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Enthymemes in Dialogues

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Abstract. Dialogical generalisations of formal logic-based argumentation are typically restricted to a limited set of locutions e.g., assert, why, claim or prefer. However, the use of enthymemes (i.e., arguments with incomplete logical structure) warrant extending this set of locutions. This paper formalises the use of additional novel locutions that account for the use of enthymemes and are typical of real world dialogues. We thus close the gap between formal logic-based models of dialogue and the kinds of dialogue studied by the informal logic community, which focus on more human-oriented models of dialogue. This is important if formal models of dialogues are to provide normative support for human-human debate, as well as for enabling computational and human agents to jointly reason via dialogue.

Keywords. enthymemes, locutions, dialogue, framework, argumentation

1. Introduction

In approaches to structured argumentation, arguments typically consist of a conclusion deductively and/or defeasibly inferred from some premises [1]. However, in practice, human agents typically assert 'incomplete' arguments known as enthymemes. Often, the intended 'complete' argument is obvious to the recipient of an enthymeme from the context and the shared common knowledge; otherwise, one may need to ask for clarification as to what is intended. Consider for example the following dialogue, which is annotated with the relevant locutions from the dialogue system proposed in this paper.

Example 1

1. Bob: *You can't afford to eat at a restaurant today.* (assert $\neg a$)
2. Alice: *Why not?* (why $\neg a$)
3. Bob: *Because you owe money and if you owe money then you probably can't afford to eat at a restaurant.* (because $c; c \Rightarrow \neg a; \neg a$)
4. Alice: *I made a deal with my creditors.* (assert f)
5. Bob: *So what?* (and-so)
6. Alice: *So I don't need to pay the bills today.* (hence $f; f \rightarrow \neg e; \neg e$)
7. Bob: *Why is that relevant?* (what-did-you-think-I-meant-by $c; c \Rightarrow \neg a; \neg a$)
8. Alice: *I thought that the reason you thought I owe money is because I have bills to pay today.* (assumed $e \rightarrow c; c$)
9. Bob: *No! I meant that you owe money because you need to pay Kate back today.* (meant $p \rightarrow c; c$)

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Bob first asserts a claim without any supporting premises (1). The reasons for believing the claim are not clear to Alice, so she asks for clarification (2), which Bob provides (3). Notice that, when combined, (1) and (3) form a 'complete argument', hence they can both be considered enthymemes for this complete argument. Alice then presents an enthymeme (4) for an argument that she believes counters the argument Bob is making. Note that the enthymeme Alice presents does not explicitly contradict anything that Bob has said, and so Bob asks for clarification (5) on what he is meant to infer from this enthymeme, which Alice provides (6). However, Alice's clarification still does not explicitly contradict anything Bob has said. Since Bob does not understand why Alice's enthymeme is relevant to what he said, he asks Alice to explain what she thought he meant (7). Alice explains the assumption she had made (8), which Bob then corrects (9). This simple example illustrates the need for locutions that allow agents to both backward expand enthymemes (where missing premises are provided in 3 above) and forward expand enthymemes (where missing inferences are given, as in 6), and to request such expansions (2 and 5). It also shows the need for locutions that allow agents to ask what another agent has assumed was intended by an enthymeme (7), to answer such a question (8), and to correct any erroneous assumptions (step 9).

The primary contribution of this paper is to formalise a set of locutions, together with a protocol defined as constraints on when they may be made. We therefore support the use of enthymemes as seen in the example dialogue above, allowing agents to deal with any misunderstandings regarding what they revealed and what their counterpart thought was intended. Most works that formalise the use of enthymemes focus on how agents may construct enthymemes from an intended argument and reconstruct intended arguments from received enthymemes, based on assumptions about shared knowledge and context, e.g. [2,3,4,5,6]. Few works account for how enthymemes are handled during dialogues between human and/or computational agents. Notable exceptions include the work of Black and Hunter [7], Hosseini [8] and Dupin de Saint-Cyr [9], who formalise dialogue systems that accommodate enthymemes. However, although [7,8] employ locutions that capture the backward expansion of enthymemes and [9] addresses both backward and forward expansion of enthymemes, none of these address the misunderstandings that may occur due to the use of enthyemems in dialogue. This work therefore helps bridge the gap between formal logic-based models of dialogue and communication as witnessed in real-world dialogues. We thus contribute to theoretical foundations for dialogical models that enable communicative interactions between computational and/or human agents.

The paper is structured as follows. In Section 2 we review background for our work. In Sections 3 and 4 we present our work on enthymemes and their use in a dialogue framework. Section 5 then concludes and includes pointers to future work.

2. Preliminaries

In this paper, a *directed graph* G is a tuple $\langle N, E \rangle$ where $N \neq \emptyset$ is a set of nodes and $E \subseteq N \times N$ is a set of directed edges. A *directed tree* T is a special instance of G which has no cycles and a unique root node (denoted $\mathsf{Root}(T)$) such that there is a unique path from the root to each node in the graph. A *forest* is a disjoint union of directed trees.

Arguments and enthymemes are formalised within the $ASPIC^+$ framework for structured argumentation, which adopts a level of generality so as to subsume other approaches to structured argumentation, as well as providing argumentative formalisations of well known non-monotonic logics [10]. *ASPIC*$^+$ arguments are defined by an *argumentation theory* $AT = \langle AS, K\rangle$ where the *argumentation system* AS is a tuple $\langle L, (\bar{\cdot}), R, n\rangle$. L is a logical language, $(\bar{\cdot}) : L \longmapsto (2^L - \{\emptyset\})$ is a function that generalises the notion of negation, so as to declare that two formulae are in conflict. $R = R_s \cup R_d$ is a set of strict (R_s) and defeasible (R_d) inference rules and $n : R_d \to L$ is a naming function which assigns names to defeasible rules. A *knowledge base* $K = K_n \cup K_p$, where $K \subseteq L$, consists of disjoint sets of axiom (infallible) premises K_n and ordinary (fallible) premises K_p. Then an argument A is a tree, with *undirected* edges, whose leaves (denoted $\mathsf{Leaves}(A)$) belong to K, yielding the argument's claim (the root node) via application of strict and/or defeasible rules. Figurative representations of arguments depict application of strict, respectively defeasible rules, by solid, respectively dotted lines (see Fig.1.i). Each node of the tree represents an element $\alpha \in L$. The sub-arguments of A (denoted $\mathsf{Sub}(A)$) are sub-trees of A, which are themselves arguments whose root nodes are nodes in A (wff in L). Now note that enthymemes may be constructed by removal of a sub-argument whose conclusion is the antecedent of a strict/defeasible rule, while retaining the rule in the enthymeme, or indeed by removal of the conclusion of a sub-argument while retaining the inference rule. Hence, figurative representations of arguments in this paper will augment the standard representation of *ASPIC*$^+$ arguments to include the strict/defeasible inference rules applied (see Fig.1.ii). Finally, X *attacks* Y (where this attack may succeed as a *defeat*, contingent on preferences defined over the arguments X and the targeted sub-argument of Y) if X's claim conflicts with an ordinary premise or the consequent or name of a defeasible rule in Y (for details see [10]).

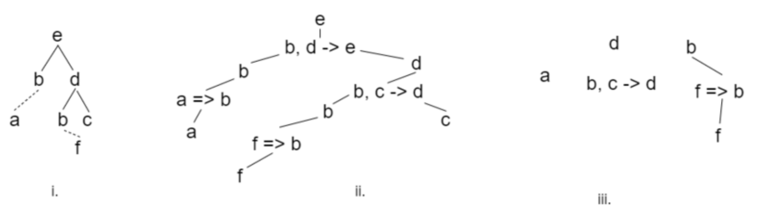

Figure 1. i. An *ASPIC*$^+$ argument. ii. An argument as represented in this paper. iii. An enthymeme constructed from the argument in ii.

3. Enthymemes

Enthymemes are incomplete arguments. Contrary to other approaches that handle enthymemes [7,8], we allow omission of an argument's claim, as well as its premises, and so may obtain a disjointed graph (as the claim is the root of the tree that is the intended argument). Hence we represent enthymemes as a forest of trees (see Fig.1.iii).

Since enthymemes are constructed from arguments, any node that is labelled with a proposition α (from L) may have at most one child, which must be labelled with an inference rule (from R) whose consequent is α (as *ASPIC*$^+$ ensures that an argument, and consequently all sub-arguments, can have at most one top rule from which the claim is inferred). The children of any node that is labelled with an inference rule (from R) must be labelled with an antecedent of that rule, and each child must have a different label so as to preclude multiple occurrences of the same proposition. Note that if an enthymeme includes the nodes n_i and n_j where either n_i is labelled with proposition p and n_j is labelled with an inference rule r whose antecedent includes p, or where n_i is labelled with rule r whose consequent is p and the node n_j is labelled with proposition p, this does not necessarily imply that n_i is a child of n_j. This allows us to handle cases where more than one sub-argument is used to support p within different branches of the same overall intended argument (see Fig.1.ii and 1.iii). Additionally, if an enthymeme E consists of a single tree, and its root and leaves are each labelled with an element of L (i.e., none are labelled with a rule) then E has the same structure as an $ASPIC^+$ argument [1]. We therefore consider arguments to be a special case of enthymemes (see Fig.1.ii).

Definition 1. Let $AS = \langle L, (\bar{\cdot}), R, n \rangle$. An **enthymeme** is $E = \langle \mathsf{Nodes}(E), \mathsf{Edges}(E), \mathsf{lab}_E \rangle$ such that:

- $\langle \mathsf{Nodes}(E), \mathsf{Edges}(E) \rangle$ is a forest;
- $\mathsf{lab}_E : \mathsf{Nodes}(E) \rightarrow L \cup R$;
- $\mathsf{Edges}(E) \subseteq \mathsf{Nodes}(E) \times \mathsf{Nodes}(E)$ such that if $(n_i, n_j) \in \mathsf{Edges}(E)$ then either:
  (a) $\mathsf{lab}_E(n_i) \in L$, $\mathsf{lab}_E(n_j) \in R$, $\mathsf{lab}_E(n_i)$ is the consequent of $\mathsf{lab}_E(n_j)$ and n_j is the only child of n_i, or;
  (b) $\mathsf{lab}_E(n_i) \in R$, $\mathsf{lab}_E(n_j) \in L$, $\mathsf{lab}_E(n_j)$ is an antecedent of $\mathsf{lab}_E(n_i)$ and there does not exist n_k, $k \neq j$, such that $\mathsf{lab}_E(n_j) = \mathsf{lab}_E(n_k)$ and $(n_i, n_k) \in \mathsf{Edges}(E)$;

$\mathsf{Rules}(E) = \{n_i \in \mathsf{Nodes}(E) \mid \mathsf{lab}_E(n_i) \in R\}$. $\mathsf{Leaves}(E) = \{n_i \in \mathsf{Nodes}(E) \mid \nexists (n_i, n_j) \in \mathsf{Edges}(E)\}$. $\mathsf{Top}(E) = \{n_i \in \mathsf{Nodes}(E) \mid \nexists (n_j, n_i) \in \mathsf{Edges}(E)\}$. The set of all enthymemes that can be constructed from an argumentation system AS is denoted E_{AS}.

If an enthymeme E includes a leaf node n labelled with a proposition $\phi \in L$, or a node labelled with a rule $r \in R$ whose antecedent is ϕ, but there is no child of r labelled with ϕ (see Fig.2.i), then there is no support for ϕ. We say that an enthymeme E' is the *backward expansion* of E on ϕ if and only if E' is a tree whose root is labelled with ϕ (see Fig.2.ii and 2.iii). Backward expansions thus expand the enthymeme 'downwards', beyond some leaf node.

Definition 2. Let $E = \langle \mathsf{Nodes}(E), \mathsf{Edges}(E), \mathsf{lab}_E \rangle$ and $E' = \langle \mathsf{Nodes}(E'), \mathsf{Edges}(E'), \mathsf{lab}_{E'} \rangle$ be enthymemes. Let $n_i \in \mathsf{Nodes}(E)$ such that either $n_i \in \mathsf{Leaves}(E)$ and $\mathsf{lab}_E(n_i) = \phi$ where $\phi \in L$; or $n_i \in \mathsf{Rules}(E)$ and there exists an antecedent ϕ of $\mathsf{lab}_E(n_i)$ such that there is no $n_j \in \mathsf{Nodes}(E)$ such that $(n_i, n_j) \in \mathsf{Edges}(E)$ and $\mathsf{lab}_E(n_j) = \phi$. We say that E' is a **backward expansion** of E on ϕ iff $\langle \mathsf{Nodes}(E'), \mathsf{Edges}(E') \rangle$ is a tree T' such that $\mathsf{lab}_{E'}(\mathsf{Root}(T')) = \phi$.

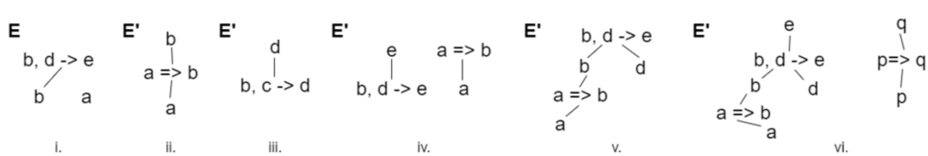

Figure 2. i. An enthymeme E. ii. The enthymeme E' is the backward expansion of E on b. iii. The enthymeme E' is the backward expansion of E on d. iv. The enthymeme E' is a forward expansion of E. v. and vi. do not represent forward expansions of E.

Since we allow omission of an argument's claim, an enthymeme E may entail some missing information. The missing information is all of the elements between the top nodes (nodes without any incoming edges) of E and the claim of the intended argument. So, we say that an enthymeme E' which consists of all (or some) of these information, including (or excluding) the claim, is the *forward expansion* of E. Forward expansions thus expand the enthymeme 'upwards', beyond one or more top nodes. For example, E' in Fig.2.iv is a forward expansion of E, but Fig.2.v and Fig.2.vi are not enthymemes that forward expand E, since a top node in E remains a top node in Fig.2.v and Fig.2.vi contains an arbitrary enthymeme.

Definition 3. Let $E = \langle \mathsf{Nodes}(E), \mathsf{Edges}(E), \mathsf{lab}_E \rangle$ and $E' = \langle \mathsf{Nodes}(E'), \mathsf{Edges}(E'), \mathsf{lab}_{E'} \rangle$ be enthymemes. We say that E' is a **forward expansion** of E iff:

- for every $n_i \in \mathsf{Top}(E)$ there exist $n_k, n_j \in \mathsf{Nodes}(E')$ such that $(n_k, n_j) \in \mathsf{Edges}(E')$, $\mathsf{lab}_{E'}(n_j) = \mathsf{lab}_E(n_i)$ and either $n_j \in \mathsf{Leaves}(E')$ or there exist $n_g \in \mathsf{Top}(E)$ and $n_h \in \mathsf{Leaves}(E')$ such that there is a path from n_j to n_h and $\mathsf{lab}_{E'}(n_h) = \mathsf{lab}_E(n_g)$;
- for every $n_i \in \mathsf{Top}(E')$ there exists $n_j \in \mathsf{Leaves}(E')$ such that there is a path from n_i to n_j and $\mathsf{lab}_{E'}(n_j) = \mathsf{lab}_E(n_k)$ where $n_k \in \mathsf{Top}(E)$.

4. Enthymeme Dialogue System

This section presents our novel two-party dialogue system for handling enthymemes. Our system permits the following locutions, described below in Table 1. From these locutions, we define a set of *moves* with which participants may move, query, and provide expansions of enthymemes. For the locutions hence, assumed, meant and agree, we employ (non-vocalised) variants, marked with either *bw*, *fw*, or *eq*, which dictate how the other participant is expected to respond (see Fig. 3 and Definition 4). Given a move's locution, Fig. 3 describes the reply structure between moves (i.e., if m replies to m' then m's locution must be a valid response to m''s locution). Note that if m is moved as a reply to m', this does not necessarily mean that m must immediately follow m' in the dialogue; agents are free to backtrack and reply to moves made previously, and it is possible that a single move may have multiple replies. Lastly, if a move m has a target m', this indicates that the content of m has been moved as a defeat against the content of m'.

Locution	Meaning
assert	Assert an enthymeme.
why	Question a particular element of a previous enthymeme, which is a request for the other participant to provide a backward expansion on that element.
because	Provide a backward expansion on a questioned element.
and-so	Request a forward expansion of a previous enthymeme.
hence^x	Provide a forward expansion of a previous enthymeme.
w.d.y.t.i.m.b.	Check the other participant's understanding of an enthymeme by asking *"what did you think I meant by ... "*.
assumed^y	Provide their own interpretation of an enthymeme.
meant^y	Correct the other participant's interpretation of an enthymeme.
agree^y	Confirm the other participant's interpretation of an enthymeme.

Table 1. Table of possible locutions, with variants for $x \in \{eq, fw\}$ and $y \in \{eq, fw, bw\}$.

Definition 4. Let Loc denote the set of possible *locutions* provided in Table 1, let the reply structure be the binary relation $\rightarrow_{\text{Loc}} \subseteq \text{Loc}^2$ depicted in Fig.3 and let $\mathscr{M}$ denote the set of all possible moves. Given an $AS = \langle L, (\bar{\cdot}), R, n \rangle$, a set of enthymemes E_{AS} and participants $\mathscr{P} = \{Prop, Opp\}$, we define a **move** to be a tuple $m = \langle sender_m, locution_m, content_m, reply_m, target_m \rangle$ where:

- $sender_m \in \mathscr{P}$ and $locution_m \in \text{Loc}$;
- $reply_m \in \mathscr{M} \cup \{\emptyset\}$ is such that:
  - If $reply_m = \emptyset$ then $locution_m = \mathsf{assert}$,
  - If $reply_m = m' \in \mathscr{M}$ then $(locution_m, locution_{m'}) \in \rightarrow_{\text{Loc}}$;
- $target_m \in \mathscr{M} \cup \{\emptyset\}$ is such that:
  - if $locution_m \in \{\mathsf{because}, \mathsf{assumed}^{bw}, \mathsf{meant}^{fw}, \mathsf{and\text{-}so}, \mathsf{stop}\}$ then $target_m = \emptyset$ (which is to say that these moves do not have a target);
  - if $locution_m \in \{\mathsf{assert}, \mathsf{why}\}$ then $target_m = reply_m$ (which is to say that these moves target the move that they reply to);
  - if $locution_m \in \{\mathsf{assumed}^{eq}, \mathsf{assumed}^{fw}, \mathsf{agree}^{eq}, \mathsf{agree}^{fw}, \mathsf{agree}^{bw}\}$, then $target_m = target_{m'}$ where $m' = reply_m$, (which is to say that these moves copy the target from the move they reply to);
  - if $locution_m = \mathsf{w.d.y.t.i.m.b.}$ then $target_m = target_{n''}$ where $n'' = target_{n'}$, $n' = target_{m'}$ and $m' = reply_m$ (which is to say that this move copies the target of the target of the move (m') it replies to);
  - if $locution_m \in \{\mathsf{hence}^{eq}, \mathsf{hence}^{fw}, \mathsf{meant}^{eq}, \mathsf{meant}^{bw}\}$, then $target_m = target_{m''}$ where $m'' = reply_{m'}$ and $m' = reply_m$ (which is to say that this move copies the target of the move (m'') which is replied to by the move m' that m replies to);
- $content_m \in E_{AS} \cup (E_{AS} \times L) \cup \{\emptyset\}$ is such that:
  - if $locution_m \in \{\mathsf{and\text{-}so}, \mathsf{stop}\}$, then $content_m = \emptyset$;
  - if $locution_m = \mathsf{assert}$, then $content_m \in E_{AS}$;
  - if $locution_m = \mathsf{why}$, then $content_m = (content_{m'}, \phi)$ where $\phi \in L$ and either $\phi = \mathsf{lab}_{content_{m'}}(n_i)$ for some leaf $n_i \in \mathsf{Leaves}(content_{m'})$ or ϕ is an antecedent of $\mathsf{lab}_{content_{m'}}(n_j)$ such that $n_j \in \mathsf{Rules}(content_{m'})$ and there does not exist $n_k \in \mathsf{Nodes}(content_{m'})$ such that $(n_j, n_k) \in \mathsf{Edges}(content_{m'})$ and $\phi = \mathsf{lab}_{content_{m'}}(n_k)$ and $m' = reply_m$;
  - if $locution_m = \mathsf{because}$, then $content_m$ is a backward expansion of A on ϕ where $content_{m'} = (A, \phi)$ and $m' = reply_m$;
  - if $locution_m = \mathsf{hence}^x$, then $content_m = content_{m''}$ or $content_m$ is a forward expansion of $content_{m''}$ where $m'' = reply_{m'}$ and $m' = reply_m$, for $x \in \{eq, fw\}$ respectively;
  - if $locution_m = \mathsf{w.d.y.t.i.m.b.}$, then $content_m = content_{n'}$ where $n' = target_{m'}$ and $m' = reply_m$;
  - if $locution_m = \{\mathsf{assumed}^{eq}, \mathsf{assumed}^{bw}, \mathsf{assumed}^{fw}\}$, then $content_m = content_{m'}$ or $content_m$ is a backward expansion or forward expansion of $content_{m'}$, respectively, where $m' = reply_m$;
  - If $locution_m = \{\mathsf{meant}^{eq}, \mathsf{meant}^{bw}, \mathsf{meant}^{fw}\}$, then $content_m \neq content_{m'}$ and either $content_m = content_{m''}$ or $content_m$ is a forward expansion or backward expansion of $content_{m''}$, respectively, where $m'' = reply_{m'}$ and $m' = reply_m$;
  - If $locution_m = \{\mathsf{agree}^{eq}, \mathsf{agree}^{bw}, \mathsf{agree}^{fw}\}$, then $content_m = content_{m'}$ and either $content_m = content_{m''}$ or $content_m$ is a backward expansion or forward expansion of $content_{m''}$, respectively, where $m'' = reply_{m'}$ and $m' = reply_m$;

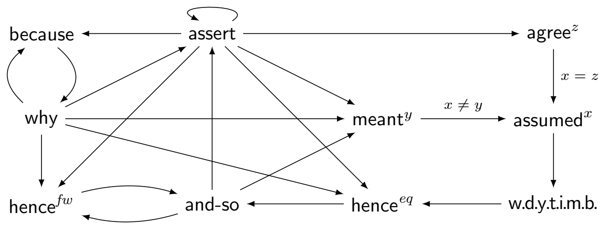

Figure 3. Illustration of the graph $\langle \mathrm{Loc}, \rightarrow_{\mathrm{Loc}} \rangle$, where $x \in \{fw, bw, eq\}$. For clarity, we have omitted the vertex stop $\in$ Loc and edges $\{(\mathsf{stop}, L) : L \in \mathrm{Loc}\} \subseteq \rightarrow_{\mathrm{Loc}}$

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We may then define an *enthymeme dialogue* (henceforth referred to as ‘dialogue’ for short) between two participants to be a (finite) sequence of moves such that each move replies to and targets some previous move or nothing, an assumed move is followed by a meant or agree move and the dialogue is concluded by two consecutive stop moves. We assume participants have the same logical language L, and the same functions $(\bar{\cdot})$ and (the naming function) n. Note that the first move of the dialogue is an assert move since it is the only move whose reply may be the emptyset. Table 2 shows how our system can capture the dialogue between Alice and Bob given in Example 1.

Definition 5. Let $AS_{\mathsf{Ag}} = \langle L_{\mathsf{Ag}}, (\bar{\cdot})_{\mathsf{Ag}}, R_{\mathsf{Ag}}, n_{\mathsf{Ag}} \rangle$ be an argumentation system for Ag $\in \{Prop, Opp\}$, such that $L_{Prop} = L_{Opp}$, $(\bar{\cdot})_{Prop} = (\bar{\cdot})_{Opp}$ and $n_{Prop} = n_{Opp}$. An enthymeme dialogue between *Prop* and *Opp* is a sequence of moves $d = [m_0, \ldots, m_\ell]$ such that for all $i \leq \ell$:
– $sender_{m_i} = Prop$ if i is even, otherwise $sender_{m_i} = Opp$;
– $target_{m_i}, reply_{m_i} \in \{\emptyset, m_0, \ldots, m_{i-1}\}$;
– If $locution_{m_{i-1}} = \mathsf{assumed}^x$, for $x \in \{fw, bw, eq\}$, then $reply_{m_i} = m_{i-1}$.
– $locution_{m_{i-1}} = locution_{m_i} = \mathsf{stop}$ if and only if $i = \ell$.

5. Discussion

If logic-based models of argumentation based dialogue are to enable human-computer dialogue and provide normative support for human-human dialogue, they need to account for the ubiquitous use of enthymemes in real-world dialogues. To this end, our work complements and extends existing work [7,8,9] by broadening the set of locutions and protocol rules governing their use. To the best of our knowledge, our dialogue system is the first to provide locutions that allow recovery from misunderstanding that may arise due to the use of enthymemes. Indeed, it is instructive to note that commonly used locutions in real-world dialogues can effectively be understood as being motivated by the need to accommodate the use of enthymemes. Future work will show how an argument framework can be constructed on the basis of locutions moved during the dialogue such that, if participants play ‘logically perfectly’ (see [11]), the status of enthymemes in this framework corresponds to the status of these enthymemes in the Dung argument framework instantiated by the contents of all the locutions moved at that stage in the dialogue. Moreover, we will explore how enthymemes may be used strategically in persuasion dialogues to yield favourable outcomes for their users.

Step	Move	Enthymeme
1	$m_0 = (Prop, \textsf{assert}, A_1, \emptyset, \emptyset)$	$A_1 = \langle \{n_1\}, \emptyset, \textsf{lab}_{A_1} \rangle$, $\textsf{lab}_{A_1}(n_1) = \neg a$
2	$m_1 = (Opp, \textsf{why}, (A_1, \neg a), m_0, m_0)$	–
3	$m_2 = (Prop, \textsf{because}, A_2, m_1, \emptyset)$	$A_2 = \langle \{n_1, n_2, n_3\}, \{(n_3, n_2), (n_2, n_1)\}, \textsf{lab}_{A_2} \rangle$ $\textsf{lab}_{A_2}(n_1) = c$, $\textsf{lab}_{A_2}(n_2) = c \Rightarrow \neg a$, $\textsf{lab}_{A_2}(n_3) = \neg a$
4	$m_3 = (Opp, \textsf{assert}, B_1, m_2, m_2)$	$B_1 = \langle \{n_1\}, \emptyset, \textsf{lab}_{B_1} \rangle$, $\textsf{lab}_{B_1}(n_1) = f$
5	$m_4 = (Prop, \textsf{and-so}, \emptyset, m_3, \emptyset)$	–
6	$m_5 = (Opp, \textsf{hence}^{fw}, B_2, m_4, m_2)$	$B_2 = \langle \{n_1, n_2, n_3\}, \{(n_3, n_2), (n_2, n_1)\}, \textsf{lab}_{B_2} \rangle$ $\textsf{lab}_{B_2}(n_1) = f$, $\textsf{lab}_{B_2}(n_2) = f \rightarrow \neg e$, $\textsf{lab}_{B_2}(n_3) = \neg e$
–	$m_6 = (Prop, \textsf{and-so}, \emptyset, m_5, \emptyset)$ $m_7 = (Opp, \textsf{hence}^{eq}, B_2, m_6, m_2)$	– B_2 same as step 6
7	$m_8 = (Prop, \textsf{w.d.y.t.i.m.b.}, A_2, m_7, \emptyset)$	A_2 same as step 3
8	$m_9 = (Opp, \textsf{assumed}^{bw}, C, m_8, \emptyset)$	$C = \langle \{n_1, n_2\}, \{(n_2, n_1)\}, \textsf{lab}_C \rangle$ $\textsf{lab}_C(n_1) = e \rightarrow c$, $\textsf{lab}_C(n_2) = c$
9	$m_{10} = (Prop, \textsf{meant}^{fw}, A_3, m_9, \emptyset)$	$A_3 = \langle \{n_1, n_2\}, \{(n_2, n_1)\}, \textsf{lab}_{A_3} \rangle$ $\textsf{lab}_{A_3}(n_1) = p \rightarrow c$, $\textsf{lab}_{A_3}(n_2) = c$
9'	$m'_{10} = (Prop, \textsf{agree}^{bw}, C, m_9, \emptyset)$	C same as step 8

Table 2. Extended version of dialogue from Example 1 (*Prop* is Bob and *Opp* is Alice). The moves between steps 6 and 7 are excluded from Example 1 for simplicity, whereas step 9' is an alternative reply to m_9.

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