problem amounts to defining a pre-ordering, usually a complete one, on a set $\mathcal{X}$ of possible choices (or decisions), on the basis of the different consequences of each decision. In our case, the set $\mathcal{X}$ may be either the set $\mathtt{Replies}(a)$ of the possible replies to a move, or the set $\mathtt{Content}(a)$. The basic idea behind an argumentation-based model is to construct arguments in favor of and against each decision, to evaluate such arguments, and finally to apply some principle for comparing the decisions on the basis of the arguments and their quality or strengths. Thus, an argumentation-based decision process can be decomposed into the following steps:

1. Constructing arguments in *favor* of /*against* each decision in $\mathcal{X}$.
2. Evaluating the strength of each argument.
3. Comparing decisions on the basis of their arguments.
4. Defining a pre-ordering on $\mathcal{X}$.

Definition 3 (Argumentation-based decision framework). *An* argumentation-based decision framework *is a tuple* $<\mathcal{X}, \mathcal{A}, \succeq, \rhd_{Princ}>$ *where:*

- $\mathcal{X}$ *is a set of all possible decisions.*
- $\mathcal{A}$ *is a set of arguments.*
- $\succeq$ *is a (partial or complete) pre-ordering on* $\mathcal{A}$.
- $\rhd_{Princ}$ *(for principle for comparing decisions), defines a (partial or complete) pre-ordering on* $\mathcal{X}$*, defined on the basis of arguments.*

The output *of the framework is a (complete or partial) pre-ordering* $\rhd_{Princ}$*, on* $\mathcal{X}$. $x_1 \rhd_{Princ} x_2$ *means that the decision* x_1 *is* at least as preferred as *the decision* x_2 *w.r.t. the* principle $Princ$.

Notation: Let A, B be two arguments of $\mathcal{A}$. If $\succeq$ is a pre-order, then $A \succeq B$ means that A is at least as 'strong' as B.
$\succ$ and $\approx$ will denote respectively the strict ordering and the relation of equivalence associated with the preference between arguments. Hence, $A \succ B$ means that A is strictly preferred to B. $A \approx B$ means that A is preferred to B and B is preferred to A.

Different definitions of $\succeq$ or different definitions of $\rhd_{Princ}$ may lead to different decision frameworks which may not return the same results.

In what follows, $\mathtt{Arg}(x)$ denotes the set of arguments in $\mathcal{A}$ which are in favor of x.
At the core of our framework is the use of a principle that allows for an argument-based comparison of decisions. Indeed, these principles capture different *profiles* of agents regarding decision making. Below we present one intuitive principle $Princ$, i.e agent profile. This principle, called *promotion focus* principle (Prom), prefers a choice that has at least one supporting argument which is preferred to (or stronger than) any supporting argument of the other choice. Formally:

Definition 4 (Promotion focus). *Let* $<\mathcal{X}, \mathcal{A}, \succeq, \lhd_{Prom}>$ *be an argumentation-based decision framework, and Let* $x_1, x_2 \in \mathcal{X}$.
$x_1 \rhd_{Prom} x_2$ *w.r.t* $Prom$ *iff* $\exists\, A \in \mathtt{Arg}(x_1)$ *such that* $\forall\, B \in \mathtt{Arg}(x_2)$, $A \succeq B$.

Obviously, this is a sample of the many principles that we may consider. Human deciders may actually use more complicated principles.

5 The strategic decision model

This section presents an instantiation of the above model in order to select the next move to utter. Let us recall the strategy problem. Let (a, x) be the current move in a dialog. What is the next move (a', x') to utter such that $a' \in \texttt{Replies}(a)$ and $x' \in \texttt{Content}(a)$? The strategic decision model will select among $\texttt{Replies}(a)$ the best act to utter, say a'. Thus, the set $\texttt{Replies}(a)$ will play the role of $\mathcal{X}$.
Let us now define the arguments in favor of each $d \in \texttt{Replies}(a)$. Those arguments are built from the strategic beliefs base $\mathcal{B}_s$ of the agent and its strategic goals base $\mathcal{G}_s$.

The idea is that a decision is justified and supported if it leads to the satisfaction of at least the most important goals of the agent, taking into account the most certain part of knowledge. Formally:

Definition 5 (Argument). *An* argument in favor of *a choice* d *is a triple* A = <S, g, d> *such that:*

- $d \in \texttt{Replies}(a)$
- $S \subseteq \mathcal{B}_s^*$ *and* $g \in \mathcal{G}_s^*$
- $S \cup \{d\}$ *is consistent*
- $S \cup \{d\} \vdash g$
- S *is minimal (for set inclusion) among the sets satisfying the above conditions.*

S *is the* support *of the argument,* g *is the* goal *which is reached by the choice* d*, and* d *is the* conclusion *of the argument. The set* $\mathcal{A}_s$ *gathers all the arguments which can be constructed from* <$\mathcal{B}_s$, $\mathcal{G}_s$, $\texttt{Replies}(a)$>.

Since the bases $\mathcal{B}_s$ and $\mathcal{G}_s$ are weighted, arguments in favor of a decision are more or less strong.

Definition 6 (Strength of an Argument). *Let* A = <S, g, d> *be an argument in* $\mathcal{A}_s$. *The* strength *of* A *is a pair* <$Level_s(A)$, $Weight_s(A)$> *such that:*

- *The* certainty level *of the argument is* $Level_s(A)$ = *min*$\{\rho_i \mid k_i \in S$ *and* $(k_i, \rho_i) \in \mathcal{B}_s\}$. *If* $S = \emptyset$ *then* $Level_s(A)$ = *1.*
- *The* degree of satisfaction *of the argument is* $Weight_s(A) = \lambda$ *with* $(g, \lambda) \in \mathcal{G}_s$.

Then, strengths of arguments make it possible to compare pairs of arguments as follows:

Definition 7. *Let* A *and* B *be two arguments in* $\mathcal{A}_s$. A *is* preferred *to* B*, denoted* $A \succeq_s B$*, iff min(*$Level_s(A)$, $Weight_s(A)$*)* $\geq$ *min(*$Level_s(B)$, $Weight_s(B)$*).*

Property 1. The relation $\succeq_s$ is a complete preorder ($\succeq_s$ is reflexive and transitive).

Now that the arguments defined, we are able to present the strategic decision model which will be used to return the best reply a' at each step of a dialog.

Definition 8 (Strategic decision model). *A* strategic decision model *is a tuple* <$\texttt{Replies}(a)$, $\mathcal{A}_s$, $\succeq_s$, $\rhd_{Princ}$>.

According to the agent profile, a principle $\rhd_{Princ}$ will be chosen to compare decisions. If for instance, an agent is pessimistic then it will select the Prom priciple and thus the decisions are compared as follows:

Definition 9. *Let* a_1, $a_2 \in \texttt{Replies}(a)$. $a_1 \rhd_{Prom} a_2$ *w.r.t* $Prom$ *iff* $\exists\ A \in \texttt{Arg}(a_1)$ *such that* $\forall\ B \in \texttt{Arg}(a_2)$, $A \succeq_s B$.

Property 2. The relation $\rhd_{Prom}$ is a complete preorder.

Since the above relation is a complete preorder, it may be the case that several choices will be equally preferred. The most preferred ones will be returned by the function `Best`.

Definition 10 (Best decisions). *The set of best decisions is* $\texttt{Best}(\texttt{Replies}(a)) = \{a_i \in \texttt{Replies}(a), s.t. \forall\ a_j \in \texttt{Replies}(a),\ a_i \rhd_{Prom} a_j\}$.

Property 3. If $\mathcal{A}_s = \emptyset$, then $\texttt{Best}(\texttt{Replies}(a)) = \emptyset$.

Note that when the set of arguments is empty, then the set of best decisions is also empty. This means that all the decisions are equally preferred, and there is no way to choose between them. In such a situation, the decision maker chooses one randomly.

Definition 11 (Best move). *The best move to play (or the next reply in a dialog) is* a' $\in \texttt{Best}(\texttt{Replies}(a))$.

6 The functional decision model

Once the speech act to utter selected by the previous strategic decision model, say a' $\in \texttt{Best}(\texttt{Replies}(a))$, one should select its content if necessary among the elements of $\texttt{Content}(a')$. Here $\texttt{Content}(a')$ depends on the nature of the selected speech act. For instance, if the selected speech act is an “Offer”, then $\texttt{Content}(a')$ will contain different objects such as prices if the agents are negotiating a price of a product, different towns if they are negotiating a place of the next holidays. Now, if the selected speech act is “Argue” which allows the exchange of arguments, then the content of this act should be an argument, thus $\texttt{Content}(a')$ will contain the possible arguments. In any case, we suppose that $\texttt{Content}(a')$ contains a set of propositional formulas. Even in the case of a set of arguments, every argument will be refered to it by a propositional formula.

Arguments in favor of each element in $\texttt{Content}(a')$ are built from the basic beliefs base and the functional goals base.

Definition 12 (Argument). *An* argument in favor of *a choice* d *is a triple* A = $<S, g, d>$ *such that:*

- $d \in \texttt{Content}(a')$
- $S \subseteq \mathcal{B}_b^*$ *and* $g \in \mathcal{G}_f^*$
- $S \cup \{d\}$ *is consistent*
- $S \cup \{d\} \vdash g$
- S *is minimal (for set inclusion) among the sets satisfying the above conditions.*

S = $Support(A)$ is the support *of the argument, C = Consequences(A) its* consequences *(the goals which are reached by the decision d) and d = $Conclusion(A)$ is the conclusion of the argument. The set $\mathcal{A}_f$ gathers all the arguments which can be constructed from <$\mathcal{B}_b$, $\mathcal{G}_f$, $\mathcal{X}$>.*

The strength of these arguments is defined exactly as in the previous section by replacing the corresponding bases.

Definition 13 (Strength of an Argument). *Let A = <S, g, d> be an argument in $\mathcal{A}_f$. The* strength *of A is a pair <$Level_f(A)$, $Weight_f(A)$> such that:*

- *The* certainty level *of the argument is $Level_f(A)$ = min$\{\rho_i \mid k_i \in S$ and $(k_i, \rho_i) \in \mathcal{B}_b\}$. If $S = \emptyset$ then $Level_f(A)$ = 1.*
- *The* degree of satisfaction *of the argument is $Weight_f(A) = \lambda$ with $(g, \lambda) \in \mathcal{G}_f$.*

Then, strengths of arguments make it possible to compare pairs of arguments as follows:

Definition 14. *Let A and B be two arguments in $\mathcal{A}_f$. A is* preferred *to B, denoted $A \succeq_f B$, iff min($Level_f(A)$, $Weight_f(A)$) $\geq$ min($Level_f(B)$, $Weight_f(B)$).*

The arguments against decisions in $\mathcal{X}$ are defined in the same way as in the previous section. We have just to replace the base $\mathcal{B}_s$ by $\mathcal{B}_b$, $\mathcal{G}_s$ by $\mathcal{G}_f$ and $\texttt{Replies}(a)$ by $\mathcal{X}$. The functional model which computes the best content of a move is defined as follows:

Definition 15 (Functional decision model). *A* functional decision model *is a tuple <$\texttt{Content}(a')$, $\mathcal{A}_f$, $\succeq_f$, $\rhd_{Princ}$>.*

Again according to the agent profile, a principle $\rhd_{Princ}$ will be chosen to compare decisions. If for instance, an agent is pessimistic then it will select the Prom principle and thus the decisions are compared as follows:

Definition 16. *Let x_1, $x_2 \in \mathcal{X}$. $x_1 \rhd_{Prom} x_2$ w.r.t $Prom$ iff $\exists$ $A \in \texttt{Arg}(x_1)$ such that $\forall$ $B \in \texttt{Arg}_P(x_2)$, $A \succeq_f B$.*

Here again, the above relation is a complete preorder, and consequently several options may be equally preferred.

Definition 17 (Best decisions). *The set of best decisions is* $\texttt{Best}(\texttt{Content}(a'))$ = $\{x_i \in \texttt{Content}(a'), s.t. \forall\, x_j \in \texttt{Content}(a'),\, x_i \rhd_{Prom} x_j\}$.

The content x' to utter is an element of $\texttt{Best}(\texttt{Content}(a'))$ chosen randomly. Formally:

Definition 18 (Best move). *The best content is x' such that* $x' \in \texttt{Best}(\texttt{Content}(a'))$.

7 Computing the next move in a dialogue

In the previous section, we have presented a formal framework for explaining, oredering and making decisions. In what follows, we will show how that framework can be used for move selection. Let (a, x) be the current move of the dialogue, and an agent has to choose the next one, say (a', x'). The act a' is returned as a best option by the framework <$\texttt{Replies}(a)$, $\mathcal{A}_s$, $\succeq_s$, $\triangleright_{Prom}$> (i.e $a' \in \texttt{Best}(\texttt{Replies}(a))$), whereas the content x' is among the best options returned by the framework <$\texttt{Content}(a')$, $\mathcal{A}_f$, $\succeq_f$, $\triangleright_{Prom}$>, i.e. $x' \in \texttt{Best}(\texttt{Content}(a'))$.

The basic idea is to look for the best replies for an act a. In case there is no solution, the answer will be (?, ?) meaning that there is no rational solution. This in fact corresponds either to the situation the set of strategic goals is empty, or the case where no alternative among the allowed replies satisfies the strategic goals of the agent.

In case there is at least one preferred solution, one should look for a possible content. If there is no possible content, then the chosen act is removed and the same process is repeated with the remaining acts. Note that the case of the existence of a preferred act but no its content is explained by the fact that the strategic goals of the agent are not compatible with its functional goals. Moreover, two forms of incompatibilities are distinguished: *strong* incompatibility in which there is no act which can be accompanied with a content, and a *weak* incompatibility in which only some acts can be associated with contents. The above idea of computing the next move is skeched in the following algorithm:

Function 1 Computing the best move

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Parameters: a current move $(a, x)$, a theory $\langle \mathcal{X}, \mathcal{B}_s, \mathcal{B}_f, \mathcal{G}_s, \mathcal{G}_f \rangle$
$\mathcal{X} \leftarrow \texttt{Replies}(a)$;
failure $\leftarrow \bot$;
while $\mathcal{X} \neq \emptyset$ and $\neg$ failure do
    if $\texttt{Best}(\mathcal{X}) = \emptyset$ then
        failure $\leftarrow \top$;
        return $(?, ?)$;
    else $a' \in \texttt{Best}(\texttt{Replies}(a))$ of the argumentation system $\langle \texttt{Replies}(a), \mathcal{A}_s, \succeq_s, \triangleleft_{Prom} \rangle$ (a' is chosen randomly);
        if $\texttt{Content}(a') = ?$ then
            failure $\leftarrow \top$;
            return $(a', ?)$;
        else
            if $\texttt{Best}(\texttt{Content}(a')) = \emptyset$ (best decisions of the argumentation system $\langle \texttt{Content}(a'), \mathcal{A}_f, \succeq_f, \triangleleft_{Prom} \rangle$); then
                $\mathcal{X} \leftarrow \mathcal{X} - \{a'\}$;
            else
                failure $\leftarrow \top$;
                return $(a', x')$ with $x' \in \texttt{Content}(a')$;
```

The following properties can be shown:

Property 4. If $\mathcal{G}_s = \emptyset$, or $\mathcal{B}_s = \emptyset$, then the next move is (?, ?).

8 Illustrative example

To illustrate the formal model, we will present an example of auction protocols, the Dutch auction, which is used in the implementation of the fish market interaction protocol [4].

The idea here is that seller S wants to sell an item using an auction. A number of potential buyers $B_1, \dots, B_n$, called also bidders, participate in rounds of auctions. There is at least one round for each item during, which the auctioneer counts down the price for the item and buyers simply send a signal to say if they want to bid at the current price or not.

In the context of fish market, the protocol is indeed, organized in terms of rounds. At each round, the seller proposes a price for the item. If there is no bidder then the price is lowered by a set amount until a bid is received. However, if the item reaches its reserve price the seller declares the item withdrawn and closes the round. If there is more than one bid, the item is not sold to any buyer, and the seller restarts the round at a higher price. Otherwise, if there is only one bid submitted at the current price, the seller atributes the item to that buyer. In this protocol, the set of allowed moves is then:

$$S = \{Offer, \mathit{Accept}, Pass, \mathit{Attribute}, Withdraw\}$$

The first move allows the seller to propose prices, the second move allows buyers to bid i.e to accept current price, the move $Pass$ allows also the buyers to pass their turn by saying nothing, the move $\mathit{Attribute}$ allows the seller to attibute the item to the selected buyer, and the last move $Withdraw$ allows the seller to withdraw the item from the auction. The following possible replies are also given by the protocol:

$\mathit{Replies}(Offer) \subseteq \{\mathit{Accept}, Pass\}$
$\mathit{Replies}(\mathit{Accept}) \subseteq \{Offer, \mathit{Attribute}\}$
$\mathit{Replies}(Pass) \subseteq \{Offer, Withdraw\}$
The dialog starts always by a move $Offer$ uttered by the seller.

The seller has a strategic goal which consists of minimizing the auction time. This goal is stored in the strategic goal base of the agent.

$$\mathcal{G}_s^S = \{(min\_time, 0.8)\}$$

This agent has some strategic beliefs such as: if the time spent in the round is higher than a certain bound $time\_bound$ then it should stop the auction.

$$\mathcal{B}_s^S = \{(time\_spent > time\_bound \land Withdraw \to min\_time, 1), (time\_spent < time\_bound \land Offer \to min\_time, 1), (time\_spent < time\_bound \land \mathit{Attribute} \to min\_time, 1)(time\_spent > time\_bound \land Offer \to \neg min\_time, 1)\}$$

The seller has also some functional goals. The first one consist of maximizing its gain $max - gain$. Moreover, a seller has a starting price and also a reserve price which represents the minimum amount that it will accept for the item. Thus a functional goal of this agent would be to have a price at least equal to the reserve price, $good - price$.

$$\mathcal{G}_f^S = \{(good\_price, 1)\}$$

The functional beliefs of the seller are given in its beliefs base:

$$\mathcal{B}_f^S = \{(current\_price > reserve\_price \wedge Offer(current\_price) \rightarrow good\_price, 1), (current\_price > reserve\_price \wedge Attribute(current\_price) \rightarrow good\_price, 1), (current\_price < reserve\_price \wedge Offer(current\_price) \rightarrow \neg good\_price, 1)\}$$

Regarding the buyers, the aim of B_1 is to get the item for the lowest possible price $cheap$ at most at $bound\_price$, and the aim of B_2 is to get the item for the lowest possible price max_profit at most at $bound\_price/2$, that is the agent B_2 bid for the current price only when he could make at least 100% profit on the item. These last are functional goals of the buyers since it concerns the subject of the negotiation. For the sake of simplicity, these agents do not have strategic beliefs and goals.

$$\mathcal{G}_f^{B_1} = \{(cheap, 0.8), (buy, 0.7)\}$$
$$\mathcal{G}_f^{B_2} = \{(max\_profit, 0.8), (buy, 0.7)\}$$

The buyers are supposed to have the following beliefs.

$$\mathcal{B}_f^{B_1} = \{(current\_price < bound\_price \wedge Accept(current\_price) \rightarrow cheap, 1), (current\_price < bound\_price \wedge Accept(current\_price) \rightarrow buy, 1), (current\_price > bound\_price \wedge Accept(current\_price) \rightarrow \neg buy, 1), (current\_price > bound\_price \wedge Accept(current\_price) \rightarrow \neg cheap, 1), (current\_price > bound\_price \wedge Pass \rightarrow \neg buy, 1)\}$$

$$\mathcal{B}_f^{B_2} = \{(current\_price < bound\_price/2 \wedge Accept(current\_price) \rightarrow max\_profit, 1), (current\_price < bound\_price/2 \wedge Accept(current\_price) \rightarrow buy, 1), (current\_price > bound\_price/2 \wedge Accept(current\_price) \rightarrow \neg buy, 1), (current\_price > bound\_price/2 \wedge Accept(current\_price) \rightarrow \neg max\_profit, 1), (current\_price > bound\_price/2 \wedge Pass \rightarrow \neg buy, 1)\}$$

Let us now consider the following dialog between the seller S and the two buyers B_1 and B_2:

$S : Offer(current\_price)$. In this case, the only possible move to the agent is $Offer$. Indeed, this is required by the protocol. An agent should select the content of that move. Here again, the agent has a starting price so it will present it. At this stage, the agent does not need its decision model in order to select the move.

$B_1 and B_2 : Accept(current\_price)$. In this case, the $current\_price$ is lower than $bound\_price/2$ for the agents. The agents have an argument in favor of $Accept$. In this case, they will choose $Accept$.

$S : Offer(current\_price)$. In this case, the item is not sold to any buyer since there is more than one bid. The seller restarts the round at a higher price. Indeed, this is required by the protocol. The only possible move to the agent is $Offer$. An agent should select the content of that move. Here again, the agent has a higher price so it will present it as the cuurent price. At this stage, the agent does not need its decision model in order to select the move. Let'us suppose that the $bound\_price/2 < current\_price < bound\_price$.

B_1 : $Accept(current\_price)$. In this case, the current price $current\_price$ is lower than the price bound of the agent. In this case the agent has an argument in favor of $Accept$ because this will support its important goal $cheap$. In this case, the agent will choose $Accept$.

B_2 : $Pass$. In this case, the current price $current\_price$ is higher than $bound\_price/2$, and then the agent could not make 100% profit on the item. In this case the agent has a counter argument again $Accept$ because this will violate its important goal max_profit, and no arguments in favor of it. However, it has an argument in favor of $Pass$ since it will not violate the important goal. In this case, the agent will choose $Pass$.

S : $Attribute(current\_price)$. The only possible move of the agent is $Attribute$. Inded this is required by the protocol since there is only one bidder submitted at the current price. Moreover, the current price is higher than the reserve price. In this case the seller has an argument in favor of the content $current\_price$ since this will support its important goal $good\_price$. The seller decides then to attribute the item to the bidder B_1 and closes the round.

9 Conclusion

A considerable amount of work has been devoted to the study of dialogs between autonomous agents and to development of formal models of dialog. In most works, the definition of a protocol poses no problems and several dialog protocols have been defined even for particular applications. However, the situation is different for dialog strategies. There are very few attemps for modeling strategies. Indeed, there is no methodology and no formal models for defining them. There is even no consensus on the different parameters involved when defining a strategy.

This paper claims that during a dialog, a strategy is used only for defining the next move to play at each step of the dialog. This amounts to define the speech act to utter and its content if necessary. The strategy is then regarded as a two steps *decision process*: among all the replies allowed by the protocol, an agent should select the best speech act to play, then it should select the best content for that speech act.

The idea behind a decision problem is to define an ordering on a set of choices on the basis of the beliefs and the goals of the agent. We have argued in this paper that selecting a speech act and selecting a content of a speech act involve two different kinds of goals and two different kinds of beliefs. Indeed, an agent may have strategic goals which represent the meta-level goals of the agents about the whole dialog. An agent may have also functional goals which are directly related to the subject of the dialog. Similarly, an agent may have strategic beliefs which are meta-level beliefs about the dialog, the other agents, etc. It may also have some basic beliefs about the subject of the dialog. We have shown that the choice of the next speech is based on the strategic beliefs and the strategic goals, whereas the choice of the content is based on the basic beliefs and the functional goals.

We have then proposed a formal framework for defining strategies. This framework can be regarded as two separate systems: one of them take as input the possible replies allowed by a protocol, a set of strategic beliefs and a set of strategic goals and returns the best speech act, and the second system takes as input a set of alternatives, a set of basic beliefs and a set of functional goals and returns the best content of a speech act. The two systems are grounded on argumentation theory. The basic idea behind each system is to construct the arguments in favour and against each choice, to compute the strength of each argument and finally to compare pairs of choices on the basis of the quality of their supporting arguments. We have shown also the agents profiles play a key role in defining principles for comparing decisions. In this paper we have presented two examples: pessimistic agents which represent very cautious agents and optimistic agents which are adventurous ones.

An extension of this work would be to study more deeply the links between the strategic and the functional goals of an agent. In this paper, we suppose implicitly that there are coherent. However, in reality it may be the case that an agent has a strategic goal which is incompatible with a functional one. Let us take the example of an agent negotiating the price of a car. This agent may have as a strategic goal to sell at the end of the dialog. It may have also the goal of selling his car with highest price. These two goals are not compatible since if the agent wants really to sell at the end its car, it should reduce the price.

References

1. L. Amgoud. A general argumentation framework for inference and decision making. In *Proceedings of the 21th Conference on Uncertainty in Artificial Intelligence*, pages 26–33, 2005.
2. L. Amgoud and N. Maudet. Strategical considerations for argumentative agents. In *Proc. of the* 10^{th} *International Workshop on Non-Monotonic Reasoning, session "Argument, Dialogue, Decision", NMR'2002*, 2002.
3. L. Amgoud and K. Souhila. On the study of negotiation strategies. In *In AAMAS 2005 Workshop on Agent Communication (AC05),*, pages 3–16, 2005.
4. P. Noriega P. Garcia J.A. Rodriguez, F.J Martin and C. Sierra. Towards a test-bed for trading agents in electronic auction markets. *AI communications, IOS Press*, 1999.
5. N. R. Jennings, P. Faratin, A. R. Lumuscio, S. Parsons, and C. Sierra. *Automated negotiation: Prospects, methods and challenges*. International Journal of Group Decision and Negotiation, 2001.
6. N. R. Jennings, E. H. Mamdani, J. Corera, I. Laresgoiti, F. Perriolat, P. Skarek, and L. Z. Varga. Using archon to develop real-word dai applications part 1. *IEEE Expert*, 11:64–70, 1996.
7. 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.
8. S. Kraus. Strategic negotiation in multi-agent environments. *MIT Press, USA*, 2001.
9. S. Kraus, K. Sycara, and A. Evenchik. *Reaching agreements through argumentation: a logical model and implementation*, volume 104. Journal of Artificial Intelligence, 1998.
10. P. Maes. Agents that reduce work and information overload. *Communication of the ACM*, 37(7):31–40, 1996.
11. S. Parsons, C. Sierra, and N. R. Jennings. Agents that reason and negotiate by arguing. *Journal of Logic and Computation*, 8(3):261—292, 1998.
12. J. A. Rodriguez, P. Noriega, C. Sierra, and J. Padget. A java-based electronic auction house. In *Proceedings of the 2nd International Conference on the Practical Application of intelligent Agents and Multi-Agent Technology*, pages 207–224, 1997.

13. J. Rosenschein and G. Zlotkin. Rules of encounter: Designing conventions for automated negotiation among computers. *MIT Press, USA*, 1994.
14. K. Sycara. Persuasive argumentation in negotiation. *Theory and Decision*, 28:203–242, 1990.
15. D. N. Walton and E. C. W. Krabbe. *Commitment in Dialogue: Basic Concepts of Interpersonal Reasoning*. State University of New York Press, Albany, NY, 1995.
16. M. P. Wellman. A market-oriented programming environment and its application to distributed multicommodity flow problems. *Artificial Intelligence and Research*, 1:1–23, 1993.
17. M. J. Wooldridge and N.R. Jennings. Intelligent agents: theory and practice. *The Knowledge Engineering Review*, 10:115–152, 1995.