An argumentation-based framework for designing dialogue strategies

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Abstract. A dialogue strategy is the set of rules followed by an agent when choosing a move (act + content) during a dialogue. This paper argues that a strategy is decision problem in which an agent selects i) among the acts allowed by the protocol the best option that, according to some *strategic beliefs* of the agent will at least satisfy the most important *strategic goals* of the agent, and ii) 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 a formal framework based on argumentation for computing the best move to play at a given step of the dialogue.

1 INTRODUCTION

A dialogue protocol identifies the different possible replies after a given act. However, the exact act to utter at a given step of the dialogue is a *strategy* matter. A strategy can be seen as a two steps *decision process*: i) among all the possible replies allowed by the protocol, to choose the move to play. ii) to choose the content of the move if any. In most works on modeling dialogues, the definition of a protocol poses no problems. However, the situation is different for dialogue strategies. There is no formal models for defining them. There is even no consensus on the different ingredients involved when defining a strategy. 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, the content of a move.

We propose a formal argumentation-based framework for defining strategies. This framework 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 use a *criterion* to compare pairs of alternatives on the basis of the quality of their supporting arguments.

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2 AGENT'S MENTAL STATES

Two different kinds of goals are involved when selecting the next act to play and its content:

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 dialogue time", "selling at the end of the dialogue", etc. Suppose that at a given step of a negotiation dialogue, an agent has to choose between making an offer and asking a question. If the agent wants to minimize the dialogue 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. These goals are generally independent of the *subject* of the dialogue.

Functional goals: The goals of the agent which are directly related to the subject of the dialogue are called *functional goals*. They represent what an agent wants to achieve or to get regarding the subject of the dialogue. 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.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 (selecting an act and a content) are also of different nature:

Strategic beliefs: which are the meta-level beliefs of the agent. They may represent the beliefs of the agent about the dialogue and about the other agents involved in the dialogue. In negotiation dialogues 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.

Basic beliefs: represent the beliefs of the agent about the environment and the subject of the dialogue. 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.

3 THE LOGICAL LANGUAGE

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

$\mathcal{B}_f = \{(k_p, \rho_p), p = 1, s\}$ where $k_p \in Wff(\mathcal{L})$, is the basic beliefs. The beliefs 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.

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

$\mathcal{G}_s = \{(g_q, \lambda_q), q = 1, t\}$ 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.

$\mathcal{G}_f = \{(go_r, \gamma_r), r = 1, v\}$ 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 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 $\mathcal{B}_f^*$, $\mathcal{B}_s^*$, $\mathcal{G}_s^*$, $\mathcal{G}_f^*$ the corresponding sets when weights are ignored.

Let $\mathcal{S}$ be the set of speech acts allowed by the protocol. Let us suppose that the function $\texttt{Replies}$: $\mathcal{S} \longmapsto 2^{\mathcal{S}}$ returns for each act, all the legal replies to it. 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 have an empty content, denoted by the symbol ?. The function $\texttt{Content}$: $\mathcal{S} \longmapsto \mathcal{L} \cup$? returns for a given act the set of its possible contents. During a dialogue, agents exchange *moves* which are pairs (a, x), where $a \in \mathcal{S}$ and $x \in \texttt{Content}(a)$. The strategy problem is formalized as follows: let (a, x) be the current move in a dialogue. 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 $\mathcal{B}_s^*$, whereas x' is the "best" element among $\texttt{Content}(a')$ that satisfies $\mathcal{G}_f^*$ according to $\mathcal{B}_f^*$.

4 THE ARGUMENTATION-BASED DECISION MODEL

Solving a decision problem amounts to defining a pre-ordering, usually a complete one, on a set $\mathcal{X}$ of possible choices, on the basis of the different consequences of each decision. In our case, the set $\mathcal{X}$ may be either the set $\texttt{Replies}(a)$ of the possible replies to a move, or the set $\texttt{Content}(a')$ with a' is the chosen act. Recently, Amgoud [1] has shown that argumentation can provide such a pre-oredering.

Let $\mathcal{B}$ be any *consistent* and *weighted* beliefs base, and $\mathcal{G}$ be a *consistent* prioritized base of goals. $\mathcal{B}^*$ and $\mathcal{G}^*$ will denote the corresponding sets when weights are ignored. From these bases, different arguments in favor of elements of $\mathcal{X}$ can be built. 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. An *argument in favor of* a choice $x \in \mathcal{X}$ is a triple $A = <S, g, x>$ such that $S \subseteq \mathcal{B}^*$, $g \in \mathcal{G}^*$, $S \cup \{x\}$ is consistent, $S \cup \{x\} \vdash g$, and 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 decision x and x is the *conclusion* of the argument. The set $\mathcal{A}(\mathcal{B}, \mathcal{G}, \mathcal{X})$ gathers all the arguments which can be constructed from $\mathcal{B}$, $\mathcal{G}$ and $\mathcal{X}$. $\texttt{Arg}(x)$ is the set of arguments whose conclusion is x.

Property 1 *If $\mathcal{B} = \emptyset$, or $\mathcal{G} = \emptyset$, then $\mathcal{A}(\mathcal{B}, \mathcal{G}, \mathcal{X}) = \emptyset$.*

Since an argument involves two kinds of information (beliefs and goals), its strength depends on the quality of both information. Thus, to each argument we associate a certainty level representing the degree of the less entrenched belief used in it, and a weight representing the importance of the goal reached by the conclusion of that argument. The *strength* of an argument $A = <S, g, x>$ is a pair $<Level(A), Weight(A)>$ such that: i) $Level(A) = \min\{\rho_i \mid k_i \in S$ and $(k_i, \rho_i) \in \mathcal{B}\}$. If $S = \emptyset$ then $Level(A) = 1$. It represents the *certainty level* of the argument. ii) $Weight(A) = \lambda$ with $(g, \lambda) \in \mathcal{G}$. It represents the *degree of satisfaction* of the argument. The strengths of arguments make it possible to compare pairs of arguments in several ways, depending on whether the agent gives the same importance to the certainty level and the weight or not. For the purpose of illustration, let us consider the following particular criterion in which goals take precedence over beliefs: let A and B be two arguments in $\mathcal{A}(\mathcal{B}, \mathcal{G})$. A is *preferred* to B, denoted $A \succeq B$, iff $Weight(A) > Weight(B)$, or $Weight(A) = Weight(B)$ and $Level(A) \geq Level(B)$. At the core of our framework is the use of a *principle* that allows for an argument-based comparison of alternatives. Each combination of a principle with a criterion for comparing arguments captures a particular agent *profile*, thus a particular strategy for selecting moves in a dialogue.

Below we present an example of a principle that takes as input the supporting arguments and prefers an alternative which has at least one supporting argument which is preferred to any supporting argument of the other alternative. Formally, let $x, x' \in \mathcal{X}$. x is preferred to x', denoted $x \rhd x'$, iff $\exists\, P \in \texttt{Arg}(x)$ s.t. $\forall\, P' \in \texttt{Arg}(x')$, $P \succeq P'$.

Property 2 *$\succeq$ and $\rhd$ are total preorder relations i.e. reflexive and transitive.*

An *argumentation-based decision framework* is a tuple $<\mathcal{X}, \mathcal{A}(\mathcal{B}, \mathcal{G}, \mathcal{X}), \succeq, \rhd>$ where $\mathcal{X}$ is a set of all possible decisions, $\mathcal{A}(\mathcal{B}, \mathcal{G}, \mathcal{X})$ is a set of arguments built from $\mathcal{B}$, $\mathcal{G}$ and $\mathcal{X}$, $\succeq$ is a (partial or complete) pre-ordering on $\mathcal{A}(\mathcal{B}, \mathcal{G}, \mathcal{X})$, and $\rhd$ defines a (partial or complete) pre-order on $\mathcal{X}$. This framework can be used for move selection. Indeed, let $\mathcal{X}$ be a set of possible decisions. The set of best decisions is $\texttt{Best}(\mathcal{X}) = \{x \in X, s.t. \forall\, x' \in \mathcal{X}, x \rhd x'\}$.

Property 3 *If $\mathcal{A}(\mathcal{B}, \mathcal{G}, \mathcal{X}) = \emptyset$, then $\texttt{Best}(\mathcal{X}) = \emptyset$.*

Now, 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 $<\texttt{Replies}(a), \mathcal{A}(\mathcal{B}_s, \mathcal{G}_s, \texttt{Replies}(a)), \succeq, \rhd>$ (i.e. $a' \in \texttt{Best}(\texttt{Replies}(a))$), whereas the content x' is among the best options returned by the framework $<\texttt{Content}(a'), \mathcal{A}(\mathcal{B}_f, \mathcal{G}_f, \texttt{Content}(a')), \succeq, \rhd>$, i.e. $x' \in \texttt{Best}(\texttt{Content}(a'))$.

Property 4 *If $\mathcal{G}_s = \emptyset$, or $\mathcal{B}_s = \emptyset$, then the next move is (?, ?) meaning that there is no rational solution.*

5 CONCLUSION

This paper claims that during a dialogue, a strategy is used only for defining the next move to play at each step of the dialogue. 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. We have shown that the choice of the next speech act 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 based on argumentation. We have shown also the agents profiles play a key role in defining principles for comparing decisions.

REFERENCES

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