Towards an Enthymeme-Based Communication Framework in Multi-Agent Systems

Alison R. Panisson[1] , **Peter McBurney**[2] , **Rafael H. Bordini**[3]
[1]Department of Computing – UFSC, Brazil
[2]Department of Informatics – KCL, UK
[3]School of Technology – PUCRS, Brazil
alison.panisson@ufsc.br, peter.mcburney@kcl.ac.uk, rafael.bordini@pucrs.br

Abstract

Communication is one of the most important aspects of multi-agent systems. Among the different communication techniques applied to multi-agent systems, argumentation-based approaches have received special interest from the community, because allowing agents to exchange arguments provides a rich form of communication. In contrast to the benefits that argumentation-based techniques provide to multi-agent communication, extra weight on the communication infrastructure results from the additional information exchanged by agents, which could restrict the practical use of such techniques. In this work, we propose an argumentation framework whereby agents are able to exchange shorter messages when engaging in dialogues by omitting information that is common knowledge (e.g., information about a shared multi-agent organisation). In particular, we focus on using *enthymemes*, shared argumentation schemes (i.e., reasoning patterns from which arguments are instantiated), and common organisational knowledge to build an enthymeme-based communication framework. We show that our approach addresses some of Grice's maxims, in particular that agents can be brief in communication, without any loss in the content of the intended arguments.

1 Introduction

Enthymemes are arguments in which one or more statements (which are part of the argument) are not explicitly stated, i.e., they are arguments with "missing premises" or even "missing conclusions" (Walton, Reed, and Macagno 2008). They are more realistic arguments, in the sense that real-world arguments (i.e., arguments made by humans) usually do not have enough explicitly stated premises for the entailment of the claim. This is because there is common knowledge that can be assumed by the arguers which allows them to encode arguments into a shorter message by ignoring the common knowledge (Black and Hunter 2008). Further, when an arguer receives an enthymeme, it can deduce the intended argument, in a process of reconstruction of such argument, looking for the missing parts, assumptions, etc., in order to recover its intended meaning (Mailly 2016). However, attributing unstated information to an arguer is a dangerous kind of inference, given that this depends on interpreting what the arguer presumably meant to say (Walton, Reed, and Macagno 2008), and this needs to be treated carefully, in order not to change the intended meaning of exchanged arguments. Changing the meaning of arguments uttered by agents in Multi-Agent Systems (MAS) could be disastrous, considering the rigour expected in multi-agent communication methods.

Although using enthymemes could be dangerous in distorting the meaning of arguments in agent communication, if the involved process could ensure that arguments do not lose the intended meaning, enthymemes could be beneficial for agent communication, allowing agents to exchange only essential information needed for a particular purpose. In this work, in order to deal with this inherent problem in using enthymemes, we propose to use argumentation schemes (Walton, Reed, and Macagno 2008) as common organisational knowledge to guide the construction of enthymemes by the proponent of arguments, as well as to guide the reconstruction of the intended argument by the recipients of such enthymemes. Thus, agents are able to exchange only the content that is needed for them to understand each other in argumentation-based communication, and it can be ensured that the arguments will not lose content or the intended meaning.

The contributions of this work are: (i) we describe a complete framework for argumentation-based dialogues, where agents are able to communicate only the information that is required for mutual understanding using enthymemes, no more than that[1]; (ii) we guarantee that both the sender and the recipient will have the same understanding for the enthymemes exchanged; (iii) we empirically evaluate our implementation; (iv) we show that our approach has various advantages for argumentation-based communication in MAS, addressing some of Grice's maxims for cooperative communication.

2 Argumentation Schemes in MAS

Argumentation schemes could be available as common knowledge to all agents in a MAS, considering that they describe usual reasoning patterns. Furthermore, such reasoning patterns tend to be domain specific (Walton 2008). For example, there is work where agents use argumentation schemes that are specific for analysing the provenance of information (Toniolo et al. 2014), argumentation schemes

[1]Intuitively, this corresponds to Grice's maxim of quantity (Grice 1975).

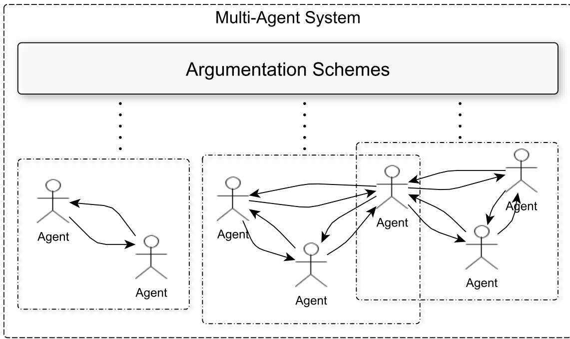

Figure 1: Argumentation schemes are shared by all agents.

for reasoning about trust (Parsons et al. 2012), argumentation schemes for arguing about human organ transplantation (Tolchinsky et al. 2007; Tolchinsky et al. 2012), argumentation schemes for reasoning about data access control (Panisson et al. 2018), argumentation schemes for reasoning about a proposed treatment (Kokciyan et al. 2018), and so forth.

Given the discussion in the relevant literature that argumentation schemes are normally both domain dependent and common knowledge, we propose an architecture for MAS where argumentation schemes are shared by all agents in the system. In particular, our approach is based on the specification of argumentation schemes as part of the organisational specifications (e.g., using the Moise organisational model (Hubner, Sichman, and Boissier 2007)), or as an interface to an external source of information such as the semantic web (Freitas et al. 2015; Freitas et al. 2017), etc. The only requirement is that all agents in the systems must have access to specifications of all such reasoning patterns at run time, so they are able to instantiate arguments from the available argumentation schemes, as well as to use such instantiated arguments to reason and to argue with other agents. An overview of our approach to argumentation schemes in MAS is shown in Figure 1, where all agents are able to instantiate arguments from the argumentation schemes at runtime.

2.1 Instantiating Arguments

To exemplify our approach, we use the argumentation schemes *Argument from Position to Know* from (Walton 1996), but here making reference to organisational concepts; for example, *roles* that agents play in the multi-agent organisation are referred to within the scheme:

> "Agent $\mathtt{Ag}$ is currently playing a role R (its position) that implies knowing things in a certain subject domain S containing proposition A **(Major Premise)**. $\mathtt{Ag}$ asserts that A (in domain S) is true (or false) **(Minor Premise)**. A is true (or false) **(Conclusion)**".

The associated critical questions are: **CQ1**: Does playing role R imply knowing whether A holds? **CQ2**: Is $\mathtt{Ag}$ an honest (trustworthy, reliable) source? **CQ3**: Did $\mathtt{Ag}$ assert that A is true (or false)? **CQ4**: Is $\mathtt{Ag}$ playing role R?

Definition 1 (Argumentation Scheme)**.** *An argumentation scheme is a tuple $\langle \mathcal{SN}, \mathcal{C}, \mathcal{P}, \mathcal{CQ}\rangle$ with $\mathcal{SN}$ the argumentation scheme name (which must be unique within the system), $\mathcal{C}$ the conclusion of the argumentation scheme, $\mathcal{P}$ the premises, and $\mathcal{CQ}$ the associated critical questions.*

The set of argumentation schemes available to agents is represented by $\Delta_{\mathtt{AS}}$. Such argumentation schemes can be represented in structured argumentation[2], using defeasible inferences, as described in (Prakken 2011; Panisson and Bordini 2017). Thus, in order to make explicit the representation of arguments, we introduce the language $\mathcal{L}$ used in this work. We use a first-order language as the basis for our representation, given that most agent-oriented programming languages are based on logic programming. In particular, we have a set of atomic formulæ $\{p_0, \ldots, p_n\} \in \mathcal{L}$, and a set of defeasible inference rules $\{(p_i, \ldots, p_j \Rightarrow p_k), \ldots, (p_l, \ldots, p_m \Rightarrow p_o)\} \in \mathcal{L}$. In order to refer to the unification process, we use a most general unifier θ (as usual in logic programming). We use uppercase letters to represent variables — e.g., `Ag` and `R` in `role(Ag,R)` — and lowercase letters to represent terms and ground literals — e.g., `john`, `doctor`, and `role(john,doctor)`. Using language $\mathcal{L}$, the argumentation scheme introduced above can be represented as the following defeasible inference:

$$\mathtt{role(Ag,R)}, \mathtt{knows(R,S)}, \mathtt{asserts(Ag,A)}, \mathtt{about(A,S)} \Rightarrow \mathtt{A}$$

with $\mathcal{P} = \{\mathtt{role(Ag,R)}, \mathtt{knows(R,S)}, \mathtt{asserts(Ag,A)}, \mathtt{about(A,S)}\}$, and $\mathcal{C} = \mathtt{A}$. In order to create an argument from this reasoning pattern, agents instantiate it using the knowledge available to them.

Definition 2 (Argument)**.** *An argument is a tuple $\langle S, c\rangle^{\theta}_{\mathtt{sn_i}}$, where $\mathtt{sn_i}$ is the name of the argumentation scheme $\langle \mathtt{sn_i}, \mathcal{C}, \mathcal{P}, \mathcal{CQ}\rangle \in \Delta_{\mathtt{AS}}$, θ is a most general unifier for the premises in $\mathcal{P}$ and the agent's current belief base, S is the set of premises and the inference rule of the scheme used to draw c (the conclusion). That is, S includes all instantiated premises from $\mathcal{P}$ — i.e., for all $p \in \mathcal{P}, p\theta \in \mathcal{S}$ — and the inference rule corresponding to the scheme ($\mathcal{P} \Rightarrow \mathcal{C}$); the conclusion c is the instantiation $\mathcal{C}\theta$ such that $S \models c$.*

Example 1. *Imagine that all agents know that* $\mathtt{john}$ *(an agent in the system) is playing the role of* $\mathtt{doctor}$ *—* $\mathtt{role(john,doctor)}$ *— within the organisational structure. Further, the agents know that doctors know about cancer —* $\mathtt{knows(doctor,cancer)}$*. Therefore, if* $\mathtt{john}$ *asserts that "smoking causes cancer" —* $\mathtt{asserts(john,causes(smoking,cancer))}$*, and causes of cancer are a subject matter related to cancer —* $\mathtt{about(causes(smoking,cancer),cancer)}$*, all agents are able to conclude that smoking causes cancer:* $\mathtt{causes(smoking,cancer)}$*.*

In this example, the organisational structure within the system ensures that all agents know that agent `john` plays the role of `doctor` within that organisational structure, and that doctors know about cancer, because it is one of the features of that role. Also, they could know that causes of cancer are a subject related to cancer, given the domain knowledge shared by them in the system. However, not all agents

[2]The best known frameworks for structured argumentation are (Modgil and Prakken 2014; García and Simari 2014; Besnard and Hunter 2014; Toni 2014).

will know that agent john has asserted that smoking causes cancer, only the ones john has communicated with. Therefore, not all agents are able to instantiate an argument from the reasoning pattern available, giving that not all premises are common knowledge.

2.2 Reasoning with Arguments

Instantiating arguments from argumentation schemes allows agents to use such arguments for both reasoning and communication processes. In both cases, agents will check conflicts among arguments they are able to instantiate, reaching acceptable conclusions, given the set of arguments available to them. There are many approaches to argumentation semantics in the literature, most of them based on Dung's well-known work (Dung 1995). In this work, for practical reasons, we use the *defeasible semantics* (Governatori et al. 2004), which has been chosen considering recent implementations of argumentation-based reasoning in the Jason platform (Bordini, Hübner, and Wooldridge 2007), as reported in (Panisson et al. 2014; Panisson and Bordini 2016; Berariu 2014). Other semantics could be used with minor changes in the framework.

Before we introduce the notion of conflicting arguments, we need to introduce the definition of conflicting information, which will point to conflicts between arguments later.

Definition 3 (Conflicting Information)**.** *Two pieces of information φ and ψ are said to be in conflict if $\varphi \equiv \neg\psi$ (where "$\neg$" represents strong negation) or there is a semantic declaration that such pieces of information are conflicting, e.g., $\mathtt{comp}(\varphi, \psi)$, stating that φ and ψ are the complement of each other. Both cases are represented in our formalisation using a general operator for contradictory information, whereby $\overline{\varphi}$ is contradictory with φ, that is, $\overline{\varphi} \equiv \neg\varphi$ and $\overline{\neg\varphi} \equiv \varphi$.*

Two kinds of attacks between arguments are considered here, which are used to evaluate the acceptable arguments in the set of arguments available for each agent.

Definition 4 (Attack Between Arguments)**.** *Let $\langle S_1, c_1\rangle^{\theta}_{\mathtt{sn_i}}$ and $\langle S_2, c_2\rangle^{\theta}_{\mathtt{sn_j}}$ be two arguments. Attacks between arguments can be generalised into two types:*

- $\langle S_1, c_1\rangle^{\theta}_{\mathtt{sn_i}}$ *rebuts* $\langle S_2, c_2\rangle^{\theta}_{\mathtt{sn_j}}$ *iff* $c_1 \equiv \overline{c_2}$.
- $\langle S_1, c_1\rangle^{\theta}_{\mathtt{sn_i}}$ *undercuts* $\langle S_2, c_2\rangle^{\theta}_{\mathtt{sn_j}}$ *iff* $c_1 \equiv \overline{\varphi}$ *for some* $\varphi \in S_2$.

Example 2. *Imagine that another agent playing also the role of doctor, called* pietro*, asserts that "smoking does not cause cancer", i.e.,* $\mathtt{asserts}(\mathtt{pietro}, \neg\mathtt{causes}(\mathtt{smoking}, \mathtt{cancer}))$. *Any agent aware of both assertions (i.e., John's and Pietro's assertions) is able to construct conflicting arguments for* $\neg\mathtt{causes}(\mathtt{smoking}, \mathtt{cancer})$ *and* $\mathtt{causes}(\mathtt{smoking}, \mathtt{cancer})$ *(both rebutting each other). However, the agents are able to check if* John *and* Pietro *are honest (trustworthy, reliable) sources, if they really play the role of* doctor*, and the other questionable points indicated by critical questions in the argumentation scheme used. For example, if an agent has an acceptable argument "Pietro does not have a degree, therefore he cannot be considered a doctor", i.e.,* $\neg\mathtt{has}(\mathtt{pietro}, \mathtt{degree}) \Rightarrow \neg\mathtt{role}(\mathtt{pietro}, \mathtt{doctor})$, *such argument undercuts* $\neg\mathtt{causes}(\mathtt{smoking}, \mathtt{cancer})$ *argument, and* $\mathtt{causes}(\mathtt{smoking}, \mathtt{cancer})$ *becomes the acceptable conclusion for that agent.*

Definition 5 (Acceptable Arguments)**.** *An argument $\langle S, c\rangle^{\theta}_{\mathtt{sn_i}}$ is acceptable to an agent* ag *(where $\Delta_{\mathtt{ag}}$ is its knowledge base) if it is not attacked by other arguments, or if every argument attacking $\langle S, c\rangle^{\theta}_{\mathtt{sn_i}}$ is defeated by some acceptable argument $\langle S_n, c_n\rangle^{\theta}_{\mathtt{sn_j}} \in \Delta_{\mathtt{ag}}$ (i.e., all arguments that attack $\langle S, c\rangle^{\theta}_{\mathtt{sn_i}}$ cannot be inferred from $\Delta_{\mathtt{ag}}$ because they are attacked by acceptable arguments in $\Delta_{\mathtt{ag}}$).*

In communication, the acceptability of arguments received from other agents is directly associated with the agent's rationality, i.e., when an agent ag receives an argument $\langle S, c\rangle^{\theta}_{\mathtt{sn_i}}$ from another agent, it is able to check if that information is or is not acceptable to itself, temporarily adding S to its knowledge base $\Delta_{\mathtt{ag}}$ (i.e., $\Delta_{\mathtt{ag}} = \Delta_{\mathtt{ag}} \cup S$) and checking the acceptability of c. We use $\Delta_{\mathtt{ag}} \models c$ to express that agent Ag is able to construct an acceptable argument $\langle S, c\rangle^{\theta}_{\mathtt{sn_i}}$, with $S \subset \Delta_{\mathtt{ag}}$. An agent will never have acceptable arguments for conflicting information, i.e., $\Delta_{\mathtt{ag}} \models c$ and $\Delta_{\mathtt{ag}} \models \overline{c}$ never both hold simultaneously. We use $\Delta_{\mathtt{ag}} \not\models c$ to denote that an agent is not able to construct an acceptable argument for c. $\Delta_{\mathtt{ag}} \not\models c$ does not imply $\Delta_{\mathtt{ag}} \models \overline{c}$; however, $\Delta_{\mathtt{ag}} \models c$ implies $\Delta_{\mathtt{ag}} \not\models \overline{c}$.

2.3 Referring to Organisational Components

Argumentation schemes as a specification on top of a MAS with an organisational model allows them to have several relations with other components in the organisational specifications of such systems, such as normative, structural, and functional specifications (although such specifications themselves are not the focus of this paper). Furthermore, there are some organisational components, such as roles, authority links, etc., that are commonly referred to from the premises and critical questions of argumentation schemes; they are also common knowledge (as ensured by existing organisation infrastructures) and, therefore, they play an important role in our approach. Of course, agents will have more common knowledge specific to the application domain; however, for simplicity, in this work we use only organisational information, which is guaranteed common knowledge in platforms for the development of MAS based on the organisational paradigm.

As described before, argument schemes could refer to organisational components, as it is the case in the argumentation schemes given as example above. In such organisational-based approaches, all agents/participants are aware of other agents' roles in the organisation and the associated features/abilities related to them. Therefore, it would be pointless to exchange such information in a communication process.

2.4 Agent Knowledge

We denote all knowledge coming from the organisational infrastructure available to agents as $\Delta_{\mathtt{Org}}$, and we emphasise that all agents are aware of the information in $\Delta_{\texttt{Org}}$ (and the organisation infrastructure ensures that this information is kept up to date with the state of open, dynamic organisations at runtime). Further, we denote all argumentation schemes, available for agents to instantiate arguments in the MAS as $\Delta_{\texttt{AS}}$; recall that, being one of the organisation specifications, argumentation schemes are also common knowledge in our approach. They represent defeasible inferences that entail a conclusion from the instantiated premises, and they point to possible doubts in such defeasible inferences by means of critical questions. Finally, we denote all knowledge available to an agent $\texttt{ag}_\texttt{i}$ as $\Delta_{\texttt{ag}_\texttt{i}}$, where $(\Delta_{\texttt{Org}} \cup \Delta_{\texttt{AS}}) \subset \Delta_{\texttt{ag}_\texttt{i}}$.

Normally, $(\Delta_{\texttt{ag}_\texttt{i}} \setminus (\Delta_{\texttt{Org}} \cup \Delta_{\texttt{AS}})) \neq \emptyset$ holds, given that agents are constantly perceiving the environment and exchanging knowledge, as well as agents have specialised knowledge depending on their position/role within the MAS. Thus, arguments are often constructed by agents using all knowledge available in $\Delta_{\texttt{ag}_\texttt{i}}$. In some cases, agents are able to construct arguments based on just $\Delta_{\texttt{Org}}$ and $\Delta_{\texttt{AS}}$, if the argument contains only organisational information. However, agents will never construct arguments using only $\Delta_{\texttt{AS}}$, given that it represents non-instantiated reasoning patterns. While we follow an approach in which agents have specialised knowledge, there are other approaches, like sharing a domain knowledge base, as presented in (Schmidt et al. 2016), that could be easily incorporated into our approach.

3 Enthymemes

Differently from logical arguments, where their supports have enough information to entail the conclusion, enthymemes only explicitly represent some of the premises needed for inferring a claim/conclusion (or even have a missing conclusion) (Walton, Reed, and Macagno 2008).

Using enthymemes in human activities has widely-known benefits, allowing for economy, efficiency, and efficacy, as claimed by Nettel in (Nettel 2011); in particular, Nettel claims that: (i) being shorter, enthymemes can be easier to follow by the audience; (ii) starting from what is known and already taken for granted is important, because the addressee will, in consequence, be well-disposed towards what is said; (iii) omitting premises is also justified by reasons of economy, where if something is well-known it is unnecessary to repeat it; (iv) omitting the conclusion has advantages in terms of economy, but might also be beneficial to efficiency because if the audience comes to the conclusion by itself, its acceptance is more easily acquired; and (v) allowing members of the audience to come to a conclusion by themselves might be more respectful towards them.

The use of enthymemes characterises more rational and "intelligent" agents; besides bringing them closer to human reasoning and communication, we also show that using enthymemes could bring some computational benefits for MAS.

When agents use enthymemes, the common knowledge is removed from the original argument by the proponent of the argument (such process is called *encoding* in (Black and Hunter 2008)), where it is assumed that all information removed from the original argument is known by the recipients and, therefore, they are able to reconstruct (or to *decode*)

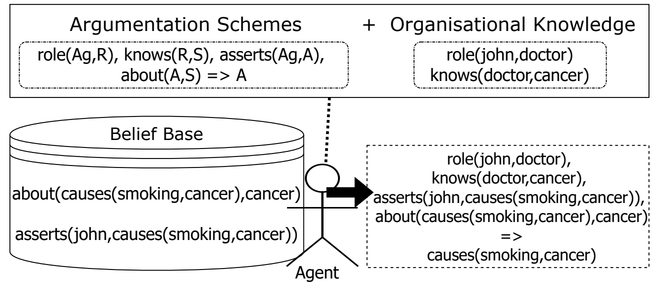

Figure 2: Constructing arguments using argumentation schemes and organisational information.

such an argument, understanding exactly what was meant to be communicated. If both the proponent and recipients in fact have the same common knowledge, then this process is straightforward (Hunter 2007). However, normally, this is not the case, and the recipients generate an approximation of such an argument in the reconstruction process, given the disparities between the different views on what constitutes common knowledge (Hunter 2007).

In our approach, however, we can guarantee that all agents, which are involved in an argumentation-based dialogue, will have the same understanding when using enthymemes, by means of guiding the reconstruction of arguments by the recipients using argumentation schemes and available organisational knowledge[3].

Definition 6 (Enthymeme)**.** *Let $\langle S, c\rangle^{\theta}_{\texttt{sn}}$ be an acceptable argument to agent $\texttt{ag}_\texttt{i}$. An enthymeme for $\langle S, c\rangle^{\theta}_{\texttt{sn}}$ is a tuple $\langle S', c\rangle^{\theta}_{\texttt{sn}}$, where $S' = (S \setminus (\Delta_{\texttt{Org}} \cup \Delta_{\texttt{AS}}))$.*

Example 3. *An argument contains, in its support, all premises and inference rules needed to entail the conclusion, and it could be constructed as*[4]*:*
$\langle\{$`role(john,doctor),`
`asserts(john,causes(smoking,cancer)),`
`knows(doctor,cancer),`
`about(causes(smoking,cancer),cancer),`
`[role(Ag,R),knows(R,S),asserts(Ag,A),`
`about(A,S)` $\Rightarrow$ `A]`$\}$,
`causes(smoking,cancer)`$\rangle^{\theta}_{\texttt{position\_to\_know}}$
where $\theta = \{\texttt{Ag} \mapsto \texttt{john}, \texttt{R} \mapsto \texttt{doctor}, \texttt{S} \mapsto \texttt{cancer}, \texttt{A} \mapsto \texttt{causes}(\texttt{smoking}, \texttt{cancer})\}$. *The corresponding enthymeme has the following format (considering the common knowledge presented in Figure 2):*
$\langle\{$`asserts(john,causes(smoking,cancer)),`
`about(causes(smoking,cancer),cancer)`$\}$,
`causes(smoking,cancer)`$\rangle^{\theta}_{\texttt{position\_to\_know}}$

Based on the label `position_to_know` *and the most general unifier θ, an agent receiving the enthymeme is able to identify the missing premises and therefore conclude that* `causes(smoking,cancer)`, *given that all missing premises are organisational information and, therefore, common knowledge.*

[3]Also, recall that we have an infrastructure that ensures that all agents will have the same perception on what constitutes common knowledge.

[4]We use `[` and `]` in order to delimit the inference rules.

Further details about encoding arguments into enthymemes and decoding enthymemes into arguments will be discussed in the next section, where both processes are properly formalised.

4 Argumentation-Based Dialogues

In the multi-agent paradigm, communication is often based on the speech-act theory (Searle 1969). In such approaches, messages have the following format $\langle \texttt{Ags}, \texttt{performative}, \texttt{content}\rangle$, where `Ags` represents the agent (or set of agents) to which the message is addressed, `performative` denotes the illocutionary force of the speech act, and `content` is the (propositional) content of the message. The performatives we use in this work and their intended meaning are informally presented below:

- `assert`: the performative `assert` is used by agents to introduce a particular claim in the dialogue. The agents receiving such a message become aware of that claim.
- `question`: the performative `question` is used by agents to question a claim, part of arguments, or a critical question related to an argument, put forward by agents in the dialogue. The `content` will be a proposition φ that either: (i) refers to a claim put forward by some agent in the dialogue; or (ii) refers to part of an argument for which its corresponding enthymeme has been put forward by some agent in the dialogue, i.e., $\varphi \in S$ for some argument $\langle S, c\rangle^{\theta}_{\texttt{sn}}$ for which the enthymeme $\langle S', c\rangle^{\theta}_{\texttt{sn}}$ has been put forward by some agent in the dialogue; or (iii) a critical question associated to an argument for which its corresponding enthymeme has been put forward by some agent in the dialogue, i.e., $\varphi = q\theta_{\texttt{sn}}$, with $q \in \mathcal{CQ}$, for an argumentation scheme[5] $\langle \texttt{sn}, \mathcal{C}, \mathcal{P}, \mathcal{CQ}\rangle$, with $\langle S, c\rangle^{\theta}_{\texttt{sn}}$ the intended argument, and $\langle S', c\rangle^{\theta}_{\texttt{sn}}$ the previously received enthymeme.
- `justify`: the performative `justify` is used by agents to introduce an enthymeme in the dialogue. The content will be $\langle S', c\rangle^{\theta}_{\texttt{sn}}$, with $\langle S, c\rangle^{\theta}_{\texttt{sn}}$ the intended argument for c.
- `refuse`: the performative `refuse` is used by agents to refuse a previous proposition put forward by some agent in the dialogue.
- `accept`: the performative `accept` is used by agents to accept a previous proposition put forward by some agent in the dialogue.

In the course of argumentation-based dialogues, agents make commitments based on which speech act they use. These commitments are stored in the commitment store (CS) that consists of one or more structures, accessible to all agents in a dialogue[6]. The CS is simply a subset of the knowledge base, and the union of the CSs can be viewed as the global state of the dialogue at a given time (Parsons, Wooldridge, and Amgoud 2002). The rules that define how CSs are updated, depending on the speech act used by agents, are summarised as follows: (i) *assert*: the agent's CS is updated with the asserted content p, $CS \leftarrow CS \cup \{p\}$; (ii) *accept*: the agent's CS is updated with the accepted content p, $CS \leftarrow CS \cup \{p\}$; (iii) *question* and *refuse*: no effect over the CS; and (iv) *justify*: the agent's CS is updated with the justified content contained in the set of rules and facts S (the support of the intend argument for p), $CS \leftarrow CS \cup S$. Using these speech acts, various protocols can be specified.

It is important to mention that, when the agent receives a justify message, the content is an enthymeme. Thus, the enthymeme is decoded into the original sender's argument, guided by the argumentation scheme. The operational semantics for the performatives we use in this work, regarding decoding enthymemes into arguments and encoding arguments into enthymemes, is presented in the short paper presented in (Panisson and Bordini 2022). We define the encoding and decoding processes as follow:

Definition 7 (Encoding Arguments into Enthymemes)**.** *When an agent ag send a message $\langle sid, \texttt{justify}, \langle S, c\rangle^{\theta}_{sn}\rangle$, the argument $\langle S, c\rangle^{\theta}_{sn}$ is encoded into the enthymeme $\langle S', c\rangle^{\theta}_{sn}$ with $S' = (S \setminus (\Delta_{AS} \cup \Delta_{org}))$.*

Definition 8 (Decoding Enthymemes into Arguments)**.** *When an agent receives a message $\langle sid, \texttt{justify}, \langle S', c\rangle^{\theta}_{sn}\rangle$, the enthymeme $\langle S', c\rangle^{\theta}_{sn}$, instantiated from the argumentation scheme $\langle sn, \mathcal{C}, \mathcal{P}, \mathcal{CQ}\rangle$ is decoded to the argument $\langle S, c\rangle^{\theta}_{sn}$, i.e., for all $p \in \mathcal{P}$ with $p\theta \in S'$, then $p[s(sid)]\theta \in S$ (everything said by the agent sid), for all $p \in \mathcal{P}$ with $p\theta \notin S'$, then $p[s(sid), dec(\texttt{sn})]\theta \in S$, and $\mathcal{P} \Rightarrow \mathcal{C})[s(sid), dec(\texttt{sn})] \in S$ (everything decoded by the receiver agent).*

5 Example

Considering the example we introduced, we show a short real-world dialogue between a nurse and two patients in a hospital scenario using the argumentation scheme `position_to_know` and an additional argumentation scheme[7] called here *cc* — $\texttt{[causes(A,I), evidences(P,A)} \Rightarrow \texttt{is\_consequence(I,A)]}_{cc}$ — stating that "*if a long-term action A causes an illness I, and there is evidence that a patient P has been doing A, probably illness I is a consequence of A*".

Imagine that the nurse is supposed to explain to two patients, *Alice* and *Bob*, who were diagnosed with cancer, how they probably got the illness[8]. Using the performatives introduced, the nurse starts a dialogue executing a `justify` move explaining that smoking causes cancer, in which the following enthymeme is built by the nurse (according to Definition 7):

$\langle\{\texttt{asserts(john,causes(smoking,cancer)),}$
$\texttt{about(causes(smoking,cancer),cancer)]}\},$
$\texttt{causes(smoking,cancer)}\rangle^{\theta}_{\texttt{position\_to\_know}}$

[5] Recall that S is different from $\mathcal{P}$, considering that $\mathcal{P}$ are non-instantiated premises, and S the entire support for c.

[6] Other names are used for CS, such as *dialogue obligation store* in (McBurney and Parsons 2004) and *dialogue store* in (Sadri, Toni, and Torroni 2001).

[7] We refer to this argumentation scheme as a domain-dependent version of the argumentation scheme *argument from cause to effect*, found in (Walton, Reed, and Macagno 2008, pg.328).

[8] It is important to mention that we assume the nurse was asked to explain the doctor's diagnosis; we do not assume that the nurse made the diagnosis themselves.

Based on the common knowledge that `john` is a doctor and doctors are experts in such domains (see Figure 2), both patients accept that "*smoking causes cancer*". After introducing this premise, following the nurse's strategy, another `justify` move is executed to explain that, probably, smoking is the cause of their illness. The enthymeme resulting (according to Definition 7) is:
$\langle\{\texttt{causes(smoking,cancer)},$
$\texttt{evidence(alice/bob,smoking)}\},$
$\texttt{is\_consequence(cancer,smoking)}\rangle^{\theta}_{\texttt{cc}}$
Considering that both *Bob* and *Alice* share the argumentation scheme *cc*, (i) *Bob* accepts the nurse's argument, given he has been smoking cigarettes for many years and he is able to make the same inference used by the nurse; and (ii) *Alice* questions the premise `evidence(alice,smoking)`, given she does not smoke. Thus, the nurse explains that she has been a second-hand smoker[9] because of her husband's smoking, thus she has been smoking for many years as well. Finally, she accepts the nurse's claim[10].

This example demonstrates that our enthymeme-based communication framework matches with real-world dialogues, which is a very important property, considering the AI community aims to achieve such rich dialogues when involving software agents too. Further, note that, when communicating the second enthymeme, the nurse uses the premise $\texttt{causes}(\texttt{smoking}, \texttt{cancer})$, which is in the CS of both patients *Bob* and *Alice* (according to `accept` performative from Section 4). While for software agents it could be interesting to omit that information, given that all agents participating in that particular dialogue accepted that information and it became common knowledge for them, when involving human-agent interaction, it is wiser to repeat that information to make the link between the moves in a dialogue, which is important for example in fields such as storytelling (Bex and Bench-Capon 2010; Bex and Bench-Capon 2014; Bex and Bench-Capon 2017), and complex explanations (Sklar and Azhar 2018; Miller 2019). Also, it addresses some of Grice's maxims for cooperative communication as we discuss in the next section.

6 Properties

Grice (Grice 1975) claims that conversational statements are often linked together, forming a cooperative effort to achieve some goal of information exchange, or social goal. Thus, Grice proposes four categories of maxims that would help to achieve such cooperative principle, namely: *quality, quantity, relation* and *manner*. The category of *quality* includes two (sub)maxims: (1) *do not say things that are believed to be false*, and (2) *do not say things for which there is no sufficient evidence*. The category of *quantity* includes two (sub)maxims: (3) *make the contribution as informative as is required*, and (4) *do not make it more informative than is required*. The category of *relation* includes only the following maxim: (5) *be relevant*. The category of *manner* includes four (sub)maxims: (6) *avoid obscurity of expression*, (7) *avoid ambiguity*, (8) *be brief*, (9) *be orderly*.

These maxims are important aspects concerning communication in MAS, including those multi-agent applications that require human-agent interaction in the context of eXplainable AI (XAI) (Gunning 2017; Gunning et al. 2019) and Hybrid Intelligence (Akata et al. 2020). Clearly, in this work, our main contribution addressing Grice's maxims for cooperative communication is centred in the category of *quantity*, in which agents will exchange shorter arguments (enthymemes) and will understand each other as if they had communicated the full intended argument.

Proposition 1. *Agents always communicate shorter arguments (enthymemes) instead of the intended arguments.*

Proof. In our approach, agents only communicate arguments using the `justify` performative (see Section 4), which encode arguments into enthymemes according to Definition 7. That way, any information from $\Delta_{\texttt{Org}}$ and $\Delta_{\texttt{AS}}$ will be removed from the intended argument. Considering that agents are only able to instantiate arguments from the argumentation schemes in $\Delta_{\texttt{AS}}$ (Definition 2), if there exists an argument $\langle S, c\rangle^{\theta}_{\texttt{sn}_\texttt{i}}$, then there exists an argumentation scheme $\langle \texttt{sn}_\texttt{i}, \mathcal{C}, \mathcal{P}, \mathcal{CQ}\rangle \in \Delta_{\texttt{AS}}$. Even if such an argument does not refer to any information from $\Delta_{\texttt{Org}}$, the resulting enthymeme $\langle S', c\rangle^{\theta}_{\texttt{sn}_\texttt{i}}$ will be shorter than the intended argument $\langle S, c\rangle^{\theta}_{\texttt{sn}_\texttt{i}}$, given $S' = S \setminus (S \cap (\Delta_{\texttt{Org}} \cup \Delta_{\texttt{AS}}))$, i.e., at least $(\mathcal{P} \Rightarrow \mathcal{C}) \notin S'$. □

Proposition 2. *Agents understand each other as if they had communicated the intended arguments instead of enthymemes.*

Proof. In our approach, agents always communicate shorter arguments (enthymemes) instead of the intended arguments (Proposition 1). Enthymemes are represented as $\langle S', c\rangle^{\theta}_{\texttt{sn}_\texttt{i}}$, making reference to the argumentation scheme $\langle \texttt{sn}_\texttt{i}, \mathcal{C}, \mathcal{P}, \mathcal{CQ}\rangle \in \Delta_{\texttt{AS}}$ and the unifier θ used to instantiate the intended argument. When decoding an enthymeme $\langle S', c\rangle^{\theta}_{\texttt{sn}}$, according to Definition 8, agents recover all information $p \in S'$ plus the omitted content $p \in \mathcal{P}$ and $p\theta \notin S'$. All information is properly annotated with the source of that information $s(sid)$ and whether it has been decoded $dec(\texttt{sn})$ or not. The reference to the argumentation scheme $\texttt{sn}$ and θ guarantees that, for all $p \notin S'$, $p \in S$, with S the support of the intended argument, with p properly annotated, i.e., $p[dec(\texttt{sn})]\}$. Thus, the agent receiving that enthymeme will have the same understanding as if it had received the intend argument — all $p \in S$ properly annotated $p[s(sid)]$ — also understanding which parts of the intended argument have been omitted in the enthymeme — for all $\forall p \in S$ and $p \notin S'$ properly annotated $p[dec(\texttt{sn}_\texttt{i})]$. □

Both properties are also supported by an empirical evaluation presented in the next section.

While Grice's maxims (3), (4), and (8) are directly addressed by our approach when using the concept of enthymemes, maxims (6) and (7) are addressed by agent communication languages through well defined semantics. In

[9] Someone who breaths other people's smoke.

[10] Note that when a patient has an argument against the causal generalisation or the evidences, the patient is able to use the critical questions listed in (Walton, Reed, and Macagno 2008, pg.328).

the context of an enthymeme-based communication framework, we also addressed those maxims through the operational semantics presented in (Panisson and Bordini 2022). Finally, Grice's maxims (1), (2), (5), and (9) can be addressed when specifying argumentation-based protocols, for example, addressing maxims (1) and (2) by constraining the justify move so that agents only introduce acceptable arguments in the dialogue. In the next section, we use two different argumentation-based protocols from the literature to evaluate the generality of our approach and support the properties described in this section, also presenting an empirical evaluation for our approach.

7 Empirical Evaluation

We have implemented our enthymeme-based communication framework using the JaCaMo Platform (Boissier et al. 2013), and its implementation is available open source[11]. Using that implementation, we have evaluated our framework using different scenarios of argumentation-based dialogues that use different argumentation schemes and different argumentation-based protocols from the literature.

The first scenario implemented is from (Panisson et al. 2018), in which the authors propose the following argumentation scheme for data-access control: (`as4dac` for short):

> Information I has security information-category C (**premise**). Agent A belongs to an access-category R which has (has no) access to information with security information-category C (**premise**). Agent A has (has no) access to information I (**conclusion**).

using this argumentation scheme and the *information-seeking* protocol specified below, the authors were able to implement data access control in MAS using an argumentation-based approach. The protocol from (Panisson et al. 2018) is specified as follow:

(1) a requester agent, named ag_i, sends a question message to an interface agent, named ag_j, asking access to a particular information φ; the protocol goes to (2);

(2) ag_j receives the request (or new information) from ag_i and checks whether it has an acceptable argument supporting $\mathtt{access}(\mathtt{ag_i}, \varphi)$. In case ag_j has an acceptable argument supporting that agent ag_i has access to the information φ, ag_j provides the information to ag_i, and the protocol goes to (4). Otherwise, when ag_j has an argument against ag_i having access to the information φ, ag_j justifies why ag_i has no access to the information φ, sending an argument supporting $\neg\mathtt{access}(\mathtt{ag_i}, \varphi)$ to $\mathtt{ra}$; the protocol goes to (3);

(3) ag_i receives an argument supporting that it has no access to the requested information, then ag_i checks whether there is any information in support of the argument received from ag_j that it disagrees with, and in case there is some information with which ag_i disagrees, for example, ag_j was not able to identify the correct role of ag_i in the MAS, ag_i provides the correct information sending an assert message to ag_j, and the protocol goes to (2). Otherwise, when the ag_i is not able to identify any wrong information about itself, used to deny access to the requested information, the protocol goes to (4);

(4) the dialogue ends, either with ag_i receiving the information or realising it has no access to the information.

Using this protocol, the authors in (Panisson et al. 2018) describe a scenario that illustrates an emergency situation that requires sharing data between two different hospitals. The scenario involves a patient, named Bob, who is being monitored and receiving treatment in a hospital H1. The patient decides to travel to another country, receiving a bracelet that informs how to contact H1 in case of emergency. During the trip, Bob starts to feel strong pain in the chest, becomes unconscious, and goes to hospital H2. Then, a doctor, named Joe, from H2 calls the hospital H1 asking for Bob's records. However, the interface agent responsible for answering the request categorises Joe as an external hospital receptionist (considering that they are from different organisations so it has no access to H2's organisational structure). There is no access control rule that grants access to a patient's records to an external hospital receptionist, thus the interface agent denies access to that information with the following enthymeme[12]:

$$\langle\ \{\mathtt{info\_category(record,patient\_data)},\ \mathtt{ac\_category(joe,ext\text{-}hospital\text{-}receptionist)},\ \neg\mathtt{access\_rule(ext\text{-}hospital\text{-}receptionist,\ patient\_data)}\ \},\ \neg\mathtt{access(joe,record)}\ \rangle^{\theta}_{\mathtt{as4dac}}$$

in which `ac_category` stands for *access category*, and `inf_category` for *information category*, which are linked by access rules, specifying when an `ac_category` has access to an `inf_category`. Continuing this scenario, when Joe receives the argument above, he realises that his role has not been correctly identified, so he provides the information that he is a doctor. However, external doctors have no access to patient's records as well, and he receives the following argument:

$$\langle\ \{\mathtt{info\_category(record,patient\_data)},\ \mathtt{ac\_category(joe,external\text{-}doctor)},\ \neg\mathtt{access\_rule(external\text{-}doctor,patient\_data)}\ \},\ \neg\mathtt{access(joe,record)}\ \rangle^{\theta}_{\mathtt{as4dac}}$$

Finally, considering that Joe has been correctly categorised, Joe provides the information that the patient is unconscious, which means it is an emergency situation. That information enables the use of emergency rules, in which external doctors have access to patient's records in emergency situations, and Bob's records are granted to Joe.

Applying our approach to this protocol enables the interface agent to communicate enthymemes when justifying why the requester agent has no access to the re-

[11] https://github.com/AlisonPanisson/EBCF

[12] Note that, the interface agent knows the requester agents share the same argumentation schemes, but they do not share information about the organisational structure, considering they are from different organisations.

quested information, sending an enthymeme supporting $\neg\texttt{access}(\texttt{ag}_\texttt{i}, \varphi)$, with ag_i the requester agent. The implementation of this protocol, using our approach for enthymeme-based communication in MAS, including the scenarios from (Panisson et al. 2018), is available in our GitHub repository[13]. Also, the repository includes an empirical evaluation in which we measure the length of messages communicated by agents in this scenario. Our results show that our approach reduces from 45% to 46% the length of arguments (enthymemes) communicated by agents.

The second scenario implemented is from (Panisson, McBurney, and Bordini 2021; Panisson and Bordini 2017; Panisson 2017), in which the authors show different examples of argumentation-based dialogues about experts' assertions, based on the argumentation scheme from role to know described in this paper, using the protocol for *inquiry* dialogues described below:

(1) an agent ag_i starts a dialogue with another agent ag_j, asserting the information φ that becomes the subject of the dialogue; the protocol goes to (2).

(2) ag_j receives the assertion of φ and checks whether it has an argument against it. When it has no argument against φ, it accepts that information, and the protocol goes to (5). Otherwise, when ag_j is able to construct an argument against φ, ag_j questions the other agent for an argument supporting that assertion; the protocol goes to (3).

(3) ag_i receives a question and it responds with an argument that supports the questioned proposition; the protocol goes to (4).

(4) ag_j receives an argument and checks whether the information received from ag_i is enough to make it accept the subject of the dialogue, i.e., if it has no argument against the subject of the dialogue, considering the argument received from ag_i. In case ag_j has no argument against the subject of the dialogue, it accepts the subject of the dialogue; the protocol goes to (5). Otherwise, when ag_j is able to construct an argument against the subject of the dialogue, either (i) it asserts $\neg\varphi$, committing itself to provide support for $\neg\varphi$, and the protocol goes to (2); or (ii) it checks whether it is able to answer negatively any critical question related to the argumentation scheme sn that ag_i has used to instantiate its argument. In the case where it is able to answer negatively a critical question from sn, it asserts $\neg cq$, with cq the critical question; the protocol goes to (2).

(5) ag_j receives an accept message, and in the case where the accepted proposition is the subject of the dialogue, the dialogue ends with both agents believing that the subject of the dialogue holds. In the case where the accepted proposition is a critical question, the agent that accepts the critical question returns to step (4) of the protocol, accepting the subject of the dialogue, questioning another critical question, or committing itself to give support for the subject of the dialogue not being the case.

[13] https://github.com/AlisonPanisson/EBCF/blob/master/Scenario_DAC.md

Using this protocol, the authors (Panisson, McBurney, and Bordini 2021; Panisson and Bordini 2017; Panisson 2017) describe an example in which two agents argue about whether *smoking causes cancer* or not, the same scenario introduced in Sections 2. In that example, agents communicate arguments similar to those presented in Section 3. Below, we describe an enthymeme communicated by an agent from the implementation of this scenario:

$\langle\{\texttt{asserts(pietro,}\neg\texttt{causes(smoking,cancer))},$
$\texttt{about(causes(smoking,cancer),cancer)}\},$
$\texttt{causes(smoking,cancer)}\rangle^{\theta}_{\texttt{position\_to\_know}}$

in which it believes that *smoking does not cause cancer*, based on Pietro's assertion. Considering that Pietro is a doctor, it is a valid argument (enthymeme). However, in the course of the dialogue, another agent argues that Pietro is not a reliable source of information, and the dialogue ends with both agents reaching the conclusion that *smoking causes cancer*, based on John's assertion (the argument used as an example in Section 2).

Applying our approach to this protocol enables agents to communicate enthymemes when justifying their previous assertions. The implementation of this scenario and protocol is available in our GitHub repository [14]. Our empirical evaluation shows that our approach reduces the length of messages communicated by agents in this scenario from 45% to 51%. This second scenario achieves better results as agents are from the same organisation, i.e., they share the organisational structure of the MAS.

Implementing both protocols presented above, using the scenario introduced with each protocol by the authors, allowed us empirically validate our approach by executing a few experiments[15]. First, we were able to confirm that our approach reduces the length of arguments without losing the meaning of those communications, supporting both Propositions 1 and 2. Second, the experiments show the generality of our framework, which allows us to represent different argumentation schemes as well as specify different argumentation-based protocols using the performatives introduced in Section 4. More details, including the output for all experiments, are publicly available in our GitHub repository[16].

8 Related Work

In (Black and Hunter 2008), the authors investigate the use of enthymemes in inquiry dialogues, and show how enthymemes can be managed by the agents involved, and how common knowledge can evolve through dialogue. Also, the authors claim that when a recipient decodes an enthymeme, it does not know for certain what the intended argument is, and it is not guaranteed to find the same premises for it. But, if both have the same understanding of common knowledge,

[14] https://github.com/AlisonPanisson/EBCF/blob/master/Scenario_RK.md

[15] All experiments are available in https://github.com/AlisonPanisson/EBCF

[16] https://github.com/AlisonPanisson/EBCF

the intended argument (the original proponent's argument) is correctly interpreted by the recipient. Also, in that paper the authors say that enthymemes make the exchanges made by agents more sensible, since they avoid the use of common knowledge. But, in case of disparities in the so called cobases (the expected common knowledge) of the two agents, the enthymeme inquiry strategy in (Black and Hunter 2008) forces the agents to exchange quiz and posit moves (additional moves) when the recipient of an enthymeme cannot decode it. Our work differs from (Black and Hunter 2008) in that we guarantee that agents will only remove from the exchanged arguments information that all agents know, and the underlying platform ensures it is kept up to date to all agents, thus there are no disparities in the expected common knowledge. Thus, our approach avoids any extra moves such as the quiz and posit moves described in (Black and Hunter 2008). Also, we use argumentation schemes in order to guide the process agents use for encoding arguments into enthymemes and decoding enthymemes into arguments. Considering that practical MAS typically require accuracy in the communication process used by agents, our approach seems more applicable to MAS development.

In (Walton 2008), Walton proposes a new theory of enthymemes. That work describes three bases for the enthymeme in a formal dialogue system: (i) the participant's commitment sets; (ii) the set of argument schemes shared by both participants; and (iii) a set of propositions representing common knowledge shared by both participants. In (Walton 2008), Walton claims that "although there is much writing on the nature and importance of enthymemes, and their function in argumentation, very little appears to be known about how they actually work." Further, he says that the common-knowledge database is domain-dependent, because what is taken to be common knowledge varies widely depending on the context of the dialogue (Walton 2008). Our work takes inspiration from (Walton 2008); however we here consider structured argumentation in MAS, using concepts, features, and the infrastructure available in well-known multi-agent frameworks, such as JaCaMo (Boissier et al. 2013). While we already implemented (ii) and (iii) from Walton's theory, (i) can be easily implemented, and it is part of a planned extension of this work.

In (Black and Hunter 2009), extending their previous work in (Black and Hunter 2008), the authors argue that humans often engage in dialogues where enthymemes are used; however, proposals for logic-based formalisations of that process remain underdeveloped. In particular, in that work the authors use relevance-theoretic ideas of maximising cognitive effect and minimising cognitive effort. It aims to enable a proponent of an intended logical argument to construct an appropriate enthymeme for the intended recipient, and for the intended recipient to reconstruct the intended logical argument from the enthymeme. The authors argue that if a proponent wants to construct an appropriate enthymeme for a recipient, they need to know about the recipient's knowledge first. Similarly when the recipient deconstructs the enthymeme received from the proponent. Further, the authors have shown that if the recipient's view of the shared knowledge is the same as that of the proponent, then the deconstruction process is guaranteed to return an argument whose claim is the same as that of the intended argument (Black and Hunter 2009). Our work takes into consideration both those interesting points in (Black and Hunter 2009): the rationality of agents in constructing and deconstructing enthymemes, as well as considering the cognitive effects and efforts. As our approach guides such construction and deconstruction processes using argumentation schemes, the cognitive efforts can be reduced, while the cognitive effects are guaranteed, given that using the argumentation schemes for guidance, the recipient will have the same understanding of the proponent's argument.

9 Conclusion

In this work, we described an argumentation framework where agents exchange only the information needed to ensure that both sides, the proponent and recipient(s), will have the same understanding of the uttered arguments. Improving the efficiency of argumentation-based communication benefits all applications that use argumentation techniques, and decreasing the network usage benefits all applications that have restricted bandwidth, e.g., applications that use mobile networks such as (Schmidt et al. 2016; Koster, Bazzan, and de Souza 2016). Our approach is based on an organisation-centred paradigm, using organisational information and argumentation schemes as common knowledge; other approaches for describing common knowledge such as those in (Black and Hunter 2009; Black and Hunter 2008) could be considered without major changes. However, note that, considering organisational information and argumentation schemes as common knowledge, our approach allows agents to construct appropriate enthymemes not only for specific agents, but also to an entire "audience" belonging to the same organisation. Thus, when considering dialogues among more than two agents, our approach is more suitable than other approaches, given that agents will be able to use the same enthymemes for the entire audience, and all will have the same understanding of that communication.

Also, considering argumentation schemes in MAS from a practical point of view seems as yet an underdeveloped research topic. Here, we described how we used argumentation schemes integrated with multi-agent platforms, and how they are used by agents to instantiate arguments as well as to decode enthymemes into arguments instantiated from those argumentation schemes.

In future work, we intend to extend our approach to consider the public statements previously made by agents during dialogues (the *commitment stores*), covering all desiderata from (Walton 2008). However, as argued in this paper, it may depend on the context of different types of dialogues. While storytelling (Bex and Bench-Capon 2010; Bex and Bench-Capon 2014; Bex and Bench-Capon 2017) and complex explanations (Sklar and Azhar 2018; Miller 2019) require agents reinforcing previous conclusions (from their CS) in order to keep the link between arguments, other types of dialogues may not require such a link between moves, thus that information can be omitted.

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