SCISPACE
formerly Typeset

Open access • Book Chapter • DOI:10.1007/11861461_4

A formal general setting for dialogue protocols — Source link

Leila Amgoud, Sihem Belabbes, Henri Prade

Institutions: Centre national de la recherche scientifique

Published on: 12 Sep 2006 - Artificial Intelligence: Methodology, Systems, Applications

Topics: Argumentation theory

Related papers:

- A formal general setting for dialogue protocols
- Commitment in Dialogue: Basic Concepts of Interpersonal Reasoning
- Games That Agents Play: A Formal Framework for Dialogues between Autonomous Agents
- Optimal utterances in dialogue protocols
- A formal model for designing dialogue strategies

Share this paper:

View more about this paper here: https://typeset.io/papers/a-formal-general-setting-for-dialogue-protocols-1jy06wbycq

A Formal General Setting for Dialogue Protocols

Leila Amgoud, Sihem Belabbès, and Henri Prade

IRIT - CNRS, 118 route de Narbonne
31062 Toulouse Cedex 9, France
{amgoud, belabbes, prade}@irit.fr

Abstract. In this paper, we propose a general and abstract formal setting for argumentative dialogue protocols. We identify a minimal set of basic parameters that characterize dialogue protocols. By combining three parameters, namely the possibility or not of backtracking, the number of moves per turn and the turn-taking of the agents, we identify eight classes of protocols. We show that those classes can be reduced to three main classes: a 'rigid' class, an 'intermediary' one and a 'flexible' one. Although different proposals have been made for characterizing dialogue protocols, they usually take place in particular settings, where the locutions uttered and the commitments taken by the agents during dialogues and even the argumentation system that is involved are fixed. The present approach only assumes a minimal specification of the notion of dialogue essentially based on its external structure. This allows for protocol comparison and ensures the generality of the results.

Keywords: Protocol, Dialogue, Multi-agent systems.

1 Introduction

An important class of interactions between agents in multi-agent systems take the form of dialogues. There is a great variety of dialogues ranging from exchanges of pre-formatted messages to argumentation-based dialogues. In this latter category, Walton and Krabbe [1] distinguish six types of dialogue including negotiation, persuasion and information seeking. A key component for designing a dialogue system is its *protocol*. A protocol is a set of rules that govern the well-behaviour of interacting agents in order to generate dialogues. It specifies for instance the set of speech acts allowed in a dialogue and their allowed types of replies. A research trend views dialogues as dialogue games [2,3], where the agents are considered as playing a game with personal goals and a set of moves (i.e. instantiated speech acts) that can be used to try to reach those goals. Once a protocol has been fixed, choosing among moves is a strategy problem. While a protocol is a public notion independent of any mental state of the agents, a strategy is crucially an individualistic matter that refers to their personal attitude (being cooperative or not) and to their knowledge, in order to optimize their benefits w.r.t. their preferences.

Various dialogue protocols can be found in the literature, especially for persuasion [4,5] and negotiation [6,7,8,9,10,11,12] dialogues. A natural question then emerges about how to compare or categorize the existing dialogue protocols,

J. Euzenat and J. Domingue (Eds.): AIMSA 2006, LNAI 4183, pp. 13–23, 2006.
© Springer-Verlag Berlin Heidelberg 2006

and more generally to characterize the minimal features that should be fixed for defining a protocol. This problem has been tackled in different ways. For instance in [13], dialogue protocols have been informally specified in terms of commencement, combination and termination rules. They have been compared essentially on the basis of the locutions uttered and the commitments taken by the agents during the generated dialogues. Subsequently and exploiting the same idea, dialogue protocols have been represented as objects of a category theory where the locutions and commitments are considered as morphisms [14].

In [15], a formal framework for persuasion dialogues have been proposed. The coherence of persuasion dialogues is ensured by relating a so-called 'reply structure' on the exchanged moves to the proof theory of argumentation theory [16]. This allows some flexibility on the structure of protocols regarding the turn-taking of the agents or the relevance of the moves.

The general setting that we propose in this paper can constitute the basis of further dialogue systems formalization. Namely, from a minimal set of basic parameters, eight classes of dialogue protocols are identified then further clustered in three main categories : a 'rigid' class, an 'intermediary' one and a 'flexible' one. This classification of protocols is essentially obtained by comparing the structure of the dialogues that they can generate, which in turn depends on the values of the basic parameters.

For instance, most of game-theoretic negotiation protocols such as bargaining [17], contract net [18] or e-commerce [19,20] are rather simple since agents only exchange offers and counter-offers[1]. Thus they can be classified in the rigid class. On the contrary, protocols for argumentative dialogues [21,22] are more complex since agents not only put forward propositions, they also try to persuade one another about their validity through arguments. Arguments may be defeated thus it would be preferable to allow agents to try other argumentative tactics. Thus such protocols need more flexibility to be handled such as the ability of backtracking or playing several moves at the same turn.

Therefore, when dealing with some dialogue type, it would be enough to instantiate the proposed parameters, and to refer to a convenient protocol from one of the main identified classes. This would help to compare, for instance, negotiation approaches which is up to now undone.

This paper is organized as follows: Section 2 proposes the basic parameters that define a formal model for dialogue protocols. Section 3 studies the classes of protocols obtained by combining the parameters, and shows their relationships. Finally, Section 4 provides some discussions of related works w.r.t. the classes of protocols and concludes.

2 A Formal Setting for Dialogue Protocols

A protocol is a set of rules that govern the construction of dialogues between agents. Those rules come from fixing a set of *basic parameters* common to all

[1] Although those models focus on the design of appropriate strategies rather than complex protocols.

argumentative dialogue protocols. Different definitions of the parameters lead to distinct protocols that may generate structurally different dialogues.

We identify seven parameters considered as essential for defining any dialogue protocol, denoted by π, as a tuple $\pi = \langle \mathcal{L}, SA, Ag, \texttt{Reply}, \texttt{Back}, \texttt{Turn}, \texttt{N\_Move} \rangle$ where:

1. $\mathcal{L}$ is a *logical language*. Let Wff($\mathcal{L}$) be the set of well-formed formulas of $\mathcal{L}$, and Arg($\mathcal{L}$) the set of *arguments*[2] that can be built from $\mathcal{L}$.
2. SA is a set of *speech acts* or *locutions* uttered in a dialogue. Examples of speech acts are '*offer*' for making propositions in a negotiation dialogue, '*assert*' for making claims and '*argue*' for arguing in a persuasion dialogue.
3. $Ag = \{a_1, \ldots, a_n\}$ is a set of agents involved in a dialogue.
4. $\texttt{Reply} : SA \longrightarrow 2^{SA}$ is a function associating to each speech act its expected replies. For instance, a challenged claim needs to be replied to by an argument.
5. $\texttt{Back} \in \{0, 1\}$ is a variable such that $\texttt{Back} = 1$ (resp. 0) means that the protocol allows (resp. or not) for backtracking. This notion consists of replying to moves (i.e. speech acts with their contents) uttered at any earlier step of the dialogue, and not only to the previous one. If backtracking is forbidden, then a move is restricted to be a reply to the move uttered just before it. Backtracking may take two forms [15]:
   - *Alternative replies*: An agent may give some reply to a move and later in the dialogue it decides to change this reply by uttering an alternative one.
   - *Postponed replies*: An agent may delay its reply to some move to a later step of the dialogue because it prefers first replying to another move.
6. $\texttt{Turn} : \mathcal{T} \longrightarrow Ag$ is a function governing the turn-taking of the agents, where $\mathcal{T} = \{t_1, \ldots, t_k, \cdots \mid t_i \in \mathbb{N}, t_i < t_{i+1}\}$ is the set of turns taken by the agents. Most of existing protocols consider that the agents take turns during the generated dialogues. However, it is interesting to consider other turn-taking patterns:
   - *Take turns*: The turns shift uniformly to all the agents,
   - *Do not take turns*: The turns shift erratically, w.r.t. some given rules.
7. $\texttt{N\_Move} : \mathcal{T} \times Ag \longrightarrow \mathbb{N}$ is a function determining at each turn and for each agent the number of moves that it is allowed to perform at that turn. It is defined as $\forall (t_i, a_j)$, $\texttt{N\_Move}(t_i, a_j) > 0$ iff $\texttt{Turn}(t_i) = a_j$. The opportunity of playing several moves per turn is well illustrated by argumentation-based negotiation dialogues. Indeed, an agent may propose an offer and arguments in its favour at the same turn in order to convince its peers [9].

Note that the above definition of Turn as a mapping from $\mathcal{T}$ to Ag covers the special case where the agents take turns:

Proposition 1. *Let $Ag = \{a_1, \ldots, a_n\}$. If $\forall t_i \in \mathcal{T}$, $\texttt{Turn}(t_i) = a_{i \textit{ modulo } n}$, then the agents take turns (supposing without loss of generality that agent a_1 plays first, at turn t_1).*

[2] An argument is a reason to believe statements. Several definitions of arguments exist. See [23] for more details.

Similarly, the definition of $\texttt{N\_Move}$ includes the particular case where the agents perform exactly one move per turn:

Proposition 2. *If* $\forall t_i \in \mathcal{T}$, $\forall a_j \in Ag$, $\texttt{Turn}(t_i) = a_j$ *and* $\texttt{N\_Move}(t_i, a_j) = 1$, *then the agents play exactly one move per turn.*

Protocols govern the construction of dialogues. Before defining that notion of dialogue, let us first introduce some basic concepts such as: *moves* and *dialogue moves.*

Definition 1 (Moves). *Let* $\pi = \langle \mathcal{L}, SA, Ag, \texttt{Reply}, \texttt{Back}, \texttt{Turn}, \texttt{N\_Move}\rangle$ *be a protocol. A* move m *is a pair* $m = (s, x)$ *s.t.* $s \in SA$, $x \in Wff(\mathcal{L})$ *or* $x \in Arg(\mathcal{L})$. *Let* $\mathcal{M}$ *be the set of moves that can be built from* $\langle SA, \mathcal{L}\rangle$. *The function* $\texttt{Speech}$ *returns the speech act of the move* m ($\texttt{Speech}(m) = s$), *and* $\texttt{Content}$ *returns its content* ($\texttt{Content}(m) = x$).

Some moves may not be allowed. For instance, a speech act '*offer*' is usually used for exchanging offers in negotiation dialogues. Thus, sending an argument using this speech act is not a '*well-formed*' move. This is captured by a mapping as follows:

Definition 2 (Well-formed moves). *Let* $\texttt{WFM} : \mathcal{M} \longrightarrow \{0, 1\}$. *A move* $m \in \mathcal{M}$ *is* well-formed *iff* $\texttt{WFM}(m) = 1$.

A second basic concept is that of '*dialogue move*'.

Definition 3 (Dialogue moves). *Let* $\pi = \langle \mathcal{L}, SA, Ag, \texttt{Reply}, \texttt{Back}, \texttt{Turn}, \texttt{N\_Move}\rangle$ *be a protocol. A* dialogue move M *in the set of all dialogue moves denoted* DM, *is a tuple* $\langle S, H, m, t\rangle$ *such that:*

- $S \in Ag$ *is the agent that utters the move, given by* $\texttt{Speaker}(M) = S$
- $H \subseteq Ag$ *denotes the set of agents to which the move is addressed, given by a function* $\texttt{Hearer}(M) = H$
- $m \in \mathcal{M}$ *is the move, given by a function* $\texttt{Move}(M) = m$ *and s.t.* $\texttt{WFM}(m) = 1$
- $t \in DM$ *is the target of the move i.e. the move which it replies to, given by a function* $\texttt{Target}(M) = t$. *We denote* $t = \emptyset$ *if* M *does not reply to any other move.*

Dialogues are about *subjects* and aim at reaching *goals*. *Subjects* may take two forms w.r.t. the dialogue type.

Definition 4 (Dialogue subject). *A dialogue* subject *is* φ *such that* $\varphi \in Wff(\mathcal{L})$, *or* $\varphi \in Arg(\mathcal{L})$.

The *goal* of a dialogue is to assign a value to its subject pertaining to some domain. Two types of domains are distinguished according to the dialogue type.

Definition 5 (Dialogue goal). *The* goal *of a* dialogue *is to assign to its subject* φ *a value* $v(\varphi)$ *in a domain* V *such that:*

- *If* $\varphi \in Wff(\mathcal{L})$, *then* $v(\varphi) \in V = V_1 \times \cdots \times V_m$
- *If* $\varphi \in Arg(\mathcal{L})$, *then* $v(\varphi) \in V = \{acc, rej, und\}$.

The nature of the domain V depends on the dialogue type. For instance, the subject of a negotiation dialogue with the goal of choosing a date and a place to organize a meeting, takes its values in $V_1 \times V_2$, where V_1 is a set of dates and V_2 a set of places. The subject of an inquiry dialogue with the goal of asking about the president's age, takes its values in a set V_1 of ages. Regarding persuasion dialogues whose goal is to assign an acceptability value to an argument[3], the possible values are *acceptable*, *rejected* and *undecided*.

Let '?' denote an empty value. By default the subject of any dialogue takes this value.

Now that the basic concepts underlying the notion of a dialogue are introduced, let us define formally a *dialogue* conducted under a given protocol π.

Definition 6 (Dialogue). *Let* $\pi = \langle \mathcal{L}, SA, Ag, \texttt{Reply}, \texttt{Back}, \texttt{Turn}, \texttt{N\_Move} \rangle$ *be a protocol. A* dialogue d *on a* subject φ *under the protocol* π*, is a non-empty (finite or infinite) sequence of dialogue moves,* $d = M_{1,1}, \ldots, M_{1,l_1}, \ldots, M_{k,1}, \ldots, M_{k,l_k}, \ldots$ *such that:*

1. $\varphi \in Wff(\mathcal{L})$ *or* $\varphi \in Arg(\mathcal{L})$. $\texttt{Subject}(d) = \varphi$ *returns the dialogue* subject
2. $\forall M_{i,j}$, $i \geq 1$, $1 \leq j \leq l_i$, $M_{i,j} \in DM$
3. $\forall i$, $i \geq 1$, $\texttt{Speaker}(M_{i,j}) = \texttt{Turn}(t_i)$
4. $\forall i$, $i \geq 1$, $l_i = \texttt{N\_Move}(t_i, \texttt{Speaker}(M_{i,l_i}))$
5. $\forall i$, $i \geq 1$, $\texttt{Speaker}(M_{i,1}) = \cdots = \texttt{Speaker}(M_{i,l_i})$
6. *If* $\texttt{Target}(M_{i,j}) \neq \emptyset$,
   then $\texttt{Speech}(\texttt{Move}(M_{i,j})) \in \texttt{Reply}(\texttt{Speech}(\texttt{Move}(\texttt{Target}(M_{i,j}))))$
7. $\forall j$, $1 \leq j \leq l_1$, $\texttt{Target}(M_{1,j}) = \emptyset$
8. $\forall M_{i,j}$, $i > 1$, $\texttt{Target}(M_{i,j}) = M_{i',j'}$ *such that:*
   - *If* $\texttt{Back} = 1$, *then* $1 \leq i' < i$ *and* $1 \leq j' \leq l_{i'}$
   - *If* $\texttt{Back} = 0$, *then* $[(i-(n-1)) \leq i' < i]$ *and* $1 \leq j' \leq l_{i'}$, *where* $[i-(n-1)) \geq 1]$ *and* n *is the number of agents.*

If the sequence $d = M_{1,1}, \ldots, M_{1,l_1}, \ldots, M_{k,1}, \ldots, M_{k,l_k}, \ldots$ is finite, then the dialogue d is *finite*, otherwise d is *infinite*.

We denote by $\mathcal{D}_\pi$ the set of all dialogues built under the protocol π.

Condition 3 states that the speaker is defined by the function `Turn`. Condition 4 specifies the number of moves to be uttered by that agent. Condition 5 ensures that effectively that number of moves is uttered by that agent. Condition 6 ensures that the uttered speech act is a legal reply to its target. Condition 7 states that the initial moves played at the first turn by the agent which starts the dialogue do not reply to any other move. Condition 8 regulates backtracking for all moves different from the initial ones. Indeed, if backtracking is allowed then a move can reply to any other move played previously in the dialogue. Otherwise, this is restricted to the moves played by the other agents at their last turn just before the current one.

[3] Dung [16] has defined three semantics for the *acceptability* of arguments. An argument can be accepted, rejected or in abeyance. Formal definitions of those status of arguments are beyond the scope of this paper.

This notion of non-backtracking can be illustrated as follows: consider a dialogue between two agents that take turns to play exactly one move per turn. If backtracking is forbidden, then each move (except the first one) replies to the one played just before it.

The above definition of backtracking captures its two types: an *alternative* reply and a *postponed* reply.

Definition 7. *Let* $\pi = \langle \mathcal{L}, SA, Ag, \texttt{Reply}, \texttt{Back}, \texttt{Turn}, \texttt{N\_Move}\rangle$ *be a protocol. Let* $d \in \mathcal{D}_\pi$ *with* $d = M_{1,1}, \ldots, M_{1,l_1}, \ldots, M_{k,1}, \ldots, M_{k,l_k}, \ldots$ *. Let* $M_{i,j}, M_{i',j'} \in DM$ *s.t.* $\texttt{Target}(M_{i,j}) = M_{i',j'}$*. If* $\texttt{Back} = 1$*, then:*

- $M_{i,j}$ *is an '*alternative reply*' to* $M_{i',j'}$ *iff* $\exists f,\ i' < f < i$ *and* $\exists k,\ 1 \leq k \leq l_f$ *s.t.* $\texttt{Target}(M_{f,k}) = M_{i',j'}$ *and* $\texttt{Speaker}(M_{f,k}) = \texttt{Speaker}(M_{i,j})$
- $M_{i,j}$ *is a '*postponed reply*' to* $M_{i',j'}$ *iff* $\forall f,\ i' < f < i$ *and* $\forall k,\ 1 \leq k \leq l_f$*, s.t. if* $\texttt{Target}(M_{f,k}) = M_{i',j'}$ *then* $\texttt{Speaker}(M_{f,k}) \neq \texttt{Speaker}(M_{i,j})$*.*

Each dialogue has an *outcome* which represents the value assigned to its subject. This *outcome* is given by a function as follows:

Definition 8 (Dialogue outcome). *Let* $\pi = \langle \mathcal{L}, SA, Ag, \texttt{Reply}, \texttt{Back}, \texttt{Turn}, \texttt{N\_Move}\rangle$ *be a protocol.* $\texttt{Outcome} : \mathcal{D}_\pi \longrightarrow V \cup \{?\}$*, s.t.* $\texttt{Outcome}(d) = ?$ *or* $\texttt{Outcome}(d) = v(\texttt{Subject}(d))$*.*

Note that if d is *infinite*, then $v(\texttt{Subject}(d)) = ?$ thus $\texttt{Outcome}(d) = ?$.

The outcome of a dialogue is not necessarily an optimal one. In order to compute the optimal outcome of a dialogue, it is necessary to specify its type, to fix all the parameters of the protocol that generates it (such as its set of speech acts), and also to specify the belief and goals bases of the agents. This is beyond the scope of this paper.

3 Classes of Dialogue Protocols

In this section, we combine three basic binary parameters, namely: *backtracking*, *turn-taking* and *number of moves per turn*. This leads to eight classes of protocols that are then compared on the basis of the structure of dialogues that they can generate. We show that some classes are equivalent, and that others are less rigid than others w.r.t. the dialogue structure. Two types of results are presented: those valid for dialogues between multiple agents ($n > 2$), and those that hold only for two agents dialogues.

In order to compare classes of protocols, we need to compare pairs of dialogues that they generate. Johnson *et al.* [13] have discussed how to determine when two dialogue protocols are similar. Their approach is based on syntax (e.g. speech acts) or agents' commitments. Our view is more semantically oriented in that we consider a notion of *equivalent dialogues* based on their subject and the outcome that they reach, by insuring that they have some moves in common. Formally:

Definition 9 (Equivalent dialogues). *Let* $\pi_1 = \langle \mathcal{L}, SA, Ag, \texttt{Reply}, \texttt{Back}, \texttt{Turn}, \texttt{N\_Move}\rangle$ *and* $\pi_2 = \langle \mathcal{L}, SA, Ag, \texttt{Reply}, \texttt{Back}, \texttt{Turn}, \texttt{N\_Move}\rangle$ *be two protocols. Let* $d_1 \in \mathcal{D}_{\pi_1}$ *and* $d_2 \in \mathcal{D}_{\pi_2}$ *be two finite dialogues. Let* DM_1 *and* DM_2

denote the set of dialogue moves of d_1 *and* d_2 *respectively.* d_1 *is* equivalent *to* d_2*, denoted* $d_1 \sim d_2$*, iff: i)* $\texttt{Subject}(d_1) \equiv^4 \texttt{Subject}(d_2)$*, ii)* $\texttt{Outcome}(d_1) = \texttt{Outcome}(d_2)$*, and iii)* $DM_1 \cap DM_2 \neq \emptyset$*.*

Let us take an illustrative example.

Example 1. *The following dialogues between* a_1 *and* a_2 *are equivalent:*[5]

a_1: Offer(x)	a_1: Offer(x)
a_2: Argue(S, x), (where $S \vdash x$)	a_2: Refuse(x)
a_1: Accept(x)	a_1: Why_refuse(x)?
	a_2: Argue($S', \neg x$), (where $S' \vdash \neg x$)
	a_1: Argue(S, x), (where $S \vdash x$)
	a_2: Accept(x)

We define *equivalent protocols* as protocols that generate equivalent dialogues.

Definition 10 (Equivalent protocols). *Let* $\pi_1 = \langle \mathcal{L}, SA, Ag, \texttt{Reply}, \texttt{Back}, \texttt{Turn}, \texttt{N\_Move} \rangle$ *and* $\pi_2 = \langle \mathcal{L}, SA, Ag, \texttt{Reply}, \texttt{Back}, \texttt{Turn}, \texttt{N\_Move} \rangle$ *be two protocols.* π_1 *is* equivalent *to* π_2*, denoted* $\pi_1 \approx \pi_2$*, iff* $\forall d_1 \in \mathcal{D}_{\pi_1}$*,* $\exists d_2 \in \mathcal{D}_{\pi_2}$ *s.t.* $d_1 \sim d_2$*, and* $\forall d_2 \in \mathcal{D}_{\pi_2}$*,* $\exists d_1 \in \mathcal{D}_{\pi_1}$ *s.t.* $d_2 \sim d_1$*.*

In all what follows, Π denotes a class of protocols. If any dialogue conducted under Π_1 has an equivalent dialogue under Π_2, then $\mathcal{D}_{\Pi_1} \subseteq \mathcal{D}_{\Pi_2}$, and we write $\Pi_1 \subseteq \Pi_2$.

Before comparing the eight classes of protocols obtained by combining the aforementioned parameters, the following results can be established where simplified notations are adopted for the values of the parameters:

- $x = \bar{B}$ if $\texttt{Back} = 0$, $x = B$ if $\texttt{Back} = 1$,
- $y = T$ if Turn requires taking turns, $y = \bar{T}$ otherwise,
- $z = S$ if N_Move allows for single move per turn, $z = M$ for multiple moves.

Let Π be a class of protocols. Π_{xyz} stands for the class of protocols such that, everything being equal elsewhere, the parameters Back, Turn and N_Move take respectively the values x, y and z. Note that we only index the parameters whose values are modified.

The following result shows that a class of protocols where one parameter is assigned some value is included in the class of protocols where this parameter takes the opposite value.

Proposition 3. *Let* Π_x*,* Π_y *and* Π_z *be three classes of protocols (where* x*,* y *and* z *are defined as above). The following inclusions hold: i)* $\Pi_{\bar{B}} \subseteq \Pi_B$*, ii)* $\Pi_T \subseteq \Pi_{\bar{T}}$*, and iii)* $\Pi_S \subseteq \Pi_M$*.*

Then, combinations of pairs of parameters lead to the following inclusions:

[4] $\equiv$ stands for logical equivalence.

[5] The role of each speech act in both dialogues can be easily understood from its designation.

Proposition 4. *Let Π_{xz}, Π_{yz} and Π_{xy} be three classes of protocols. We have: i) $\Pi_{\bar{B}S} \subseteq \Pi_{BM}$, ii) $\Pi_{TS} \subseteq \Pi_{\bar{T}M}$, and iii) $\Pi_{\bar{B}T} \subseteq \Pi_{B\bar{T}}$.*

The next result shows that combining pairs of parameters gives birth to equivalent classes of protocols. If $n > 2$, then we can only state the inclusion relationship between classes where the parameter *turn-taking* is fixed.

Proposition 5. *Let Π_{xz}, Π_{yz} and Π_{xy} be three classes of protocols. The following equivalences hold:*

- $\Pi_{\bar{B}M} \approx \Pi_{BS}$
- *If $n = 2$, then $\Pi_{TM} \approx \Pi_{\bar{T}S}$. If $n > 2$, then $\Pi_{TM} \subseteq \Pi_{\bar{T}S}$*
- *If $n = 2$, then $\Pi_{BT} \approx \Pi_{\bar{B}\bar{T}}$. If $n > 2$, then $\Pi_{BT} \subseteq \Pi_{\bar{B}\bar{T}}$.*

Finally, it is worth pointing out that by fixing the three parameters, we are able to compare the eight classes of protocols and to identify the equivalent ones.

Proposition 6. *Let Π_{xyz} be a class of protocols. The following equivalences and inclusions hold:*

- *If $n = 2$, then*
  $\Pi_{\bar{B}TS} \subseteq \Pi_{\bar{B}\bar{T}M} \approx \Pi_{BTM} \approx \Pi_{B\bar{T}S} \approx \Pi_{\bar{B}TM} \approx \Pi_{\bar{B}\bar{T}S} \approx \Pi_{BTS} \subseteq \Pi_{B\bar{T}M}$
- *If $n > 2$, then*
  $\Pi_{\bar{B}TS} \subseteq \Pi_{BTS} \approx \Pi_{\bar{B}TM} \subseteq \Pi_{BTM} \subseteq \Pi_{B\bar{T}S} \approx \Pi_{\bar{B}\bar{T}M} \subseteq \Pi_{B\bar{T}M}$, *and*
  $\Pi_{\bar{B}TS} \subseteq \Pi_{BTS} \approx \Pi_{\bar{B}TM} \subseteq \Pi_{\bar{B}\bar{T}S} \subseteq \Pi_{B\bar{T}S} \approx \Pi_{\bar{B}\bar{T}M} \subseteq \Pi_{B\bar{T}M}$.

This result shows that when dealing with interactions between two agents, the eight classes of protocols reduce to three classes. Thus, a protocol for any dialogue system involving two agents can be formalized by choosing the adequate protocol in one of those three classes.

It also shows the intuitive result that protocols of the class $\Pi_{\bar{B}TS}$, i.e. generating dialogues where backtracking is forbidden, the agents take turns and play one move per turn, are the most '*rigid*' ones in terms of dialogue structure. This gathers for instance e-commerce protocols. Conversely, protocols of the class $\Pi_{B\bar{T}M}$, i.e. generating dialogues where backtracking is allowed, the agents do not take turns and play several moves per turn, are the most '*flexible*' ones. This encompasses for instance argumentation-based dialogue protocols. Indeed, most of game-theoretic negotiation protocols such as bargaining [17], contract net [18] or e-commerce [19,20] are rather simple since agents only exchange offers and counter-offers[6]. Thus they can be classified in the rigid class. On the contrary, protocols for argumentative dialogues [21,22] are more complex and need more flexibility to be handled. The remaining protocols are called 'intermediary' in that they allow for flexibility on one or two parameters among the three binary ones, but not on all of them at the same time. For instance, protocols from the class $\Pi_{B\bar{T}S}$ impose some rigidity by enforcing the agents to play a single move per turn.

[6] Although those models focus on the design of appropriate strategies rather than complex protocols.

4 Discussion and Conclusion

In this paper, we have proposed a general and abstract framework for dialogue protocols. In particular, we have presented a minimal set of basic parameters that define a protocol. Some parameters depend on the intended application of the framework. Indeed, the logical language used in the framework, the set of speech acts and the replying function directly relate to the dialogue type and to the context in which it occurs. Other parameters are more generic since they relate to the external structure of the generated dialogues. Those are the possibility or not of backtracking, the turn-taking of the agents and the number of moves per turn. Combinations of those three parameters give birth to eight classes of protocols.

In the particular case of dialogues between two agents, and which is the most common in the literature, we have shown that those classes reduce to three main classes: a first class containing 'rigid' protocols, a second one containing 'intermediary' ones, and a third one containing 'flexible' ones. We have also studied the relationships between the eight classes in the general case of dialogues between more than two agents.

Recently, Prakken [15] has proposed a formal dialogue system for persuasion, where two agents aim at resolving a conflict of opinion. Each agent gives arguments in favour of its opinion or against the one of its opponent, such that arguments conflict. By analyzing the defeat relation between those arguments and counterarguments, the introduced protocol is structured as an argument game, like the Dung's argumentation proof theory [16]. Thus each performed move is considered to 'attack' or 'surrender to' a previous one, and is attributed a 'dialogical status' as either 'in' or 'out'. A labeling procedure governs the assignment of those statuses. It allows for defining a turn-taking rule, it regulates backtracking by checking the relevance of moves. This framework is intended to maintain coherence of persuasion dialogues. Although it is well-defined and well-motivated, it is specific to dialogue systems modeling defeasible reasoning. With respect to our main result, this protocol belongs to the intermediary class denoted by Π_{BTM}, where $n = 2$ (the number of agents).

We now consider other protocols that can be found in the literature. For instance, McBurney *et al.* [22] have proposed an informal protocol for deliberation dialogues between more than two agents. Agents interact to decide what course of action should be adopted in a given situation. Following this protocol, agents do not take turns, utter single move per turn and are not allowed to backtrack. Thus it is contained in the intermediary class $\Pi_{\bar{B}\bar{T}S}$ where $n > 2$.

In a game-theoretic negotiation context, Alonso [6] has introduced a protocol for task allocation. Dialogues consist of sequences of offers and counter-offers between two agents. Agents take turns and utter single move per turn. Backtracking is allowed but not formalized. The protocol is in the intermediary class Π_{BTS} where $n = 2$.

In an e-commerce scenario, Fatima *et al.* [19] have proposed a negotiation protocol where two agents (a 'buyer' and a 'seller') bargain over the price of an item. Agents alternately exchange multi-attribute bids (or offers) in order to reach an acceptable one. This protocol can then be classified in the most rigid class $\Pi_{\bar{B}TS}$ where $n = 2$.

Thus we believe that in order to formalize a dialogue system, it would be enough to instantiate the minimal basic parameters w.r.t. the constraints of the domain or the application, and to refer to a convenient protocol in one of the main identified classes.

This classification being based on the external structure of dialogues, we are currently working on the coherence of dialogues. Indeed, the different protocols that we have proposed can generate incoherent dialogues in the sense that we do not impose conditions on when the performed moves are allowed. We plan to get rid of this by examining each dialogue type with its own specificities, and more importantly by considering agents' mental states. In other words, we need to look at agents' strategies to obtain a complete dialogue framework.

We are also examining a list of suitable quality criteria for evaluating dialogue protocols, such as the capacity to reach an outcome and the efficiency in terms of the quality of the outcome. Some of those criteria depend directly on the parameters for backtracking, the number of moves per turn and the turn-taking, while others relate to particular instantiations of the framework. Of course the proposed parameters are not exhaustive so we intend to identify a wider variety of them such as those relating to agents' roles in a dialogue or to dialogue execution time. Evaluation criteria for game-theoretic negotiation protocols [24,25] already exist. However, as they are related to agents' individual utilities which remain static in such contexts, they could not be used for dialogues where agents' preferences may evolve through dialogue. A tentative of transposing game-theoretic criteria to argumentative dialogues has been proposed [26] but they are informal.

To sum up, such development may help to identify classes of protocols that are more suitable for each dialogue type, and also to evaluate them. For instance, negotiation dialogues can be conducted under flexible or rigid protocols, depending on whether the approach allows or not for arguing. We would then be able to compare negotiation approaches, namely: game-theoretic, heuristic-based and argumentation-based ones.

References

1. D. N. Walton and E. C. W. Krabbe. *Commitment in Dialogue: Basic Concepts of Interpersonal Reasoning*. State University of New York Press, Albany, 1995.
2. C.L. Hamblin. *Fallacies*. Methuen, London, 1970.
3. J. MacKenzie. Question-begging in non-cumulative systems. *Journal of Philosophical Logic*, 8:117–133, 1979.
4. S. Parsons, M. Wooldridge, and L. Amgoud. On the outcomes of formal inter-agent dialogues. In *Proc. AAMAS'03*, pages 616–623, Melbourne, 2003.
5. H. Prakken. Relating protocols for dynamic dispute with logics for defeasible argumentation. *Synthese*, 127:187–219, 2001.
6. E. Alonso. A formal framework for the representation of negotiation protocols. *Inteligencia Artificial*, 3/97:30–49, 1997.
7. L. Amgoud, S. Parsons, and N. Maudet. Arguments, dialogue, and negotiation. In *Proc. ECAI'00*, pages 338–342, Berlin, 2000.

8. M. K. Chang and C. C. Woo. A speech-act-based negotiation protocol: design, implementation, and test use. *ACM Transactions on Information Systems*, 12(4):360–382, 1994.
9. S. Kraus, K. Sycara, and A. Evenchik. Reaching agreements through argumentation: a logical model and implementation. *Artificial Intelligence*, 104(1–2):1–69, 1998.
10. 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.
11. F. Sadri, F. Toni, and P. Torroni. An abductive logic programming architecture for negotiating agents. In *Proc. JELIA'02*, LNAI 2424, pages 419–431, Cosenza, 2002.
12. C. Sierra, N. R. Jennings, P. Noriega, and S. Parsons. A framework for argumentation-based negotiation. In *Proc. 4th Intl. Workshop on Agent Theories, Architectures and Languages (ATAL'97)*, pages 167–182, Providence, 1997.
13. M. Johnson, P. McBurney, and S. Parsons. When are two protocols the same? In *Communication in Multiagent Systems: Agent Communication Languages and Conversation Policies*, LNAI 2650, pages 253–268, 2003.
14. M. Johnson, P. McBurney, and S. Parsons. A mathematical model of dialog. *Electronic Notes in Theoretical Computer Science*, 2005. In press.
15. H. Prakken. Coherence and flexibility in dialogue games for argumentation. *Journal of Logic and Computation*, 15:1009–1040, 2005.
16. P. M. Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artificial Intelligence*, 77:321–357, 1995.
17. A. Rubinstein. Perfect equilibrium in a bargaining model. *Econometrica*, 50:97–109, 1982.
18. R. G. Smith. The contract net protocol: high-level communication and control in a distributed problem solver. *IEEE Transactions on Computers*, 29(12):1104–1113, 1980.
19. S.S. Fatima, M. Wooldridge, and N. R. Jennings. An agenda based framework for multi-issues negotiation. *Artificial Intelligence*, 152(1):1–45, 2004.
20. A.R. Lomuscio, M. Wooldridge, and N.R. Jennings. A classification scheme for negotiation in electronic commerce. *Intl. Journal of Group Decision and Negotiation*, 12(1):31–56, 2003.
21. J. van Veenen and H. Prakken. A protocol for arguing about rejections in negotiation. In *Proc. 2nd Intl Workshop on Argumentation in Multi-Agent Systems (ArgMas-05)*, Utrecht, 2005.
22. P. McBurney, D. Hitchcock, and S. Parsons. The eight-fold way of deliberation dialogue. *Intelligent Systems*, 2005. In press.
23. H. Prakken and G. Vreeswijk. Logics for defeasible argumentation. In *Handbook of Philosophical Logic, second edition*, volume 4, pages 218–319. 2002.
24. J.S. Rosenschein and G. Zlotkin. *Rules of encounter: Designing conventions for automated negotiation among computers*. MIT Press, Cambridge, 1994.
25. T.W. Sandholm. Distributed rational decision making. In G. Wei, editor, *Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence*, pages 201–258. MIT Press, Cambridge, 1999.
26. P. McBurney, S. Parsons, and M. Wooldridge. Desiderata for agent argumentation protocols. In *Proc. AAMAS'02*, pages 402–409, Bologna, 2002.