Interleaved Argumentation and Explanation in Dialog

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Abstract. Our goal is to provide computational models for natural arguments for the concepts of argument and explanation studied in the informal logic literature. Apart from distinguishing explanations from arguments we show our approach for modeling them. We describe the communicative acts of the agents by representing their different views on the topics of the dialog. By using description logics to define the differences, its reasoning is used to distinguish arguments from explanations.

1 INTRODUCTION

Argument and explanation are considered distinct and equally fundamental [8], whose complementary relationship [9] is a central issue for identifying the structure of natural dialogs. Considering the costs or arguing [13], the thesis of this research states that in the majority of natural dialogs people prefer to explain things and not just arguing on them.

In this study we also investigate the relation between knowledge, argument, and explanation. The role of knowledge in argumentation have been stressed out by Walton [17]. In natural dialogs knowledge interleaves with argumentation. When performing reasoning tasks on available knowledge, agents perform better if the reason is argumentative [11]. On the one hand, knowledge of agents is exploited when generating, conveying, and assessing arguments. On the other hand, argumentation can be an efficient tool for knowledge acquisition or collaborative knowledge construction.

The complementarity between argument and explanation is best characterized by the fact that humans tend to take decision both on knowledge and understanding [18]. For instance, in judicial cases, circumstantial evidence needs to be complemented by a motive explaining the crime, whilst the explanation itself is not enough without plausible evidence [9]. In both situations the pleading is considered incomplete if either argumentation or explanation is missing.

The following section stresses out the differences between argument and explanation as they already have been addressed in the current schools of thought in philosophical sciences. Section 3 illustrates how the distinguishing features of arguments and explanation can be modeled in description logic. Section 4 analysis the situation when parties differently interpret reasons as argument and explanation. Section 5 approaches the specific communicative acts from the perspective of differentiating between argument and explanation and shows the dynamics of these two interpretation in a natural dialog. After browsing related work in section 6, section 7 concludes the paper.

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2 DISTINGUISHING ARGUMENT FROM EXPLANATION

The role of argument is to establish knowledge, whilst the role of explanation is to facilitate understanding. Thus, to make an instrumental distinction between argument and explanation, one has to distinguish between knowledge and understanding. One legitimate question would be: does understanding represent more knowledge? From the perspective of [citation needed], knowledge represents awareness of information, whilst understanding represents the awareness of the connections between pieces of information. In the simplest computational model, understanding of a concept can be quantified in terms of the number of relations an agent is aware in a given context regarding that concept. A supplementary constraint would impose these relations to include causal, and other types of roles among them, in order to assign a meaning to concept. Note that both concepts are defined in terms of the epistemic notion of awareness. From an operational or behavioral viewpoint, understanding allows the knowledge to be put in practice. In this line, understanding represents a deeper level than knowledge.

The interaction between argument and explanation is the basic mechanism for augmenting an agent's knowledge and understanding. We consider the following distinctive features of argument and explanation:

1. Argumentation starts with a conflict. Explanation starts with non-understanding.
2. In explanation the roles are usually asymmetric: the explainer is assumed to have more understanding and wants to transfer it to the explainee. In argumentation, both parties start the debate from equal positions, thus initially having the same roles. Only at the end of the debate the asymmetry arises when the winner is considered to have more relevant knowledge on the subject.
3. In explanation one party supplies information. There is a linguistics indicator which requests that information. Because in argumentation it is assumed that all parties supply information, no indicator of demanding the information is required.

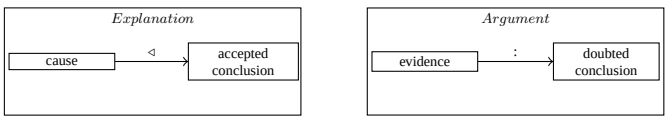


Figure 1. Distinguishing argument from explanation.

Regarding the first topic, for an argument, premises represent evidence supporting a doubted conclusion. For an explanation, the con-

clusion is accepted and the premises represent the causes of the consequent (see figure 1). The explanation aims to understanding the explanandum by indicating what causes it, whilst an argument aims to persuade the other party about a believed state of the world. An argument in considered adequate in principle if there is at least one agent who justifiably believes that the premises are true but who does not justifiably believe this about the consequent [7]. An explanation is adequate in principle if all the agents accepting the premises would also accept the consequent. The function of argument is to "transfer of justified belief", whilst the role of explanation is to "transfer of understanding".

Regarding the second topic above, consider the dialog between a teacher an a sophomore student which is almost entirely explicative. The ontology of the student regarding the specific scientific field is included in the ontology of the teacher. As the ontology of the student increases, resulting in different perspectives on the subject, exchanging arguments may occur.

The above scenario helps us to extract several knowledge conditions for arguments. Firstly, a doubted conclusion arises from different knowledge bases. Assuming the same reasoning capabilities, the precondition states that the agents should have different ontologies in order to be able to rise arguments. Formally, the intersection between agents ontologies shouldn't be empty ($\mathcal{O}_i \cap \mathcal{O}_j = \mathcal{O}_{ij} \neq \emptyset$), such that the agents can communicate, but the differences should be consistent enough to generate arguments ($\mathcal{O}_i \setminus \mathcal{O}_j \neq \emptyset$ and $\mathcal{O}_j \setminus \mathcal{O}_i \neq \emptyset$). The arguments are constructed based on knowledge in the symmetric difference of the agents ontology $\mathcal{O}_i \Delta \mathcal{O}_j = \mathcal{O}_i \setminus \mathcal{O}_j \cup \mathcal{O}_j \setminus \mathcal{O}_i$. Depending on the granularity of the common ontology $\mathcal{O}_{ij}$, one agent should convey more abstract or more concrete arguments in order to adapt them to the audience.

Regarding the third topic, the easiest way to distinguish between explanation and argument is to compare arguments $for\ F$ and explanations $of\ F$. The mechanism should distinguish between whether F is true and why F is true. In case F is a normative sentence, the distinction is difficult [18]. If F is an event, the question why F happened is clear delimited by the whether F happened.

3 REPRESENTING ARGUMENTS AND EXPLANATION

After browsing the technical instrumentation provided by description logics, this section models the distinguishing features of arguments and explanation in description logics (DL).

This section assumes that the reader is familiar with the basic concepts of description logics and the main idea of the Argument Interchange Format (AIF) ontology. Given that $Reason \sqsubseteq RuleScheme$ in the AIF ontology, we have:

Definition 1 *An argument is a reason in which the premises represent evidence in support of a doubted conclusion.*

$$Argument \sqsubseteq Reason \sqcap \forall hasPremise.Evidence \quad (1)$$

$$Argument \sqsubseteq (=1) hasConclusion.DoubtedStatement \quad (2)$$

Definition 2 *An explanation is a reason in which the premises represent a cause of an accepted fact.*

$$Explanation \sqsubseteq Reason \sqcap \forall hasPremise.Cause \quad (3)$$

$$Explanation \sqsubseteq (=1) hasConclusion.Fact \quad (4)$$

We define a doubted statement as a statement that is challenged by one agent:

$$DoubtedStatement \sqsubseteq \exists challenge.Statement \quad (5)$$

where the $challenge$ role has the concept $Agent$ as domain:

$$\exists rejects.Statement \sqsubseteq Agent \quad (6)$$

No $challenge$ relation should exist for a statement accepted as a fact, given by:

$$Fact \sqsubseteq Statement \sqcap \forall challenge.\ \bot \quad (7)$$

Both pieces of evidence and causes represent statements:

$$Evidence \sqsubseteq Statement, Cause \sqsubseteq Statement \quad (8)$$

We can refine this top level ontology by classifying evidence (in shortcut notation Ev), in direct or circumstantial evidence:

$$DirectEv \sqsubseteq Ev \sqcap \exists directsupport.DoubtedStatement \quad (9)$$

$$CircumstantialEv \sqsubseteq Ev \sqcap \exists indirectsupport.DoubtedStatement \quad (10)$$

where the practice in law treats a motive as circumstantial evidence: $Motive \sqsubseteq CircumstantialEvidence$.

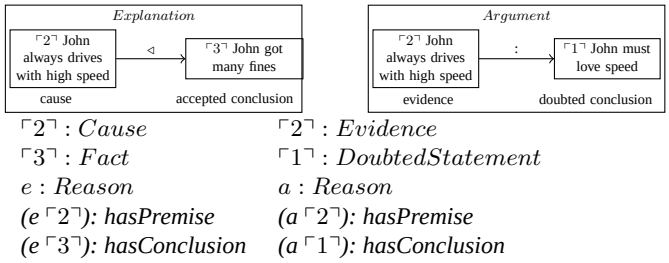


Figure 2. Argument-explanation pattern: the same statement acts as a cause for an accepted statement and as an evidence for a doubted statement.

Example 1 (Argument-explanation pattern) ⌜1⌝ *John must love speed.* ⌜2⌝ *He drives with high speed all the time.* ⌜3⌝ *That's why, he got so many fines.* ⌜2⌝ *represents the support of argument* ⌜1⌝*, but also it acts as an explanation for* ⌜3⌝ *(see figure 2).*

Given the assertions in figure 2, e is classified by the agent p possessing the above knowledge as an explanation, whilst a as an argument.

Assuming that his partner o has the following assertion: *(related o* ⌜3⌝ *rejects)*. It means that the agent o classifies the statement ⌜3⌝ as doubted, and thus it does not treat the reason e as an explanation.

Each agent can have different interpretation functions of the same chain of statements.

Example 2 ⌜1⌝ *Heloise and Abelard are in love.* ⌜2⌝ *Heloise and Abelard are getting married.*

One agent can interpret ⌜1⌝ as a cause for the accepted fact ⌜2⌝, treating the reason as an explanation. An agent with a different interpretation function $\mathcal{I}$ will assert ⌜2⌝ as evidence for the doubted conclusion ⌜1⌝, therefore rising an argument.

If one does not have any assumptions or contextual clue about the acceptance status of the other agent regarding the consequent, does

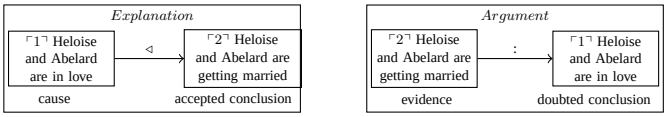
Agent A ($\mathcal{O}_A$)
$u : GoodUniversity$
$GoodUniversity \sqsubseteq \exists hasGood.ResearchFacility$

Agent's A view on agent B ($\mathcal{O}_{AB}$)
$u : GoodUniversity$
$GoodUniversity \equiv \exists hasGood.(ResearchFacility \sqcap TeachingFacility)$

Agent B view on agent A. ($\mathcal{O}_{BA}$)
$u : ResearchInstitute$
$ResearchInstitute \sqsubseteq \exists hasGood.ResearchFacility$

Agent B ($\mathcal{O}_B$)
$u : GoodUniversity$
$GoodUniversity \equiv \exists hasGood.ResearchFacility \sqcup \forall hasGood.TeachingFacility$

Figure 4. Subjective views of the agents.



$\ulcorner 1 \urcorner : Cause$	$\ulcorner 2 \urcorner : Evidence$
$\ulcorner 2 \urcorner : Fact$	$\ulcorner 1 \urcorner : DoubtedStatement$
$e : Reason$	$a : Reason$
(e $\ulcorner 1 \urcorner$*): hasPremise*	*(a* $\ulcorner 2 \urcorner$*): hasPremise*
(e $\ulcorner 2 \urcorner$*): hasConclusion*	*(a* $\ulcorner 1 \urcorner$*): hasConclusion*

Figure 3. Different interpretation functions on the same statements. $\ulcorner 1 \urcorner$ acts as a premise in the first interpretation and as a conclusion in the second one.

the agent consider it as a fact or as doubted conclusion? We argue that, human agents tend to explain things instead of arguing on them, if no reason to argue or conflict have been previously identified. The usual reluctance of the human agent to argue is supported by the fact that the involvement in an argument may lead to more costs than benefits [13], in many quotidian scenarios. It means that, in our model, by default, agents convey explanations instead of arguments. If an agent accepts the conclusion according to its interpretation function, it treats the reason as an explanation.

One question regards how the agents can exploit the information that the given dialog is interpreted as an explanation by one party and as an argument by the other one, in order to eliminate the ambiguity?

Consider the example in [5]:

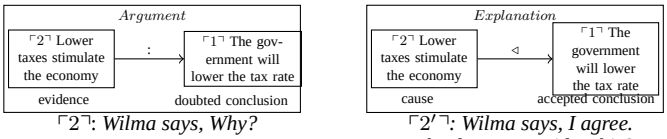
$\ulcorner 1 \urcorner$: Bob says, The government will inevitably lower the tax rate.

$\ulcorner 2 \urcorner$: Wilma says, Why?

$\ulcorner 3 \urcorner$: Bob says, Because lower taxes stimulate the economy.

It is presented as an argument with the consequent $\ulcorner 1 \urcorner$ supported by the premise $\ulcorner 3 \urcorner$. Assume the Wilma's reply is slightly modified, given by:

$\ulcorner 2' \urcorner$: Wilma says, I agree. Why do you consider this?



$\ulcorner 2 \urcorner$: *Wilma says, Why?*

$\ulcorner 2' \urcorner$*: Wilma says, I agree. Why do you consider this?*

Figure 5. The dialog provides indicators of the status of the consequent: accepted or doubted.

By accepting the statement $\ulcorner 1 \urcorner$, it becomes a fact in the system represented by the two agents Bob and Wilma. Consequently, the reason becomes an explanation in which the cause "lower taxes stimulate the economy" may explain the government decision (figure 5). Under the assumption that an agent accepts a statement only if it has a level of understanding of that sentence[2], one can infer that Wilma has own explanation regarding the fact $\ulcorner 1 \urcorner$, but she wants to find out the explanation of her partner.

Another issue regards the distinction between evidence and cause. Cognitive experiments [4] have shown difficulties when distinguishing between them, only 74% have correctly classified pieces of information as evidence or cause. Moreover, human agents are able to build a strategy of substituting explanation in case evidence is not available [4].

4 SUBJECTIVE VIEWS

The agents construct arguments and explanations from their knowledge bases which do no completely overlap. In the same time, each party has a model about the knowledge of his partner. Consider the partial knowledge in figure 4. Here the agent A sees the individual u as a good university, where a good university is something included in all objects for which the role $hasGood$ points towards concepts of type $ResearchFacility$. According to agent's B knowledge, u is also a good university, but the definition is more relaxed: something is a good university if it has at least one good research facility or all the teaching facilities are good. According to agent A perspective on the knowledge of the agent B, u belongs to the concept of good universities, but the definition is perceived as being more restrictive: a good university should have at least one good research facility but also at least one good teaching facility. From the opposite side, agent B imagines that A asserts u as an research institute, where a research institute should have good research facility.

Suppose the agent A conveys different reasons supporting the statement c_1: "u has good research facility" and c_2: "u has either good research or good teaching". For instance:

r_1: "Because u attracted large funding from research projects, it manages to build a good research facility."

r_2: "Because u attracted large funding from research projects, it should have either good research or good teaching."

The above reasons are graphically represented in figure 6.

[2] One can imagine a situation in which an expert explains something to you, you do not understand, but given the reputation or trust relation that you have with the expert, you accept the explanation.

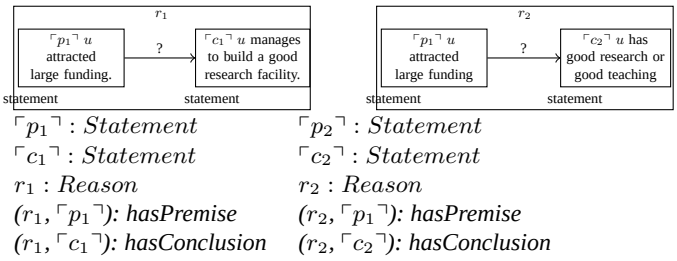


Figure 6. Possible reasons conveyed by the agent A. Are they arguments or explanations?

The question regards how does the agent A treat the reason, as an explanation or as an argument, when conveying it to the agent B. Given the models in figure 4, how the receiving agent B perceives the reason: an explanatory or an argumentative one? The following technical details are introduced to approach these questions.

Agents ontologies/consequent	c_1	c_2
$\mathcal{O}_A$	$\oplus$	$\oplus$
$\mathcal{O}_{AB}$	$\oplus$	$\ominus$
$\mathcal{O}_B$	$\ominus$	$\oplus$
$\mathcal{O}_{BA}$	$\oplus$	$\oplus$

Table 1. The acceptance of the consequents c_1 and c_2 based on agents ontologies.

To distinguish between explanation and argument, the most important issue regards the acceptance of the consequent. In table 1, $\oplus$ denotes that the ontology $\mathcal{O}_i$ entails the consequent c_j. The statement c_1 can be derived from the ontology $\mathcal{O}_A$ (figure 5.3). It cannot be inferred (noted with $\ominus$) by the agent B based on his ontology $\mathcal{O}_B$, because in his interpretation a university with all teaching facilities good but without good research facilities is also a good university.

Instead, the statement c_2 fits the definition of good ontology in $\mathcal{O}_B$. Because agent A accepts its first part "u has good research", he should consider c_2:u has good research or good teaching" as valid. Similarly, agent A considers that agent B cannot infer c_2 ($\ominus$ in table 1), even if the $\mathcal{O}_B$ ontology entails c_2. The agent A has a wrong representation $\mathcal{O}_{AB}$ regarding how the agent B views the statement c_2. Even if the agent B has a wrong model $\mathcal{O}_{BA}$, based on which he believes that the agent A interprets u as a research institute instead of a university, the consequent c_2 is still derived based on axiom $ResearchInstitute \sqsubseteq \exists hasGood.ResearchFacility$.

Firstly, the knowledge of agent A and its model about the knowledge of B represents the world of agent A, noted with w_A. Similarly, the subjective world w_B of agent B consists of the knowledge of B and his view on the knowledge of the agent A. The knowledge of A combined with the knowledge of B, represent the objective world w_O (table 2). A statement is considered $accepted$ if it is entailed by both ontologies. If at least one ontology does not support the statement it is considered $doubted$. The following algebra encapsulates this:

$$\oplus + \oplus = Accepted \quad \oplus + \ominus = Doubted$$
$$\ominus + \oplus = Doubted \quad \ominus + \ominus = Doubted$$

In table 2, the agent A treats c_1 as accepted, meaning that from his point of view the reason r_1 represent an explanation. Agent B

World	Ontologies	c_1	c_2
w_O	$\mathcal{O}_A + \mathcal{O}_B$	Accepted	Doubted
w_A	$\mathcal{O}_A + \mathcal{O}_{AB}$	Doubted	Accepted
w_B	$\mathcal{O}_B + \mathcal{O}_{BA}$	Accepted	Doubted

Table 2. The acceptance of the consequents c_1 and c_2 based on agents ontologies.

perceives the sentence c_1 as doubted, therefore it considers that he is hearing an argument. Note that in the objective world w_O, the reason r_1 is actually an argument. Which means that agent A is wrong about the model of his partner B. Consider that the reason r_1 is uttered by the agent B. He believes that he is conveying an argument, which is true in the objective world w_O. Agent A considers that he is receiving an explanation.

The statement c_2 being perceived as doubted in w_A, the agent A consider that he is conveying an argument. In the world w_B, the conclusion is accepted, thus agent B hearing an explanation, which is true in the objective world w_O. In this situation, agent B should signal to his partner: "There is no need to persuade me. I agree with the consequent."

The rightness or adequacy of conveying either argument or explanation should be computed relative to the objective world w_O. Given the difference between expecting explanations or arguments (subjective worlds w_A and w_B) and legitimate ones (objective world w_O), the agents may wrongly expect explanations instead of arguments and vice-versa. For the rightness or adequacy of conveying/expecting argument or explanation, the algebra in figure 7 is used.

$Accepted_O$ + $Accepted_X = \oplus_X^w$ agreement rightness
$Accepted_O$ + $Doubted_X = \oplus_X^{\neg w}$ agreement not aware
$Doubted_O$ + $Accepted_X = \ominus_X^{\neg w}$ conflict not aware
$Doubted_O$ + $Doubted_X = \ominus_X^w$ conflict rightness

Figure 7. Rightness/inadvertence regarding expecting/conveying argument or explanation. The first operator represents the actual world w_O, while the second one the subjective perspective of agent X.

The situation resulting by applying the algebra in 7 on the given scenario is presented in table 3. Agent B, even if his model about A is not accurate, manages to figure out the status of both consequents c_1 and c_2. Quite differently, agent A is ignorant with respect to both conclusions.

Agent	Awareness and Ignorance	c_1	c_2
A	$w_O + w_A$	$\ominus_A^{\neg w}$	$\oplus_A^{\neg w}$
B	$w_O + w_B$	$\ominus_B^w$	$\oplus_A^w$

Table 3. Agreement and conflict awareness for agents A and B regarding the consequents c_1 and c_2.

The question is if it is possible for the hearing agent to indicate to the conveyor agent that a wrong assumption has been made. The problem is that no agents are aware of the objective world w_O. Under certain conditions, the inadvertence could be identified and solved. If a mediator would be introduced, aware of w_O, it would be able to identify conflict and to provide guidance for increasing the dialog

efficiency. The second option would be by analyzing the communicative acts. If the agent A announces that r_1 is an explanation, agent B can disclose his doubts about c_1. By updating his model $\mathcal{O}_{AB}$, the agent A will re-interpret r_1 as an argument. By specifying pre-conditions and post-conditions of such communicative acts, the participants in the dialog can infer the status of a reason: argument or explanation.

5 COMMUNICATIVE ACTS

The following speech acts are analyzed only from the perspective of distinguishing between argument and explanation. After modeling the communicative acts in DL, their preconditions and postcodntions are formally specified. The dynamics of the dialog is illustrated by a scenario.

5.1 Speech acts in description logic

The definition presented here are in line with the speech acts proposed by Reed [14] for modeling dialogs in the AIF ontology. Our refinement focuses on the distinction between argument and explanation.

Firstly we need to distinguish between explicative and argumentative questions, where a question is linked to the AIF ontology based on the subsumption relation $Question \sqsubseteq LocutionDescriptor$. An argumentative question should have a doubted conclusion as topic, given by axiom 11.

$$ArgumentativeQ \sqsubseteq Question \sqcap \exists hasTopic.DoubtedStatement \tag{11}$$

When conveying an argumentative question a doubt regarding the topic is indicated to receiving agent. In a general model allowing more topics for a single question, one doubted topic is enough to interpret the question as an argumentative one, given by the existential quantification of the role $hasTopic$. Questions of type "How do you know" are a particular case of argumentative ones, given by:

$$HowDoYouKnow? \sqsubseteq ArgumentativeQ \tag{12}$$

For an explicative question all the topics should be not doubted:

$$ExplicativeQ \sqsubseteq Question \sqcap \forall hasTopic.\neg DoubtedStatement \tag{13}$$

Questions of type "Why?" are particularly considered to request for explanation: $Why \sqsubseteq ExplicativeQuestion$.

Similar to [14], a response is a compound concept triggered by a specific question and ended by something which can be a statement, a reason, or another rule, but which remain unspecified at the top level of the ontology:

$$Response \sqsubseteq \exists hasStart.Question \sqcap hasEnd.\top \tag{14}$$

In the AIF ontology the statements can be challenged and when this happens this is a good indicator for us that the particular statement is doubted. In our model, $challenge$ is seen as a particular role, refined by:

$$reject \sqsubseteq challenge, contest \sqsubseteq challenge \tag{15}$$

Beside rules application nodes, AIF includes also conflict nodes. Here, all the roles of type $hasStatement$ of a conflict application rule necessarily point to doubted statements.

$$Conflict \sqsubseteq Rule \sqcap (=2) hasStatement.DoubtedStatement \tag{16}$$

5.2 Pre- and post-conditions

claim argument r
prec $w_x \models \{c\} \in Doubted^{\mathcal{I}_x}$
$w_x \models \{p\} \in \neg Doubted^{\mathcal{I}_x} \cap Evidence^{\mathcal{I}_x}$
post $\mathcal{O}_{yx} \models \{c\} \in Doubted^{\mathcal{I}_x}$
$\mathcal{O}_{yx} \models \{p\} \in \neg Doubted^{\mathcal{I}_x} \cap Evidence^{\mathcal{I}_x}$
if $\mathcal{O}_y \models \{c\} \in \neg Doubted^{\mathcal{I}_y} \Rightarrow \mathcal{O}_y \models \{c\} \in \neg Doubted^{\mathcal{I}_y}$
claim explanation r
prec $w_x \models \{c\} \in \neg Doubted^{\mathcal{I}_x}$
$w_x \models \{p\} \in \neg Doubted^{\mathcal{I}_x} \cap Cause^{\mathcal{I}_x}$
post $\mathcal{O}_{yx} \models \{c\} \in \neg Doubted^{\mathcal{I}_x}$
$\mathcal{O}_{yx} \models \{p\} \in \neg Doubted^{\mathcal{I}_x} \cap Cause^{\mathcal{I}_x}$

Figure 8. Claiming arguments and explanations.

Claim argument The main precondition to utter an argument is that the agent should believe from his knowledge base that a divergence of opinion exists with his partner. Assume that an agent x conveys agent y an argument r having the support p and consequent c (figure 8). The first precondition states that based on the axioms in the world of x the consequent should be interpreted as doubted. The second precondition for the agent x to convey an argument is to consider the precondition p as an evidence which is not doubted at the moment. The first tow post-conditions regards how the world of agent y is updated in the light of new information. Especially, the model $\mathcal{O}_{yx}$ about his partner is updated.

Claim explanation. The precondition to convey an explanation, is that the agent x should interpret the consequent c in his world w_x as not doubted. From the pragmatics of natural dialogs perspective, an explanation occurs only if a request for such an explanation has been conveyed [8, 16]. Such an explanation request signals the possibility that a transfer of understanding may occur. Rather then rejecting an explanation, the explainee would consider it as $irrelevant$.

Argumentative question. An agent x conveys an argumentative question only when the consequent c of the reason is not interpreted as factive in his knowledge base: $O_x \models \{c\} \in \neg Doubted^{\mathcal{I}_x}$. The hearing agent y realizes that the consequent is doubted in his world: $w_y \models \{c\} \in \neg Doubted^{\mathcal{I}_y}$.

Explicative question. An agent x can utter an explicative question if the consequent c of the reason is interpreted as factive in his knowledge base: $O_x \models \{c\} \in \neg Doubted^{\mathcal{I}_x}$. The hearing agent y realizes that the consequent is accepted by his partner: $\mathcal{O}_{YX} \models \{c\} \in \neg Doubted^{\mathcal{I}_y}$.

Challenge. In the common ontology the range of the challenge role is the top level concept $\top$: It means that one can attack a statement, either evidence or cause, but also a reason, either argumentative or explicative. For accepting a reason there two flavors: $agree$ speech act for arguments and $understand$-like acts for explanations.

5.3 Dialog dynamics

Consider the dialog in education domain from figure 9, taking place between a scholar S and administrator A: Assume that after the move m_1 both parties correctly identified the reason r_1, interpreting the statement $\ulcorner 1 \urcorner$ as the premise and the statement $\ulcorner 2 \urcorner$ as the conclusion. (figure 10). Moreover, the conveyor agent S interprets $\ulcorner 1 \urcorner$ as a cause which makes possible to assign more founds for investments. Given no support for rejecting the statements $\ulcorner 2 \urcorner$ and $\ulcorner 1 \urcorner$, based on axiom (7) they are interpreted as facts by the agent S: $Fact^{I_S} = \{\ulcorner 2 \urcorner, \ulcorner 1 \urcorner\}$. With the causal premise $\ulcorner 1 \urcorner$ and a factual consequent $\ulcorner 2 \urcorner$, both axioms (3) and (4) being satisfied by the reason r_1. Thus, it represents an explanation for the agent S, given by $Explanation^{I_S} = \{r_1\}$.

m_1	S:	Because the global income of our department has increased, it brings the possibility to assign more funds for teaching and research facilities.
m_2	A:	Are you sure that the global income has increased?
m_3	S:	Because the number of students has increased, the partial income has increased.
m_4	A:	Partial income has been affected by the wage being increased.
m_5	S:	Is it so? My wage did not increase.
m_6	A:	The wage expenses has risen due to the recruitment of new staff in the last semester.
m_7	S:	Maybe that's why my wage did not increase.
m_7	A:	Anyhow, knowing that .... it is a good idea to increase the research facilities.

Figure 9. Dialog in education domain.

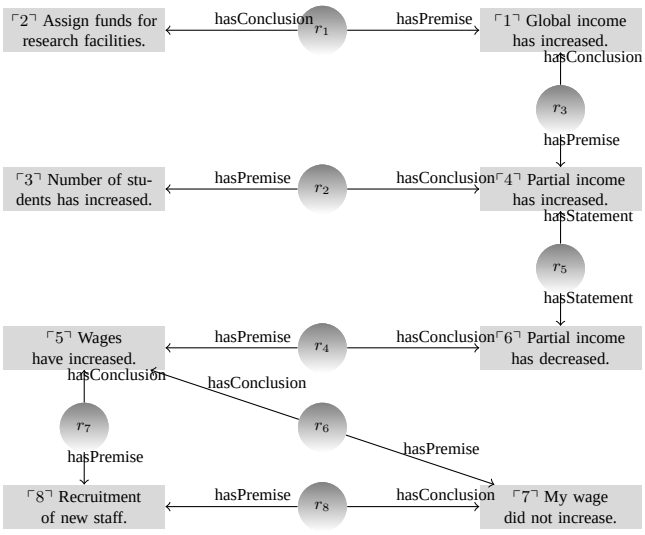


Figure 10. Supporting reasons in dialog.

Assume that the agent A contests all the statements that are not proved, given by:

$$\forall isProved.\ \bot \sqsubseteq \exists contest.Statement \tag{17}$$

No proof existing at this moment, the statement $\ulcorner 1 \urcorner$ is labeled as contested by the agent A: $contest^{I_A} = \{(A, \ulcorner 1 \urcorner)\}$. $Contest$ being a subrole of $challenge$ (according to common vocabulary in figure 10), the statement $\ulcorner 1 \urcorner$ is interpreted as doubted statement based on definition (5). It means that the preconditions to utter an argumentative question are satisfied.

The move m_2 clearly introduces some doubts regarding the statement $\ulcorner 1 \urcorner$, meaning that the agent A has no difficulties to interpret the question *Are you sure that...*, notes with q_1, as an argumentative question (line 3 in figure 11), with the topic represented by the statement $\ulcorner 1 \urcorner$, given by: $(q_1, \ulcorner 1 \urcorner) : hasTopic)$. Consequently, based on the common axiom (14), both agents become aware that the topic $\ulcorner 1 \urcorner)$ is doubted in the current dialog: $DoubtedStatement^{I_S} = DoubtedStatement^{I_A} = \{\ulcorner 1 \urcorner\}$.

At this moment, agent S solves the inconsistency risen by the axioms $Fact \sqsubseteq \neg DoubtedStatement$, $Fact^{I_S} = \{\ulcorner 1 \urcorner\}$ after the move m_1, and $DoubtedStatement^{I_S} = \{\ulcorner 1 \urcorner\}$ after the move m_2 by removing his initially wrong interpretation of $\ulcorner 1 \urcorner$ as a fact.

Both agents identify the move m_3 as a reason $Reason^{I_S} = Reason^{I_A} = \{r_1, r_2\}$, with the corresponding premise $\ulcorner 3 \urcorner$ and consequent $\ulcorner 4 \urcorner$. Given the interpretation of the premise $\ulcorner 3 \urcorner$ as a $Cause$ by the agent S, and no rejection of the consequent, the reason r_2 is also interpreted at this moment as an explanation: $Explanation^{I_S} = \{r_2\}$.

The move m_3 represents also the response of agent S triggered by the question q_1. The formalization says that starting by the question q_1 $(r_2, q_1) : hasStart$, agent S answers with r_2, where r_2 is interpreted as an response by the agent S uttering it, based on axiom (16). Being interpreted as a response by the conveyor, one of the statements in r_2 should have be related with the topic risen by q_1. Thus, according to the cognitive map of S, the cognitive consistency is assured by the reason r_3. Because it has the conclusion $\ulcorner 1 \urcorner$ which doubted and the premise $\ulcorner 1 \urcorner$ representing a fact, the reason r_3 represents an argument from the agent S viewpoint.

Recall that the topic of the q_1 question is the statement $\ulcorner 1 \urcorner$, but the topic itself does not explicitly appear in the declaration r_2. It means that the hearing agent A can correctly interpret it as the response for q_1, but also as an independent declaration in the dialog flow, with the issue risen by q_1 still open. One option would be to ask for clarifications regarding the membership of the individual r_2 to the $Response$ class, or the second one, simply to react to the just uttered sentence r_2. The clarification may come on the form of the r_2 reason, which will synchronize the cognitive maps of the two agents.

In the current dialog, A chooses to focus on one of the statements risen by r_2 because it is aware of a conflict regarding the statement $\ulcorner 4 \urcorner$. Based on definition 11, the statement is categorized by the agent A as doubted, thus interpreting the reason r_2 as an argument: $Argument^{I_A} = \{r_2\}$.

In move m_4, the premises and the conclusion of reason r_4 are correctly identified by both agents. The conflict between the statements "partial income has increased" and "partial income has decreased" is also clear. Based on common axiom 11 regarding conflict rules, both agents become aware the the consequents $\ulcorner 4 \urcorner$ and $\ulcorner 6 \urcorner$ are doubted. At this moment r_4 and r_2 should be interpreted as arguments by both parties: $Argument^{I_S} = \{r_1, r_2, r_3, r_4\}$, respectively $Argument^{I_A} = \{r_1, r_2, r_4\}$. Being the agent who proposed the argument, the agent A is not aware of any attack relation on the premise $\ulcorner 5 \urcorner$ supporting it. Therefore, according to agent's A knowledge base, the statement is a fact: $Fact^{I_A} = \{\ulcorner 5 \urcorner\}$.

The move m_5 indicates that agent S has a different opinion. Firstly, it rises the argumentative question q_2: "Is it so?". Based on

it and on the common knowledge in axiom 14, agent S realizes that the statement $\ulcorner 5 \urcorner$ is doubted. Agent S also provides evidence $\ulcorner 5 \urcorner$ in support of his argument r_6.

At move m_6, knowing that the statement $\ulcorner 5 \urcorner$ is doubted, the agent A can rise only arguments supporting it. The argument r_7 is valid because its premise $\ulcorner 8 \urcorner$ is not attacked at this moment of dialog, according to the knowledge base of the conveyor agent A. According to the current interpretation function of A, the statement $\ulcorner 8 \urcorner$ is both evidence for r_7 and also a fact.

In the move m_7, agent S interprets the statement $\ulcorner 8 \urcorner$ as an explanation why his salary did not increase, given that the global income of the department has increased: $Explanation^{I_S} = \{r_8\}$. Depending on the next moves and possible challenge relations on $\ulcorner 8 \urcorner$ from the administrator A, the reason r_8 may shift to an argument. Note that at this moment a transfer of understanding takes place.

Move	I_S	I_A
m_1	$r_1 : Reason$ $(r_1, \ulcorner 1 \urcorner) : hasPremise$ $(r_1, \ulcorner 2 \urcorner) : hasConclusion$ $\ulcorner 1 \urcorner) : Cause$	$r_1 : Reason$ $(r_1, \ulcorner 1 \urcorner) : hasPremise$ $(r_1, \ulcorner 2 \urcorner) : hasConclusion$ $(A, \ulcorner 1 \urcorner) : contest$
m_2	$q_1 : ArgumentativeQ$ $(q_1, \ulcorner 1 \urcorner) : hasTopic$	$q_1 : ArgumentativeQ$ $(q_1, \ulcorner 1 \urcorner) : hasTopic$
m_3	$(r_2, q_1) : hasStart$ $(r_2, r_2) : hasEnd$ $r_2 : Response$ $r_3 : Reason$ $(r_3, \ulcorner 4 \urcorner) : hasPremise$ $(r_2, \ulcorner 1 \urcorner) : hasConclusion$ $r_2 : Reason$ $(r_2, \ulcorner 3 \urcorner) : hasPremise$ $(r_2, \ulcorner 4 \urcorner) : hasConclusion$ $\ulcorner 3 \urcorner : Cause$	$r_2 : Reason$ $(r_2, \ulcorner 3 \urcorner) : hasPremise$ $(r_1, \ulcorner 4 \urcorner) : hasConclusion$
m_4	$r_4 : Reason$ $(r_4, \ulcorner 5 \urcorner) : hasPremise$ $(r_4, \ulcorner 6 \urcorner) : hasConclusion$ $r_5 : ConflictRule$ $\ulcorner 6 \urcorner : DoubtedStatement$ $\ulcorner 4 \urcorner : DoubtedStatement$	$r_4 : Reason$ $(r_4, \ulcorner 5 \urcorner) : hasPremise$ $(r_4, \ulcorner 6 \urcorner) : hasConclusion$ $r_5 : ConflictRule$ $\ulcorner 6 \urcorner : DoubtedStatement$ $\ulcorner 4 \urcorner : DoubtedStatement$ $\ulcorner 5 \urcorner : Fact$
m_5	$q_2 : ArgumentativeQ$ $(q_2, \ulcorner 5 \urcorner) : hasTopic$ $\ulcorner 7 \urcorner : Evidence$ $r_6 : Reason$ $(r_6, \ulcorner 7 \urcorner) : hasPremise$ $(r_6, \ulcorner 5 \urcorner) : hasConclusion$	$q_2 : ArgumentativeQ$ $(q_2, \ulcorner 5 \urcorner) : hasTopic$ $\ulcorner 7 \urcorner : Statement$ $r_6 : Reason$ $(r_6, \ulcorner 7 \urcorner) : hasPremise$ $(r_6, \ulcorner 5 \urcorner) : hasConclusion$
m_6	$r_7 : Reason$ $(r_7, \ulcorner 8 \urcorner) : hasPremise$ $(r_7, \ulcorner 5 \urcorner) : hasConclusion$	$r_7 : Reason$ $(r_6, \ulcorner 8 \urcorner) : hasPremise$ $(r_6, \ulcorner 5 \urcorner) : hasConclusion$ $\ulcorner 8 \urcorner : Evidence$
m_7	$r_8 : Reason$ $(r_8, \ulcorner 8 \urcorner) : hasPremise$ $(r_8, \ulcorner 7 \urcorner) : hasConclusion$ $\ulcorner 8 \urcorner : Cause$	$r_8 : Reason$ $(r_8, \ulcorner 8 \urcorner) : hasPremise$ $(r_8, \ulcorner 7 \urcorner) : hasConclusion$

Figure 11. Dialog interpretation for each agent. I_A and I_S are the interpretation functions for the agent A, respectively S.

The following observations sum up the analysis of the dialog.

- Some reasons are explicit, some are implicit. For instance, the implicit conflicting rule r_5 is identified by both agents, whilst the implicit reason r_3 is known only by the agent S.
- An agent may consider that he conveys an explanation, but actually it represents in argument. (i.e r_2 after the move m_3).
- An agent may consider that he conveys arguments, but the reason represent an explanation.
- In the light of new information, the wrong interpretation may be updated (i.e. with the uttering of an argumentative question in move m_2, the reason r_1 is interpreted by the the agent S as an argument and not as an explanation based on initial assumptions in move m_1).
- Understanding can arise from conveying arguments: the explanation r_8 is constructed based on statements from two arguments r_7 and r_6.

Move	$Expl^{I_S}$	Arg^{I_S}	$Expl^{I_A}$	Arg^{I_A}
m_1	r_1			r_1
m_2		r_1		r_1
m_3	r_2	r_1,r_3		r_2
m_4		r_1,r_3,r_2,r_4		r_1, r_2, r_4
m_5		r_1,r_3,r_2,r_4,r_6		r_1, r_2, r_4, r_6
m_6		r_1,r_3,r_2,r_4,r_6,r_7		r_1, r_2, r_4, r_6, r_7
m_7	r_8	r_1,r_3,r_2,r_4,r_6,r_7		r_1, r_2, r_4, r_6, r_7

Table 4. Dynamics of argument and explanation in dialog.

6 DISCUSSION AND RELATED WORK

Explanation and argumentation capabilities [12] for more persuasive agents have already considered some aspects of user modeling. We have improved on this integration by also including the difference of the DL knowledge bases of agents. The informal approach [18] has been developed in this paper into a computational model of both argument and explanation.

Bex exploits in [3] argument-explanation complementarity for legal reasoning, while [12] for building more persuasive agents. Interleaving argument and explanation in natural dialogs has been investigated in [2] and [10]. Except for McBurney and Parsons', these models do not contain multiple perspectives.

Given different types of explanation patterns in social sciences, we have limited the approach to causal explanations. A broader investigation would include *constructive explanations*, explaining events by accounting knowledge structures such as scripts and plans or *contrastive explanations*, explaining surprising events by showing the deviation from expectation based on the available knowledge structures. One can also distinguish between conversational explanations and scientific explanations. The second category includes domain specific explanations: computing explanations, historical explanations, legal explanations, evolutionary biology explanations, which means that the top level ontology of explanations needs to be extended for each specific scientific field. Restricting explanations to causality, supports the idea that explanations are asymmetrical: if j explains F, then F does not explain j. Instead, arguments are not necessarily asymmetrical.

The problem is more complex when, besides knowledge, one considers different reasoning capabilities, but also different goals, preferences, or values of the agents. An argument may be more valuable from the individual perspective or from the collective viewpoint. In individualistic cultures values like egalitarianism, competitiveness, and self-reliance are higher ranked compared to hierarchies or cooperativeness in collective cultures. Consider the argument "Higher trained persons have good communication competencies" would be easily accepted by societies promoting activeness and implication of citizen, but most probable will be rejected by the Asian societies which rank lower eloquence skills.

Explanation aims to transfer understanding. For human agents, understanding occurs in different degrees, relative to their knowledge

bases, beliefs, and goals. Cognitive understanding requires similar ontologies, but assumes agents have different goals and beliefs. The explainer should be able to explain how it comes to the conclusion and what hypotheses he had considered and rejected. The smallest degree of understanding, making sense, demands a coherent explanation, which usually is also an incomplete one. It means that, when the explainee conveys "I understand" speech act, the explainer can shift to an examination dialog in order to figure out the level of understanding, rather than a crisp value understand/not understand as suggested by Walton [16]. Acceptability standards of explanation can be defined similarly to the standard of proof in argumentative theory [6].

In their explanatory argumentation framework [15], the authors are showing how to apply abstract argumentation in scientific debates. We have been concerned here in mixing argument and explanation using DL knowledge so that human agents would be able to easily follow such a process. Therefore, our explanation was directed towards explaining on the knowledge level of the explainee, and not on explaining the workings of the abstract argumentation mechanism.

7 CONCLUSIONS AND FURTHER WORK

Our contributions are: (i) evidencing the instrumental role of knowledge structures through argumentation and explanation; (ii) providing guidelines to determine whether something in a dialog is an argument or an explanation [16]; (iii) modeling explanations similar to arguments in the AIF ontology. By using description logic to define the differences, its reasoning services are exploited aiming at automatic classification of arguments and explanations.

Ongoing work regards the exploitation of a more expressive DL-language for representing the model an agent has on his partner, as for instance a multi-agent version extension of $\mathcal{ALC}$ with multi-modal operators, as introduced by [1]. Here, the belief, knowledge and temporal operators are encapsulated within the language itself.

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