A first attempt to allow enthymemes in persuasion dialogs*

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Abstract

This paper is a first attempt to define a protocol able to handle enthymemes in a persuasion dialog. An enthymeme is an incomplete argument that uses implicit information either in the support of the argument or even in its conclusion. We propose a protocol that enables the agent to enunciate statements or to utter maybe incomplete arguments, retract or re-precise them. This protocol is designed to forbid inconsistency and redundancy and to ensure that agents listen to each other. The system is illustrated on a small example and some of its properties are presented.

1 Introduction

A person who could acquire and develop the skill of always being right in a debate could be regarded as a very clever one. Indeed many authors (starting from Aristotle) have studied this art, some of them have even proposed lessons or advices for this purpose. Namely, Schopenhauer [7] proposes 38 ways to win an argument. For instance, he gives the following example in order to illustrate the first stratagem called *Extension* which consists in "carrying the opponent's proposition beyond its natural limits (...) so as to exaggerate it; and, on the other hand, in giving its own proposition as restricted a sense as one can".

Example 1. *"I asserted that the English were supreme in drama. My opponent attempted to give an instance to the contrary, and replied that it was a well-known fact that in music, and consequently in opera, they could do nothing at all. I repelled the attack by reminding him that music was not included in dramatic art, which covered tragedy and comedy alone. This he knew very well."*

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A very appealing challenge for AI should be to design good artificial orators, *i.e.*, able to find strategies to win debates. In order to be able to do so, we should first dispose of a persuasion dialog system allowing agents (artificial or human) to exchange arguments and able to decide the winner. Such systems have already been developed in the literature but as far as we know the dialog persuasion systems that have been developed either handle abstract arguments or always assume that an argument is a "perfect" minimal proof of a formula. Our purpose is to develop a system in which it is possible to express imperfect arguments, called "approximate arguments" by [6] or "enthymemes" by Aristotle and in [10, 12, 3].

Handling enthymemes in persuasion dialog has two advantages: first it is more realistic, second enthymemes are also used on purpose by agents in a strategic manner, namely giving a shorter argument may be less subject to attacks or may enable to cheat by pretending that implicit knowledge can help to prove a claim while it is not the case... This paper first states the notion of enthymeme then proposes a protocol for handling persuasion dialogs with enthymemes and finally studies the properties of the generated dialogs.

2 Arguments and enthymemes

We consider a propositional language $\mathscr{L}$, formulas of $\mathscr{L}$ will be denoted by Greek lower-case letters, namely φ, ψ. $\vdash$ denotes logical inference. $\bot$ is the contradiction. $\subset$ denotes strict set inclusion, while $\subseteq$ denotes the non-strict one. We first recall the definitions of logical argument and approximate arguments given by [6]:

Definition 1. *A pair $\langle S, \varphi \rangle$ where $S \subseteq \mathscr{L}$ is a set of propositional formulas (called the* support*) and $\varphi \in \mathscr{L}$ (called the* claim*) is called an* approximate argument*.*

A logical argument *is an approximate argument $\langle S, \varphi \rangle$ such that:* $\begin{cases} (1) & S \nvdash \bot, \\ (2) & S \vdash \varphi, \\ (3) & \nexists S' \subset S \text{ s.t. } S' \vdash \varphi \end{cases}$

Notation 1. *If A is a set of arguments, the set of formulas pertaining to the supports and claims of these arguments is denoted by* $\texttt{form}(A)$*:* $\texttt{form}(A) = \bigcup_{\langle S,\varphi \rangle \in A} S \cup \{\varphi\}$.

In order to be able to deal with arguments that have incomplete support or incompletely developed conclusion we first define an incomplete argument and then extend the enthymeme formalization proposed in [3].

Definition 2. *An* incomplete argument *is an approximate argument $\langle S, \varphi \rangle$ such that* $\begin{cases} (1) & S \nvdash \varphi \\ (2) & \exists \psi \in \mathscr{L} \text{ s.t. } \langle S \cup \{\psi\}, \varphi \rangle \text{ is a logical argument.} \end{cases}$

In this definition[1], the first condition expresses the fact that the argument is strictly incomplete, *i.e.,* the support is not sufficient to infer the conclusion. The second one imposes that it is possible to complete it in order to obtain a logical argument.

Notation 2. Arg_Σ *(resp.* AArg_Σ, IArg_Σ*) denotes the set of logical (resp. approximate, incomplete) arguments that can be built on a set of formulas* Σ.

Note that the support of an incomplete argument should be consistent or else adding any formula to it would still give an inconsistent support (hence violate condition (1) for logical arguments). Moreover S should be consistent with φ, more formally:

Remark 1. *-If* $\langle S, \varphi\rangle \in \text{IArg}_\mathscr{L}$ *then* $S \nvdash \bot$ *and* $S \nvdash \neg\varphi$.
-$\forall F \subseteq \mathscr{L}$, $\text{Arg}_F \subseteq \text{AArg}_F$, $\text{IArg}_F \subseteq \text{AArg}_F$, $\text{Arg}_F \cap \text{IArg}_F = \varnothing$.

Example 1 (continued): *The argument proposed by Schopenhauer adversary is an incomplete argument. Indeed, "in music, and consequently in opera, English are not supreme" maybe transcribed into the approximate argument:* $\alpha_1 = \langle\{m \to \neg s\}, o \to \neg s\rangle$. *And by adding the formula* $o \to m$ *to its support we obtain the logical argument:* $\beta_1 = \langle\{m \to \neg s, o \to m\}, o \to \neg s\rangle$

According to Aristotle an enthymeme is a syllogism keeping at least one of the premises or conclusion unsaid[2].

Definition 3. *Let* $\alpha = \langle S, \varphi\rangle$, $\alpha' = \langle S', \varphi'\rangle \in \text{AArg}_\mathscr{L}$,
$\langle S', \varphi'\rangle$ completes $\langle S, \varphi\rangle$
$$\textit{iff} \quad \begin{cases} (1) & S \subset S' \text{ or} \\ (2) & S \subseteq S' \text{ and } \{\varphi'\} \cup S' \vdash \varphi \text{ and } \varphi \nvdash \varphi' \end{cases}$$
α *is an* enthymeme *for* α' *iff* $\alpha' \in \text{Arg}_\mathscr{L}$ *and* α' *completes* α.
Let $\Sigma \subseteq \mathscr{L}$, $\texttt{Decode}_\Sigma(\langle S, \varphi\rangle) = \{\langle S', \varphi'\rangle \in \text{Arg}_\mathscr{L}$ *s.t.* $S' \backslash S \subseteq \Sigma$ *and* $\langle S, \varphi\rangle$ *is an enthymeme for* $\langle S', \varphi'\rangle\}$.
`Decode` *is extended to* $\text{Arg}_\mathscr{L}$ *as follows: if* $\alpha \in \text{Arg}_\mathscr{L}$ *then* $\texttt{Decode}_\Sigma(\alpha) = \{\alpha\}$.

Example 1 (continued): *We may build an infinity of logical arguments decoding an incomplete argument. For instance,* α_1 *is an enthymeme for the logical argument* β_1 *but also for the logical argument:* $\gamma_1 = \langle\{m \to \neg s, o \to m, o, o \to d\}, \neg(d \to s)\rangle$. *This means that* $\beta_1, \gamma_1 \in \texttt{Decode}_\mathscr{L}(\alpha_1)$.

It is easy to see that incomplete arguments are enthymemes for the logical arguments obtained by completing their support. In other words,

Remark 2. *If* $\langle S, \varphi\rangle \in \text{IArg}_\mathscr{L}$ *then* $\texttt{Decode}_\mathscr{L}(\langle S, \varphi\rangle) \neq \varnothing$.

[1] An incomplete argument is a special case of Hunter's *precursor* which is an approximate argument $\langle S, \varphi\rangle$ such that $S \nvdash \varphi$ and $S \nvdash \neg\varphi$. Indeed, a "completed" precursor may not be minimal, for instance $\langle\{a, b, a \wedge b\}, c\rangle$ is a "precursor" but it is not an "incomplete argument" (since any completion will not satisfy (3) in Definition 1).

[2] It is different from the definition given in [3] where an approximate argument is an enthymeme for a logical argument if its claim is directly inferred from the claim of the logical argument while we allow for claims any formula that can be inferred from the completed premises.

3 A protocol for persuasion dialogs

In persuasion dialogs [5, 11], two or more participants are arguing about a claim, and each party is trying to impose the adversary to concede that its own claim is right. We are going to focus on a dialog between two agents (it is convenient to make this assumption but a generalization for more than two agents can easily be done) in front of a given audience (including the second speaker), we suppose that they can rest on a common core of knowledge agreed beforehand by them. This common knowledge may come from previous dialogs for instance. Each communicative act, called move, involves a *Sender* which is an agent, an *Act* and a *Content*.

Definition 4. *Let $AG = \{1, 2\}$ be the set representing the two agents. A* move *is a triplet $(sender, act, content)$, where $sender \in AG$ is the agent uttering the move, $act \in \{$*`Accept`*,* `Agree`*,* `Argue`*,* `Assert`*,* `Challenge`*,* `Close`*,* `Dismantle`*,* `Quiz`*,* `Quizlink`*,* `Replace`*,* `Retract`*$\}$ and content is either empty or is a propositional formula or an approximate argument or a pair of approximate arguments. For a given move, the functions* `Sender`*,* `Act` *and* `Content` *are returning respectively, the first, second and third element of the triplet. When there is no ambiguity about the sender, the move is denoted by $(act\ content)$.*

A move m is well-formed *if* $($`Act`(m) `Content`$(m))$ *matches a utterance given in Table 1. Let $\mathscr{M}$ be the set of all well-formed moves.*

We consider a set of eleven speech acts that are described in Table 1. These are the six usual speech acts used in persuasion dialog augmented with the two speech acts `Quiz` and `Agree` proposed by [3] enabling to handle incomplete arguments to which we add `Quizlink` enabling to ask for a completion concerning the conclusion of an argument, `Replace` allowing to replace an argument when precision are requested by the other agent and `Dismantle` for retracting an argument. Although some speech acts are "assertive" (according to Searle [8]) namely `Assert` and `Argue`, or "declarative" we claim that they are all "commissive" in the sense that they commit the utterer to both be able to explain them when challenged and avoid to contradict them, and they commit the hearer to be polite i.e., answer to explicit request as well as implicit ones (an assertion should for instance be followed by an acceptance of the hearer (unless it has been retracted)).

These commitments will be transcribed into a commitment store (this entity was first introduced by [5] in the dialog game DC). At a given stage of the dialog, the protocol is a boolean function that checks if a move is acceptable with respect to the agents commitments (stored in the commitment store) and it takes into account the move legally uttered in order to update the agents commitments. We propose to extend the idea proposed by [1] to define commitment stores where the internal commitments are separated from the external commitments, but here we also consider the "common" commitments that represent the core of knowledge agreed by the two agents. We define the commitment store as a tuple $(F_1, A_1, R_1, F_\circ, A_\circ, F_2, A_2, R_2)$ based on three knowledge bases: a base containing common knowledge divided into two parts, namely the common for-

Utterance	Meaning
`Accept` φ	acceptance of φ
`Agree` $\langle S, \varphi \rangle$	acceptance of argument $\langle S, \varphi \rangle$
`Argue` $\langle S, \varphi \rangle$	providing a set of formulas S which may support φ if completed
`Assert` φ	statement of assertion φ
`Challenge` φ	asking for an argument supporting φ
`Close`	closing the dialog
`Dismantle` $\langle S, \varphi \rangle$	withdrawal of argument $\langle S, \varphi \rangle$
`Quiz` $\langle S, \varphi \rangle$	seeking for a completion of argument $\langle S, \varphi \rangle$
`Quizlink` $\langle S, \varphi \rangle$	asking for a link between this argument and the dialog
`Replace` (α, β)	providing a new argument β completing a previous one α
`Retract` φ	withdrawal of assertion φ

Table 1: Speech acts for enthymeme persuasion dialogs

mulas, denoted by $F_\circ$, and the common arguments, denoted by $A_\circ$, and two knowledge-bases for the commitment stores of each agents. Each commitment store is divided into three parts: the first two contains the assertive commitment of agent 1 (resp. 2) they are separated into a set of propositional formulas, denoted by F_1 (resp. F_2) and a set of approximate arguments, denoted by A_1 (resp. A_2) the third one contains the commitments towards the other agent, i.e., the requests to which 1 (resp. 2) should answer, denoted by R_1 (resp. R_2). Table 2 describes the effects and preconditions of each move done by agent x towards the other agent denoted $\overline{x}$.

Definition 5. *Let $p \in \mathbb{N} \cup \{\infty\}$, let (F, A) be a common knowledge base s.t. $F \subseteq \mathscr{L}$ and $A \subseteq$ AArg and $F \cup \mathtt{form}(A)$ is consistent, a sequence $(m_n)_{n \in [\![1,p]\!]}$, of p well formed moves, is a* persuasion dialog *of* length p *based on (F, A) iff $\mathtt{Act}(m_1) = \mathtt{Assert}$ and there is a sequence $(CS_n)_{n \in [\![1,p+1]\!]}$ such that: $\forall n \in [\![1, p+1]\!]$, CS_n is a tuple $(F_1, A_1, R_1, F_\circ, A_\circ, F_2, A_2, R_2) \in 2^{\mathscr{L}} \times 2^{\mathrm{AArg}_{\mathscr{L}}} \times 2^{\mathscr{M}} \times 2^{\mathscr{L}} \times 2^{\mathrm{AArg}_{\mathscr{L}}} \times 2^{\mathscr{L}} \times 2^{\mathrm{AArg}_{\mathscr{L}}} \times 2^{\mathscr{M}}$ called* commitment store at stage n *satisfying the following conditions:*
-Starting condition: $CS_1 = (\varnothing, \varnothing, \varnothing, F, A, \varnothing, \varnothing, \varnothing)$ and
-Current conditions: $\forall n \in [\![1, p-1]\!]$, let $x = \mathtt{Sender}(m_n)$,

- $\mathtt{Close} \notin R_x$ *and*
- $\mathtt{precond}(m_n)$ *is true in CS_n and*
- $CS_{n+1} = (F'_1, A'_1, R'_1, {F_\circ}', {A_\circ}', F'_2, A'_2, R'_2)$ *defined by* $\mathtt{effect}(m_n, CS_n)$ *and*

-Ending conditions: let $x = \mathtt{Sender}(m_p)$,

- $\texttt{precond}(m_p)$ *is true in* CS_p *and*
- $\texttt{Act}(m_p) = \texttt{Close}$ *and* $\texttt{Close} \in R_{\overline{x}}$

where `precond` *and* `effect` *are given in Table 2* [3].

The "current conditions" require that in order to make a move the sender should not have already closed his participation to the dialog and ensure that every move is done under the adequate preconditions and that the commitments taken by uttering this move are updated in the commitment store after this move. The "ending conditions" ensure that the last move of the dialog is a `Close` move (which should be allowed in this stage, i.e., it requires that all the commitments of the agent are fulfilled) and that the other agent has already closed his participation to the dialog. If these "ending conditions" are not possible then the dialog has no end.

In Table 2 we can see that agent x may "accept" a formula φ only if this formula have been uttered by the other agent $\overline{x}$ and is consistent with both the common knowledge and all the formulas that x has already uttered. After this move the formula becomes common knowledge and is no more considered as $\overline{x}$ own utterance.

Note that it seems important that agents listen to each other, for that purpose, each `Assert` or `Argue` move commits the receiver to accept or agree with it or to make the sender retract this move. This is why these move have a post-condition that involves the commitment store of the receiver. This commitment is dropped when the move is retracted or replaced or accepted.

The `Challenge` is authorized only if the formula has been uttered by the other agent (hence if it is not common knowledge) but not already be proved by him. After this move the other agent is committed to give an argument for the challenged formula or to "retract" it.

A move ($\texttt{Quiz}\ \langle S, \varphi\rangle$) can be done by an agent x only if there is no logical argument completing the argument advanced by the other agent that can be built from the common knowledge and the formulas already asserted by x. A move ($\texttt{Quizlink}\langle S, \varphi\rangle$) requires that there is no obvious link between φ and someting said previously by neither x nor $\overline{x}$ *i.e.,* that there is no completion of $\langle S, \varphi\rangle$ whose conclusion has been asserted by x or $\overline{x}$ or has been negated by $\overline{x}$.

In order to "replace" an argument the agent should give a more precise argument, *i.e.*, an argument that completes the old one. Note that if this replacement is an answer to a `Quizlink` then the new argument should have a different conclusion than the previous one.

Note that after a `Retract` move the formula is removed from the utterances of agent x as well as every argument containing x either for claim or support, it is also removed from the requesting commitment that involve it.

Remark 3. *Due to Definition 5, the sequence of commitment stores associated to a persuasion dialog is unique.*

[3] For sake of shortness, in the "effect" column, the sets that remain unchanged are not mentioned.

Example 1 (continued): *Let us consider the following persuasion sub-dialog:*
($Shopenhauer$, `Assert`, $d \rightarrow s$)
($Adversary$, `Argue`, $\langle \{m \rightarrow \neg s\}, o \rightarrow \neg s \rangle$)
($Shopenhauer$, `Argue`, $\langle \{d \leftrightarrow t \vee s\}, m \rightarrow \neg d \rangle$)
($Adversary$, `Agree`, $\langle \{d \leftrightarrow t \vee s\}, m \rightarrow \neg d \rangle$)
Suppose that common knowledge is the following: $F_{\circ} = \{o \rightarrow m, o\}$ *meaning that "opera is music" and that "opera exists". The commitment store after the third move is:* ($\{d \rightarrow s\}$,$\{\alpha_2\}$,$\{$(`Agree` α_1)$\}$, $\{o \rightarrow m, o\}$,$\varnothing$, $\varnothing$,$\{\alpha_1\}$,$\{$(`Accept` $d \rightarrow s$),(`Agree` α_2)$\}$)*, with* α_1*,* α_2 *denoting respectively* $\langle \{m \rightarrow \neg s\}, o \rightarrow \neg s \rangle$ *and* $\langle \{d \leftrightarrow t \vee s\}, m \rightarrow \neg d \rangle$*.*

And after the fourth move: ($\{d \rightarrow s\}$,$\varnothing$, $\{$(`Agree` α_1)$\}$, $\{o \rightarrow m,\ o,\ d \leftrightarrow t \vee s,\ m \rightarrow \neg d\}$, $\{\alpha_2\}$, $\{\alpha_1\}$,$\{$(`Accept` $d \rightarrow s$)$\}$)*.*

After these moves the dialog is not finished since two requests are not yet answered. Schopenhauer has to options either (1) he agrees with his adversary's argument α_1 *(since it is consistent with common knowledge) then he would have no more commitments and his adversary will be obliged either to accept the first claim or to provide another argument against it or (2) he may ask his adversary to precise the link that argument* α_1 *has with the formulas already asserted. In that case the adversary would not be able to* `Replace` *his argument since the logical argument that completes* α_1 *which has a link with the subject is* γ_1 ($\langle \{m \rightarrow \neg s, o \rightarrow m, o, o \rightarrow d\}, \neg(d \rightarrow s) \rangle$) *whose support is now inconsistent with the common knowledge. Hence, after the move* ($Shopenhauer$, `Quizlink`, α_1)*, the move* ($Adversary$, `Dismantle`, α_1) *should be done, leading to:* ($\{d \rightarrow s\}$, $\varnothing$, $\varnothing$, $\{o \rightarrow m,\ o,\ d \leftrightarrow t \vee s,\ m \rightarrow \neg d\}$, $\{\alpha_2\}$, $\varnothing$,$\{$(`Accept` $d \rightarrow s$)$\}$)*.*

Now, if the Adversary has no other argument related to the subject, then he is forced to do the move ($Adversary$, `Accept`, $d \rightarrow s$) *in order to be authorized to close the dialog, leading to:* ($\varnothing$, $\varnothing$, $\varnothing$ $\{o \rightarrow m,\ o,\ d \leftrightarrow t \vee s,\ m \rightarrow \neg d, d \rightarrow s\}$, $\{\alpha_2\}$, $\varnothing$, $\varnothing$, $\varnothing$)

Proposition 1. *Every argument exchanged in a persuasion dialog is either logical or incomplete.*

Proposition 2. *If a persuasion dialog contains two* `Close` *moves then they have been uttered by two distinct senders.*

Proof. Due to the definition of the precondition of `Close`, in order to be able to do it there should not remain any commitment unfulfilled, however a `Close` move commits the sender by adding `Close` to R_x. □

Note that a persuasion dialog maybe infinite since there is no guarantee that the agents would agree to answer to each other requests, hence they may never be authorized to "close" the dialog, more formally:

Proposition 3. *A persuasion dialog is finite iff two* `Close` *move have been uttered during it.*

Proof. If two `Close` moves have been uttered Prop. 2 implies that they have been uttered by two distinct agents hence the last speaker (since they can not speak simultaneously, because a dialog is a *sequence* of moves) has ended the dialog (the converse is due to Def. 5). □

Remark 4. *Even if a persuasion dialog $D = (m_n)_{n \in [\![1,p]\!]}$ is finite, it may be the case that in CS_{p+1} neither* $\texttt{Content}(m_1) \in F_\circ$ *nor* $\neg\texttt{Content}(m_1) \in F_\circ$

Proof. Consider the dialog $((1, \texttt{Assert}, \varphi), (1, \texttt{Retract}, \varphi), (1, \texttt{Close}), (2, \texttt{Close}))$. □

Definition 6. *Let D be a persuasion dialog of length p, with $(CS_n)_{n \in [\![1,p+1]\!]}$ its associated sequence of commitment stores,* ***Output****(D) is:*
- ***Undecided*** *if $p = \infty$*
- *otherwise* $\begin{cases} \texttt{Public agreement that}\, \varphi \textit{ holds,} \\ \quad \textit{if in } CS_{p+1} \textit{ it holds that } \varphi \in F_\circ \\ \texttt{Public agreement that}\, \neg\varphi \textit{ holds,} \\ \quad \textit{if in } CS_{p+1} \textit{ it holds that } \neg\varphi \in F_\circ \\ \texttt{No public agreement on}\, \varphi \textit{ else.} \end{cases}$

Note that common knowledge can only increase:

Proposition 4. *Given a persuasion dialog D of length p, with $(CS_n)_{n \in [\![1,p+1]\!]}$ its associated sequence of commitment stores,*
$\forall i, j \in [\![1, p+1]\!]$ s.t. $i < j$, if $\varphi \in F_\circ$ of CS_i then $\varphi \in F_\circ$ of CS_j and if $\alpha \in A_\circ$ of CS_i then $\alpha \in A_\circ$ of CS_j.

Proof. There is no effect able to remove a formula or an argument from the sets of common formulas and arguments. □

Remark 5. *All the new formulas and arguments that are in the common knowledge of the commitment store at a given stage can be considered as an output of the dialog.*

The following proposition shows that *at each stage* the agent remains consistent with all he has said before and with the common knowledge, moreover at each stage the asserted formulas/arguments are either accepted/agreed by the other agent (thus become common knowledge) or not yet agreed. Moreover, if there is one asserted formula in the commitment store of one agent then it is not yet in the common knowledge thus there is at least one unanswered request in the commitment store of the other agent.

Proposition 5. *If D is a persuasion dialog of length p and $(CS_n)_{n \in [\![1,p+1]\!]}$ its associated sequence of commitment stores, then $\forall n \in [\![1, p+1]\!]$, $\forall x \in AG$, CS_n is s.t.:*

- $F_x \cup \texttt{form}(A_x) \cup F_\circ \cup \texttt{form}(A_\circ)$ *consistent and*
- $F_x \cap F_\circ = \varnothing$ *and*
- $A_x \cap A_\circ = \varnothing$
- *if $F_x \neq \varnothing$ then $R_{\overline{x}} \neq \varnothing$*

- *if* $A_x \neq \varnothing$ *then* $R_{\overline{x}} \neq \varnothing$

The following proposition shows that when a dialog is closed by the two participants, they have fulfilled all their commitments (their CS only contains `Close`).

Proposition 6. *If* `Close` *appears twice in a persuasion dialog with* $(CS_n)_{n \in [\![1,p+1]\!]}$ *its associated sequence of commitment stores then in* CS_{p+1} *it holds that* $R_x = R_{\overline{x}} = \{Close\}$ *and* $F_x = F_{\overline{x}} = \varnothing$ *and* $A_x = A_{\overline{x}} = \varnothing$*.*

Proof. Due to Proposition 2, the two `Close` moves have been done by two distinct agents. Moreover, in order to do a `Close` move $R_x = R_{\overline{x}} = \varnothing$ should hold. Furthermore, if all their commitments are fulfilled then due to Proposition 5, $F_x = F_{\overline{x}} = A_x = A_{\overline{x}} = \varnothing$ hence either they have agreed or accepted adversary's arguments or he has retracted them. □

Corollary 1. *If a persuasion dialog is finite then*

- *every asserted formula has been either accepted by the other agent or been retracted by its utterer.*
- *every argument has been either agreed by the other agent or dismantled by its utterer.*

Hence when the two agents do not agree on a formula, if one of them asserts it, the other may challenge it, he may also assert the opposite, but at the end, one of them should either admit that he cannot prove his formula (so retract it) or should give an acceptable proof of it. But if the dialog ends then one of the utterer (or both of them) has retracted his assertion. Otherwise the dialog may never end, both agents would have failed to persuade the other. Note that if the dialog ends with a given output then it is consistent with common knowledge and there is no agreed argument against it.

Corollary 2. *If* D *is a persuasion dialog of length* p *and* $(CS_n)_{n \in [\![1,p+1]\!]}$ *its associated sequence of commitment stores, then, if* $\texttt{Output}(D) = \varphi$ *then* $\varphi \cup F_\circ$ *is consistent and* $\nexists \langle S, \psi \rangle \in A_\circ$ *s.t.* $\psi = \neg\varphi$*.*

4 Concluding remarks

This current work is a first attempt to handle enthymemes in persuasion dialogs. The ambition was to handle incomplete information both in the premises and in the claim of an argument. We design a protocol that ensures that the agents are polite and consistent, indeed since they engage in a public persuasion dialog they have to always remain consistent with what they have said during the dialog (they are however allowed to change their mind provided they have retracted the previous utterance), moreover they engage to dialog, thus to listen to each other, thus to answer to each assertion of the other, either by accepting it or by giving another assertion that will make the adversary retract himself. A particularity of our proposal is that, at the end of the dialog, all agreed assertions are kept in the common knowledge base that can be used for further dialogs.

The protocol we propose do not use Dung like argumentation systems, since we wanted to be close to concrete dialogs, hence, when an argument is attacked during the dialog, the situation should evolve in such a way that this attack is removed: either because the argument is amended or retracted by its owner or because the attack is retracted.

Apprehending public statements without considering what is in the agent's mind but only what has been said, is also done for instance by [4], where a public utterance is called "grounded". Their proposal is a framework to represent and reason about the public knowledge during a persuasion dialog, their approach allows to deal with inconsistent assertions (which is not allowed in our framework) like in Walton & Krabbe's system PPD_0. This feature seems more realistic since it is up to the other agent to detect and denounce inconsistency by asking the adversary to "resolve" it. However we could argue that what is public should be consistent in order to be civilized and respectful of the audience and of the debate quality. Note that in our approach "dark side commitments" (so called by [11]) may be revealed by means of a `Quizlink` or a `Quiz` move.

A very appealing development of this framework concerns the strategical part, we plan to translate our protocol rules into the Game player project language GDL2 [9], indeed in GDL2 it is possible to handle games with imperfect information. After this translation, strategies coming from game theory and strategies dedicated to dialog games (e.g. [2]) could be compared. Moreover, since a persuasion dialog may be infinite, we plan to introduce a restrictions on the speaking time. This notion requires to define the duration associated to a move that could be computed with respect to the length of their content for instance. Duration is well suited with enthymemes, since they are often used for sake of shortness (even if sometimes it is more a strategical choice). [4]

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m	$\texttt{precond}(m)$ (with $K_x = F_x \cup \texttt{form}(A_x) \cup F_\circ$)	$\texttt{effect}(m,\ (F_x,\ A_x,\ R_x,\ F_\circ,\ A_\circ,\ F_{\overline{x}},\ A_{\overline{x}},\ R_{\overline{x}}))$
$\texttt{Accept}\ \varphi$	$\varphi \in F_{\overline{x}}$ and $\{\varphi\} \cup K_x$ consistent	$R'_x = R_x \backslash \{(\texttt{Accept}\,\varphi)\}$ ${F_\circ}' = F_\circ \cup \{\varphi\}$ $F'_{\overline{x}} = F_{\overline{x}} \backslash \{\varphi\}$
$\texttt{Agree}$ $\langle S, \varphi \rangle$	$\langle S, \varphi \rangle \in A_{\overline{x}}$ and $S \cup \{\varphi\} \cup K_x$ consistent	$R'_x = R_x \backslash \{(\texttt{Agree}\,\langle S, \varphi \rangle)\}$ ${F_\circ}' = F_\circ \cup \{\varphi\} \cup S$, ${A_\circ}' = A_\circ \cup \{\langle S, \varphi \rangle\}$ $A'_{\overline{x}} = A_{\overline{x}} \backslash \{\langle S, \varphi \rangle\}$
$\texttt{Argue}$ $\langle S, \varphi \rangle$	$\langle S, \varphi \rangle \notin A_\circ \cup A_x \cup A_{\overline{x}}$ and $S \cup \{\varphi\} \cup K_x$ consistent	$A'_x = A_x \cup \{\langle S, \varphi \rangle\}$ $R'_x = R_x \backslash \{(\texttt{Challenge}\,\varphi)\}$ $R'_{\overline{x}} = R_{\overline{x}} \cup \{(\texttt{Agree}\,\langle S, \varphi \rangle)\}$
$\texttt{Assert}\ \varphi$	$\varphi \notin K_x \cup F_{\overline{x}}$ and $\{\varphi\} \cup K_x$ consistent	$F'_x = F_x \cup \{\varphi\}$ $R'_{\overline{x}} = R_{\overline{x}} \cup \{(\texttt{Accept}\,\varphi)\}$
$\texttt{Challenge}\ \varphi$	$\varphi \in F_{\overline{x}}$ and $(\texttt{Challenge}\varphi) \notin R_{\overline{x}}$ and $\nexists \langle S, \varphi \rangle \in A_x \cup A_{\overline{x}} \cup A_\circ$	$R'_{\overline{x}} = R_{\overline{x}} \cup \{(\texttt{Challenge}\,\varphi)\}$
$\texttt{Close}$	$R_x = \varnothing$	$R'_x = \{\texttt{Close}\}$
$\texttt{Dismantle}\ \alpha$	$\alpha \in A_x$	$A'_x = A_x \backslash \{\alpha\}$ $R'_x = R_x \backslash \{(\texttt{Quiz}\,\alpha), (\texttt{Quizlink}\,\alpha)\}$, $R'_{\overline{x}} = R_{\overline{x}} \backslash \{(\texttt{Agree}\,\alpha)\}$
$\texttt{Quiz}\ \alpha$	$\alpha \in A_{\overline{x}}$ and $(\texttt{Quiz}\ \alpha) \notin R_{\overline{x}}$ and $\texttt{Decode}_{K_x}(\alpha) = \varnothing$	$R'_{\overline{x}} = R_{\overline{x}} \cup \{(\texttt{Quiz}\,\alpha)\}$
$\texttt{Quizlink}\,\alpha$	$\alpha \in A_{\overline{x}}$ and $(\texttt{Quizlink}\,\alpha) \notin R_{\overline{x}}$ and $(\nexists \langle S', \varphi' \rangle \in \texttt{Decode}_{K_x}(\alpha)$ s.t. $\{\varphi', \neg\varphi'\} \cap (F_x \cup \texttt{form}(A_x))$ $\neq \varnothing$ or $\varphi' \in F_{\overline{x}} \cup \texttt{form}(A_{\overline{x}}))$	$R'_{\overline{x}} = R_{\overline{x}} \cup \{(\texttt{Quizlink}\,\alpha)\}$
$\texttt{Replace}$ $(\alpha = \langle S, \varphi \rangle,$ $\beta = \langle S', \varphi' \rangle)$	$\alpha \in A_x$ and β completes α and $\beta \notin A_\circ \cup A_x \cup A_{\overline{x}}$ and $S' \cup \{\varphi'\} \cup K_x$ consistent and if $(\texttt{Quizlink}\,\alpha) \in R_x$ then $\varphi' \neq \varphi$	$A'_x = A_x \backslash \{\alpha\} \cup \{\beta\}$ $R'_x = R_x \backslash \{(\texttt{Quiz}\,\alpha), (\texttt{Quizlink}\,\alpha)\}$ $R'_{\overline{x}} = R_{\overline{x}} \backslash \{(\texttt{Agree}\,\alpha)\} \cup \{(\texttt{Agree}\,\beta)\}$
$\texttt{Retract}\ \varphi$	$\varphi \in F_x$	$F'_x = F_x \backslash \{\varphi\}$ $A'_x = A_x \backslash \{\langle S, \psi \rangle \mid S \subseteq \mathscr{L}$ and $(\varphi \in S$ or $\psi = \varphi)\}$, $R'_x = R_x \backslash \{(\texttt{Challenge}\,\varphi), (\texttt{Quizlink}\,\langle S, \varphi \rangle), (\texttt{Quiz}\,\langle S, \varphi \rangle) \mid S \subseteq \mathscr{L}\}$ $R'_{\overline{x}} = R_{\overline{x}} \backslash \{(\texttt{Accept}\,\varphi), (\texttt{Agree}\,\langle S, \varphi \rangle) \mid S \subseteq \mathscr{L}\}$

Table 2: Effects and conditions of a move from x towards $\overline{x}$