

A formal model for designing dialogue strategies

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ABSTRACT

Modeling different types of dialogue between autonomous agents is becoming an important research issue. Several proposals exist with a clear definition of the dialogue protocol, which is the set of rules governing the high level behaviour of the dialogue. 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 two steps *decision* process: i) to select the type of act to utter at a given step of a dialogue, and ii) to select the content which will accompany the act. The first step consists of selecting 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 step consists of selecting among different alternatives (eg. different offers), the best one which, 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 dialogue.

Categories and Subject Descriptors

I.2.3 [Deduction and Theorem Proving]: Nonmonotonic reasoning and belief revision

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

General Terms

Human Factors, Theory

Keywords

Dialogue, Strategies

1. INTRODUCTION

In a multi-agent system, agents need the ability to engage in *dialogues* such as the ones identified in [4], namely persuasion and

negotiation. Work in the literature has focused on defining formal models for dialogues. Generally, a dialogue system contains the following three components: the agents involved in the dialogue (i.e their *mental states* and reasoning capabilities), a *protocol*, and a set of *strategies*. The dialogue protocol is the set of *rules of encounter* governing the high-level behavior of interacting agents. A protocol defines: i) the set of permissible acts (eg. asking questions, making offers, etc.); ii) the legal replies for each act. Indeed, a protocol identifies the different possible replies after a given act. However, the exact act as well as a possible content to utter at a given step of the dialogue is a *strategy* matter. While the protocol is a public notion, strategy is crucially an individualistic matter. In most works on modeling dialogues, the definition of a protocol poses no problems. However, the situation is different for dialogue strategies. There are very few works on strategies [3, 2]. 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.

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.

2. AGENT'S MENTAL STATES

Two 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

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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 an 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 its 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, about the other agents involved in the dialogue, and about ways for reaching the strategic goals. 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, the subject of the dialogue, and about ways for reaching the functional goals. 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 dialogue subject such as the meeting cannot be at the same time in London and in Tunisia.

3. THE LOGICAL LANGUAGE

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

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

$\mathcal{B}_s = \{(l_j, \delta_j), j = 1, m\}$ 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 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 classical propositions 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 dialogues, "Question" for asking questions, "Assert" for asserting information such as "the weather is beautiful", "Argue" for presenting arguments in persuasion dialogues, 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.

$$\text{Replies}: \mathcal{S} \longrightarrow 2^{\mathcal{S}}$$

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

DEFINITION 1 (MOVES). A move M is a pair (a, x) , where $a \in \mathcal{S}$ and $x \in Wff(\mathcal{L})$.

$\text{Act}(M) = a$ is a function which returns the speech act a , and $\text{Content}(M) = x$ is a function which returns the content x .

The strategy problem is formalized as follows:

DEFINITION 2 (THE STRATEGY PROBLEM). Let (a, x) be the current move in a dialogue. What is the next move (a', x') to utter such that $a' \in \text{Replies}(a)$ and $x' \in Wff(\mathcal{L})$?

To answer this question, one should find both a' and x' . Indeed, a' is the "best" element in $\text{Replies}(a)$ 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 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 (or alternatives), on the basis of the different consequences of each choice. In our case, the set $\mathcal{X}$ may be either the set $\text{Replies}(a)$ of the possible replies to a move, or the set $\text{Content}(a')$ with a' is the chosen act. Argumentation can provide such a pre-ordering. 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. The basic idea behind an argumentation-based approach is to construct *arguments* in favor of each alternative from the different bases, to evaluate such arguments, and finally to apply some criterion or principle for comparing the alternatives on the basis of the arguments and their quality or strengths.

Let $\mathcal{B} = \{(b_i, \alpha_i), i = 1, \dots, n\}$ be any *consistent* and *weighted* beliefs base, and $\mathcal{G} = \{(g_j, \beta_j), j = 1, \dots, m\}$ 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 choice is justified and supported if it leads to the satisfaction of at least one goal of the agent, taking into account its beliefs. Formally:

DEFINITION 3 (ARGUMENT). An argument in favor of a choice x is a triple $A = \langle S, g, x \rangle$ such that:

- $S \subseteq \mathcal{B}^*$, $g \in \mathcal{G}^*$, and $x \in \mathcal{X}$
- $S \cup \{x\}$ is consistent
- $S \cup \{x\} \vdash g$
- 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 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 $\mathcal{X}$. $\text{Arg}(x)$ is the set of arguments whose conclusion is x .

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

DEFINITION 4 (STRENGTH OF AN ARGUMENT). Let $A = \langle S, g, x \rangle$ be an argument in $\mathcal{A}(\mathcal{B}, \mathcal{G})$. The strength of A is a pair $\langle \text{Level}(A), \text{Weight}(A) \rangle$ such that:

- $\text{Level}(A) = \min\{\rho_i \mid k_i \in S \text{ and } (k_i, \rho_i) \in \mathcal{B}\}$. If $S = \emptyset$ then $\text{Level}(A) = 1$. It represents the certainty level of the argument.
- $\text{Weight}(A) = \lambda$ with $(\lambda, g) \in \mathcal{G}$. 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. The aim of this paper is not to give an exhaustive list of comparison criteria, but to show what are the main components that define a dialogue strategy. For the purpose of illustration, let us consider the following particular criterion in which goals take precedence over beliefs:

DEFINITION 5. Let A and B be two arguments in $\mathcal{A}(\mathcal{B}, \mathcal{G})$. A is preferred to B , denoted $A \succeq B$, iff:

- $\text{Weight}(A) > \text{Weight}(B)$, or
- $\text{Weight}(A) = \text{Weight}(B)$ and $\text{Level}(A) \geq \text{Level}(B)$

PROPERTY 1. The relation $\succeq$ is a total preorder, i.e. $\succeq$ is reflexive and transitive.

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:

DEFINITION 6. Let $x, x' \in \mathcal{X}$. x is preferred to x' , denoted $x \triangleright x'$, iff $\exists P \in \text{Arg}(x)$ s.t. $\forall P' \in \text{Arg}(x')$, $P \succeq P'$.

PROPERTY 2. The relation $\triangleright$ is a total preorder.

DEFINITION 7 (BEST DECISIONS). Let $\mathcal{X}$ be a set of possible decisions. The set of best decisions is $\text{Best}(\mathcal{X}) = \{x \in \mathcal{X}, \text{s.t. } \forall x' \in \mathcal{X}, x \triangleright x'\}$.

DEFINITION 8 (ARGUMENTATION-BASED DECISION FRAMEWORK). An argumentation-based decision framework is a tuple $\langle \mathcal{X}, \mathcal{A}(\mathcal{B}, \mathcal{G}, \mathcal{X}), \succeq, \triangleright \rangle$ 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 $\mathcal{A}(\mathcal{B}, \mathcal{G}, \mathcal{X})$.
- $\triangleright$ defines a (partial or complete) pre-order on $\mathcal{X}$.

5. COMPUTING THE NEXT MOVE IN A DIALOGUE

In the previous section, we have presented a formal framework for explaining, ordering 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 $\langle \text{Replies}(a), \mathcal{A}(\mathcal{B}_s, \mathcal{G}_s, \text{Replies}(a)), \succeq, \triangleright \rangle$ (i.e. $a' \in \text{Best}(\text{Replies}(a))$), whereas a content x' is among the best options returned by the framework $\langle \text{Content}(a'), \mathcal{A}(\mathcal{B}_f, \mathcal{G}_f, \text{Content}(a')), \succeq, \triangleright \rangle$, i.e. $x' \in \text{Best}(\text{Content}(a'))$.

6. CONCLUSION

This paper has 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 of 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.

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