A Cognitive Approach to Relevant Argument Generation

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Abstract. Acceptable arguments must be logically relevant. This paper describes an attempt to retro-engineer the human argumentative competence. The aim is to produce a minimal cognitive procedure that generates logically relevant arguments at the right time. Such a procedure is proposed. Its eventual validation however depends on the quality of the available domain knowledge.

Keywords: Argumentation, relevance, cognition, minimality.

1 Introduction

Argumentative dialogues constitute the major part of the human language performance. Human beings spend about 6 hours a day in verbal interactions (Mehl & Pennebaker, 2003), uttering 16 000 words on average (Mehl *et al.*, 2007). The two major types of verbal interactions are conversational narratives and argumentative dialogues (Bruner, 1986; Dessalles, 2007).

Argumentative dialogues are produced spontaneously and effortlessly in any group of healthy adult individuals. The ability to generate argumentative moves in spontaneous conversation is crucial to social life, as judgments of rationality and of social competence depend on it. Moreover, various cognitive processes seem to be common to argumentation and to deliberative reasoning (Dessalles, 2008). Modeling the human argumentative ability should therefore be a central endeavor in Cognitive Science.

The previous statement relies on the implicit hypothesis that argumentation is a unitary phenomenon. There is no consensus on this. For instance, Walton considers various types of argumentative dialogues governed by different rules: persuasion, inquiry, negotiation, information-seeking, deliberation and eristic (strife) dialogue (Walton, 1982; Walton & Macagno, 2007). Other authors build on the idea that interacting individuals choose which "dialogue game" they agree to play, among a set of conventional dialogue games available to them (Hulstijn, 2000; Maudet, 2001). The present paper makes the strong assumption that there is a cognitive core common to all argumentative dialogues, regardless of the category they fall into.

It is quite common to see argumentative dialogues as a process involving people. As arguments are often described in terms of challenge, commitment, withdrawal or support, the social level is not clearly separated from the logical (or knowledge) level.

In this paper, we pay attention only to conceptual aspects of argumentation. The challenge is to show that logical relevance can be computed in a phase relying on knowledge and preferences that can be kept separate from other computations relying on social roles or motives. We regard logical relevance as a prerequisite for any other computation regarding argumentation, as no valid argument can be logically irrelevant. The extreme version of our hypothesis consists in saying that the propositional content of argumentative moves follows a definite mechanical procedure, regardless of who makes them. At the knowledge level, it is not possible to tell whether a given argumentative sequence involved three people, two people or was a soliloquy. Thanks to this hypothesis, we can ignore some issues, independently from their importance in further computations, such as pragmatic goals (convince, influence, gain the upper hand) or saving/losing face. At the knowledge level, it is more urgent to concentrate on the logical relationships between utterances (Quilici *et al.*, 1988). This, of course, amounts to supposing that the logical level has some form of autonomy.

Even if we limit our study of argumentation to computations performed at the logical (or knowledge) level, we must still determine which entities are processed by these computations. In most approaches to argument generation, a pre-computed set of arguments is supposed to be available. Arguments may be propositions that are known for instance to be in relation of support or attack with another argument (Dung, 1995). Such a set may be given or be computed through a planning module (Amgoud & Prade, 2007). Various questions are then asked, such as finding 'acceptable' arguments (Dung, 1995), or finding best argumentative strategies following rhetorical principles (van Eemeren, Garssen & Meuffels, 2007, 2012). Postulating a graph of pre-existing arguments with attack/support weighted relations may be appropriate in task-oriented dialogues, in which at least some participants are expert not only in the domain of the task, but also in conducting dialogues about the task. Pre-established argument graphs may also be natural to study professional debating behavior, like in political debates. In spontaneous everyday dialogues, however, people are not expected to be experts. They are not even supposed to have any awareness about the possible existence of pre-existing argument collections to choose from. We must assume that every argumentative move is computed on the fly instead of being selected or retrieved. We do not postulate static graphs of arguments; we do not postulate complex procedures such as the search for minimal acyclic paths in such graphs either. It would not be parsimonious to grant such powers to brains. On the other hand, a purely structural approach that would only look only at the surface of the arguments (Rips, 1998) is unlikely to predict the content of utterances.

We choose to settle for the kind of computation considered in BDI approaches, *i.e.* computations about propositions (or predicates), about beliefs and about desires. We must, however, put further restrictions about the kind of computations that are acceptable as cognitively plausible. Since cognitive systems are "embedded systems", we cannot postulate any access to external oracles of truth. We cannot make use of notions such as possible worlds, as long as these "worlds" are supposed to be external entities. And as in any modeling enterprise, we must seek for minimal procedures.

We present here a tentative minimalist model of logically relevant argument generation. Following (Reed & Grasso, 2007), this approach is an attempt of modeling *of* argument (rather that *with* argument), as the purpose is to understand the human argumentative *competence* (as opposed to *performance*), rather than using argumentation processes to develop artificial reasoning. In what follows, we will first define what 'logical relevant' here means. Then we will introduce the notion of 'necessity', which usefully subsumes attitudes such as beliefs and desires. We then present the conflict-abduction-negation model, before discussing its scope and its limits.

2 Logical relevance

Logical relevance is what makes the difference between acceptable dialogue moves and unacceptable ones, or more generally between rationality and pathological discourse. Logical relevance predicts the conditions in which saying that the carpet is grey is appropriate or, on the contrary, would lead to an expression of incomprehension like "So what?" (Labov, 1997). Note that sentences may be meaningful (*e.g.* "the carpet is grey") and yet be fully logically irrelevant. Philosophical definitions of relevance that rely on the quantity and the cost of inferred information (Sperber & Wilson, 1986) are of little help here, as they are too permissive and do not predict irrelevance. For instance, new knowledge may be easily inferred from "the carpet is grey" (*e.g.* it is not green, it differs from the one in the other room) without conferring any bit of relevance to the sentence in most contexts (*e.g.* during a dialogue about the death of a cousin).

Many task-oriented approaches to argumentation (often implicitly) rely on definitions of relevance or acceptability that refer to *goals*. A move is relevant in these contexts if it helps in achieving one of the speaker's goals. Many spontaneous dialogues, however, occur in the absence of any definite task to be fulfilled. For instance, when people discuss about the recent death of a cousin, they may exchanges arguments about the suddenness or the unexpectedness of the death without trying to achieve anything concrete. Another problem with 'goals' is that there is no way to circumscribe the set from which they would be drawn. Do people talking and reasoning about the sudden death have zero, one, ten or hundreds of goals?

The observation of spontaneous conversation (Dessalles, 2007) suggests that *problems*, *i.e.* contradictions between beliefs and/or desires, are more basic and more systematic than the existence of goals. For instance, the cousin's sudden deadly stroke contradicts the belief that she was perfectly healthy. The definition of logical relevance that will be used here is straightforward:

A proposition T is logically relevant iff
it creates a contradiction or solves a contradiction.

(for a more precise definition, see (Dessalles, 2013)). It has long been recognized that aspects of argumentation have to do with incompatible beliefs and desires, and with belief revision. "Practical reasoning is a matter of weighing conflicting considerations for and against competing options, where the relevant considerations are provided by what the agent desires about and what the agent believes" (Bratman 1990). The above definition of logical relevance provides a tight constraint on the kind of move that is admissible in argumentation.

Suppose you want to go hiking. Your friend could make a relevant argumentative move by saying "They announce heavy rains this afternoon" because her move creates a contradiction between two desires (hiking and not getting wet). By contrast, saying "They announce heavy rains this afternoon in Kuala Lumpur" would have been irrelevant as long as the argument cannot be related to any contradiction (*e.g.* if you are hiking in the Alps). A further argument such as "Oh yes, I can see some clouds over there" may be argumentatively relevant, for instance by negating on term in the contradiction between 'observing a blue sky' and 'having heavy rain soon'. Describing such a move as merely 'strengthening' the preceding argument (heavy rains) is problematic as long as there is no way to compute such a 'strengthening' relation. Fortunately, it is unnecessary as soon as the intermediary contradiction (blue sky *vs.* rain) is taken into account.

To be logically relevant, people or artificial systems must abide by the constraint above, or be at risk of being perceived as socially inept. Note that while some models seek for conflict-free arguments (Dung, 1995), we must consider arguments as logically relevant precisely because they create a conflict. Conversely, it is not enough for an argument to be logically consistent with the current state of knowledge. To be logically relevant, such an argument must *restore* logical consistency. In our framework, the only admissible 'goals' are prospective situations in which logical consistency is restored (which comes with the strong presupposition that the current situation is regarded as inconsistent).

3 Conflicting necessities

Basic attitudes such as *true* and *false* have long been recognized to be insufficient to model argumentation. In line with the BDI approach, we consider that propositional attitudes can be gradual and may include both beliefs and desires. As we experience beliefs and desires as very different mental attitudes, we may expect them to be processed through two radically different mechanisms, one for beliefs and one for desires. One of our findings is that both mechanisms can be naturally merged into a single one. As far as the computation of logical relevance is concerned, the distinction between beliefs and desires can be (momentarily) ignored. To describe the argumentation procedure, we use a single notion, called *necessity* (note that the word 'necessity' is close here to the naïve notion and does not refer to a modality). The distinctions belief *vs.* desires must be of course maintained when it comes to argument wording. The claim is that it does not have any role during the computation of logically relevant arguments. We call *necessity* the intensity with which a given state of affairs is believed or wished[1]. Necessities are negative in case of disbelief or avoidance. At each step t of the planning procedure, a function $\nu_t(T)$ is supposed to provide the necessity of proposition T on demand. The necessity of T may be unknown at time t. (We may omit subscripts t to improve readability). We suppose that $\nu(\neg T) = -\nu(T)$.

The argumentation procedure (see below) propagates necessities through logical or causal links. If $(T_1, T_2, \ldots T_n)$ is an incompatible set, which we note $(T_1 \uparrow T_2 \uparrow \ldots T_n)$, then $\nu(T_i)$ may be inferred as $\nu(T_i) = -\min_{k \neq I} \nu(T_k)$ if all $\nu(T_k)$ are positive. The knowledge base used in our current implementation of the model includes not only logical rules (stored as incompatibility sets), but also causal links. Causal links differ from logical

[1] In (Dessalles, 2008 ; 2013), we show how the notion of complexity (*i.e.* minimal description length) can be used to measure beliefs and desires on a same intensity scale.

links by the fact that the state of the world is supposed to change between the left-hand side of a causal rule and its right-hand side. Thanks to the argumentation procedure, an effect may inherit the necessity of its weakest known cause through the causal link. If $(C_1\&C_2\&\ldots C_n) \rightarrow E$ is a causal relation in the knowledge base in which all $\nu(C_i) > 0$, then $\nu(E)$ may be inferred as $min_i\ \nu(C_i)$.

Necessity propagation may lead to conflicting necessities. Argumentation emerges from the fact that there are several sources of necessity. A proposition T may receive two necessity values $\nu^j(T)$ and $\nu^j(T)$ at the same time. Necessity sources i and j may be different individuals, different knowledge sources or may result from necessity propagation through rules.

A *cognitive conflict* is defined as a situation in which a same proposition receives two opposite necessities: $\nu^j(T) \times \nu^j(T) < 0$. The conflict between the two necessity sources i and j, noted $\nu^i(T)\uparrow\nu^j(T)$, has an intensity I which is given by the smaller necessity $I = min(|\nu^i(T)|, |\nu^j(T)|)$. If the weaker necessity happens to change sign or to be changed into a negligible value, the conflict is solved. Note that cognitive conflicts are internal to the agent; they are not supposed to be "objective". More important, *cognitive conflicts do not oppose individuals*, but beliefs and/or desires.

Within the preceding framework, argumentative dialogues can be seen as the trace of a sequential multi-valued logical satisfaction procedure. The point is not to find an absolute optimum (which may not be achieved in reasonable time when the knowledge base is large). The point is to discover a procedure that matches human argumentative behavior while remaining cognitively plausible.

4 The conflict–abduction–negation model

Our problem is to design a cognitively plausible model of spontaneous argumentation. In a nutshell, the program tries to find a cognitive conflict, and then attempts to solve it. Solutions can be found by changing some attitudes, for instance by revising default assumptions, or by revising beliefs and preferences, or by proposing actions that change the state of the world. To remain cognitively plausible, we impose the following restrictions.

- An argument can be any proposition. Its effect on consistency is computed, rather than retrieved from pre-stored relations such as 'support' or 'attack'.
- The knowledge base is addressed by content. We exclude the possibility of scanning the entire knowledge. Queries for rules must have at least one term instantiated.
- The procedure is supposed to be sequential, considering one problem (conflict) and one tentative solution at a time.
- The procedure should be kept minimal. A cognitive model of natural argument processing cannot consist in a general-purpose theorem prover with the power of a universal Turing machine that derives arguments from complex axioms.

After a series of refinement, we succeeded in designing a minimal procedure, named CAN (for Conflict–Abduction–Negation) (figure 1). Figure 2 shows the sequence of operations in CAN. I_0 is a parameter representing a tolerance threshold depending on the social context. For instance, I_0 may get larger when individuals become tired or have pressing needs other than discussing.

We could not find a more concise procedure that generates only logically relevant arguments and that generates all logically relevant arguments. The revision phase allows actions to be performed and therefore lose there necessity. For other terms, revision consists in changing necessity. This operation represents the fact that when reconsidering a situation, people may change the strength of their belief or their desire.

Note that thanks to negation, positive and negative necessities play symmetrical roles.

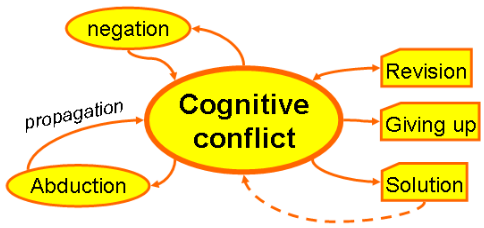

Fig. 1. CAN operations

The procedure has been implemented in Prolog. We tested it to reconstruct the production of arguments in real conversational excerpts. Here is an example of conversation.

[Context: A is repainting doors. He decided to remove the old paint first, which proves to be a hard work (adapted from French)]

A1- I have to repaint my doors. I've burned off the old paint. It worked OK, but not everywhere. It's really tough work! [...] In the corners, all this, the mouldings, it's not feasible!
[...]
B1- You should use a wire brush.
A2- Yes, but that wrecks the wood.
B2- It wrecks the wood...
[pause 5 seconds]
A3- It's crazy! It's more trouble than buying a new door.
B3- Oh, that's why you'd do better just sanding and repainting them.
A4- Yes, but if we are the fifteenth ones to think of that!
B4- Oh, yeah...
A5- There are already three layers of paint.
B5- If the old remaining paint sticks well, you can fill in the peeled spots with filler compound.
A6- Yeah, but the surface won't look great. It'll look like an old door.

If we just keep the argumentative skeleton, we get:

A1- repaint, burn-off, mouldings, tough work
B1- wire brush
A2- wood wrecked
A3- tough work
B3- sanding

A5- several layers
B5- filler compound
A6- not nice surface

Conflict:	Look for $v^i(T)\uparrow v^j(T)$ where T is a recently visited state of affairs: $v^i(T) \times v^j(T) < 0$. The conflict holds if $min(\lvert v^i(T)\rvert, \lvert v^j(T)\rvert) > I_0$. Let's suppose (without loss of generality) $v^i(T) > 0$.
Revision:	If T is an action, do it or simulate it. Otherwise, reconsider $v^i(T)$. If $min(\lvert v^i(T)\rvert, \lvert v^j(T)\rvert)$ is now $< I_0$ or if $v^i(T)\times v^j(T)$ is now > 0, success. Start the whole procedure anew.
Abduction:	Look for a cause or a reason C for T such that $v(C) > 0$ and $\lvert v(C)\rvert < \lvert v^j(T)\rvert$. Make $v^j(C) = v^j(T)$ and restart from $v^j(C)\uparrow v(C)$. If there is no such C and $\lvert v^j(T)\rvert > \lvert v^i(T)\rvert$, make $v^i(T) = -v^j(T)$.
Negation:	Restart the procedure from $v^i(\neg T)\uparrow v^j(\neg T)$.
Give up:	Increase threshold I_0. If $min(\lvert v^i(T)\rvert, \lvert v^j(T)\rvert)$ is now $< I_0$, start the whole procedure anew.

Fig. 2. The sequence of operations in the CAN procedure.

The challenge is to predict the dynamic unfolding of this argumentative dialogue using a static set of rules representing the domain knowledge. We make the simplifying assumption that the predicates included in the arguments are present in the domain knowledge. Still, the reconstruction of the dialogue is a challenging task. The relevant predicates must be selected in the right order and with the right sign (positive or negated) from a (potentially vast) background knowledge that has ideally been developed independently. For illustrative purposes, we used the following domain knowledge.

```
(C1)  burn_off & not wood_wrecked → nice_surface
(C2)  filler_compound → nice_surface
(C3)  sanding & not several_layers → nice_surface
(C4)  burn_off & mouldings & not wire_brush → tough_work
(C5)  wire_brush & wood_soft → wood_wrecked
(C6)  wood_wrecked → not nice_surface
(C7)  repaint & nice_surface → nice_doors
actions([repaint, burn_off, wire_brush, sanding,
filler_compound]).
default([not wood_soft, not several_layers]).
initial_situation(-nice_doors).
```

The program needs a few attitudes in addition. These attitudes are represented as numerical values. Only the hierarchy of values is relevant, not the values themselves.

```
desirable(tough_work, –10)
```

```
desirable(not nice_doors, −20)
```

With this knowledge, or ideally with any finer grain expert knowledge on the same domain, the CAN procedure is able to generate exactly the arguments of this conversation excerpt and in the right order. The program starts by detecting a conflict on 'nice_doors', which both observed and undesirable. This conflict has intensity 20. Abduction leads to a tentative solution, 'burn_off', but this generates a new conflict of intensity 10 on 'tough_work'. Then the program considers the solution 'wire_brush', which solves the conflict. But when the default knowledge 'not wood_soft' is negated, this solution must be abandoned. Then abduction leads to consider 'sanding', but a new conflict appears when the default knowledge 'not several_layers' is negated. And so on, until the sytems gets eventually stuck in a conflict of intensity 10 (as in the real conversation).

5 Discussion

Other systems rely on consistency checking to model argumentation (*e.g.* Thagard, 1989; Pasquier *et al.*, 2006). The present model has several qualities that make it more plausible cognitively.

- Locality: All operations are performed locally or through content addressing. There is no scanning of knowledge.
- Minimalism: The procedure is meant to be the most concise one.
- CAN is recursive, but not centrally recursive. This means that memory requirements do not grow during execution.
- CAN does not loop. Instructions such as "make $v^j(T) = -v^j(T)$" prevent abduction from being performed twice identically with the same terms. However, repeated revisions may simulate the fact that some argumentation dialogues go around in circles.
- Despite the fact that CAN ignores argument authorship, it captures the dialectical nature of argumentation. Each call of CAN represents a move that can be taken on by the same speaker or by another one.

One merit of the CAN procedure is to separate logical relevance processing from the creative part of argumentation. The latter is captured by the abduction procedure. This procedure is external to the model. For testing purposes, we implemented it using a small knowledge base with default assumptions. The CAN procedure can however be "plugged" into any reasonable abduction device.

At this point, we got little more than a proof of principle. We wanted to prove that part of the human argumentation competence could be modeled through a cognitively plausible procedure.

The CAN procedure aims at capturing the rational aspect of argumentation. By enforcing logical relevance, it guarantees the well-formedness of reasoning. It does not take any notion of strategy, such as defeating the opponent's counterarguments, into account. It does not even consider the subjective nature of the social game (convincing game, dispute, counseling…) in which argumentation takes place.

On the other hand, it is hard to imagine how logical relevance could be computed without a procedure like CAN. Even during a quarrel, arguments must be logically relevant, *i.e.* point to inconsistencies or restore consistency. Of course, a general-purpose satisfaction algorithm could produce an optimal solution to restore consistency with minimal attitude change. There is no guarantee, however, that such a solution would be perceived as relevant by a human user. People make attempts to restore consistency step by step, following a local procedure like CAN. Logical relevance is checked at each step, changing one attitude at a time. A constraint satisfaction system that would propose a new set of attitudes is likely to be considered irrelevant, as it would be unable to justify the solution stepwise.

Much work remains to be done to demonstrate that CAN (or a better version of it) is a convincing reasoning module for an argumentation system. We must still seek for yet smaller versions of it. We could not yet find a natural way of merging these two cases into one. Much progress can be also done on the abduction procedure, which is currently crudely implemented. The challenge is to find a plausible abduction procedure that would scale up when the size of the knowledge base increases. There are also issues with the accuracy of the available knowledge. The main point of this paper is that the CAN procedure would help produce convincing argumentative dialogues as soon as an adequate abduction operation would be available.

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