Decalog 2007: Proceedings of the 11th Workshop on the Semantics and Pragmatics of Dialogue, pages 155–156.
Trento, Italy, 30 May – 1 June 2007. Edited by Ron Artstein and Laure Vieu.

A Game-Based Strategy for Optimizing Agents' Argumentation in Deliberation Dialogues

Gemma Bel-Enguix and **M. Dolores Jiménez-López**
Research Group on Mathematical Linguistics
Universitat Rovira i Virgili
Pl. Imperial Tarraco, 1
43005 Tarragona, Spain
gemma.bel,mariadolores.jimenez@urv.cat

Dialogue can be understood as a pragmatic entity where the participants try to maximize the possibilities of success in their argumentation.

Reed and Long (1997) make an interesting distinction between cooperation and collaboration. For a dialogue to be brought about, cooperation is necessary, but collaboration not always exists.

For us, a crucial and non-static element in dialogue is context, understood as the environmental and personal states and circumstances that can affect the development of the dialogue. This context is in constant evolution, not only because of external factors, but also because of the speech acts of participants. Therefore, like Bunt (1994), we think that the configuration of the dialogue is directly related to the intentions of the speakers/hearers and to the context.

In what refers to the types of dialogues according to human argumentation, Walton and Krabbe (1995) introduced a taxonomy that has become classical. They distinguish between *information seeking*, *inquiry*, *persuasion*, *negotiation*, *deliberation* and *eristic* dialogues. Our work is mainly focused in *deliberation*, a kind of dialogue in which participants have to reach an agreement and make a decision.

We approach deliberation from the perspective of dialogue games (Carlson, 1983) with two participants. We use the extensive form of games representation because we assume the participation of the speakers is sequential and they alternate in turn. In this research, we are mainly interested in defining games where the participants in the deliberation have secret intentions. In the sequel, the term dialogue refers to "deliberation dialogue".

The first step for describing deliberation is to define two participants, A_1 and A_2. Each one has a set of dialogue acts $\Theta(A_1)$, $\Theta(A_2)$, which are subsets of the acts store $\Theta = \{p, r, s, a, q, x\}$. Such store is an intentionally limited one, where p and s are two different types of arguments, r is a counter-argument rejection, a is acceptance, q is a question and x represents that an agent is quitting the dialogue. We also establish that r and a cannot be initial productions of the dialogue because they are only valid as a counter-argument.

$\mathcal{R}$ is a set of combinations of argumentation-counterargumentation that relates elements from $\Theta(A_1)$ to acts belonging to $\Theta(A_2)$. These rules have the form $p \rightarrow q$. Every agent has its own set of rules, R_1 for A_2 and R_2 for A_2. If single elements are found in the sets of rules of the agents, they can be used only as starting productions. They are, then, the starting symbols of the system. By definition, the participant that starts the dialogue is A_1, if it has at least one starting symbol. Therefore, if both agents have starting acts, only A_1 will be able of using them.

We denote a production w of an agent A_n in a given state as $A_n(w)$, and the set of possible productions for an agent A_n in a given state as $\theta(A_1)$.

The possible outcomes of the deliberation are represented with upper-case roman letters. They belong to the set O, such that $O = \{A, B, ..., Z\}$. Some of the elements of Θ are associated to elements of O by an application $\mathcal{F}$. Such elements are named terminal acts.

Keeping in mind the parameters explained above, a definition of deliberation games can be introduced:

Definition 1 *Having two speakers A_1 and A_2, a deliberation game G between them is defined as a 4-tuple:*

$$G = (\Theta, \mathcal{R}, O, \mathcal{F})$$

where:

- Θ *is an acts store;*
- $\mathcal{R} = R_1 \cup R_2$ *is the set of argumentation rules for each agent;*
- O *is the set of possible outcomes of the deliberation;*

- *$\mathcal{F}$ is an application relating elements of Θ to elements of O. Such application is denoted by the symbol '$\Rightarrow$'. If there is not an O element for a sign belonging to Θ, then the result is Ind, which means that the outcome is undecidable and the deliberation has to go on.*

As for the tree diagram, we introduce a distinction between *terminal nodes* and *final nodes*. Terminal refers to the nodes which cannot be developed any more, which corresponds to the classical definition of "terminal". However, final nodes are the last nodes generated after a given move. The nodes that, after the application of $\mathcal{F}$ are not labelled wit Ind are terminal. Nodes Ind are final but non terminal nodes. Tree-diagram will show all the possible productions of the game, where the nodes are the agents speaking and the edges denote dialogue acts.

A *trajectory of dialogue* is every lineal path of the tree starting in the initial node. A *complete trajectory* is every path from the starting utterance to a terminal symbol.

Being G a deliberation game, and $\Theta = \{w\}$ the acts store, we denote a trajectory n of this game in the form $G_n(w_1, w_2, ..., w_n)$, being $w_1, w_2, ..., w_n$ the utterances generated to reach the final agreement in order of generation. Since a dialogue has as many trajectories as final results, then we say that a $G = \{G_1, G_2, ..., G_n\}$. The width of a dialogue $width(G)$ is the maximal number of trajectories it has. The trajectories are ordered starting with the leftmost and finishing by the rightmost. We call *paired trajectories* those that have an even number of edges and unpaired *trajectories* those that have an odd number of edges.

We define a move M as an adjacency pair that consists of argument and counterargument. A sequence is a set of moves $M_m, M_n, ..., M_i$. A deliberation game can have one or more moves. As in real life, some dialogues stop after a number of productions that has been determined before, and other can compute after all possibilities have been explored. The productions generated after a move M_n are $\theta(M_n)$. In $\theta(M_n)$, two types of acts can be distinguished: non-terminal $nt(M_n)$ and terminal $t(M_n)$. The state of the dialogue after M_n, denoted $\Theta(M_n)$ includes $\theta(M_n)$ and all the terminal acts that have been achieved before M_n, denoted by $T(M_n)$. Being M_m, M_n the first and second moves in a deliberation, it is clear that in M_m, $\Theta(M_m) = \theta(M_m)$, while in M_n, $\Theta(M_n) = t(M_m) \cup \theta(M_n)$. Being $M = \{M_m, M_n, ..., M_i\}$, $\Theta(M_i) = t(M_m) \cup t(M_n) ... \cup ... \theta(M_i)$, or its equivalent $\Theta(M_i) = T(M_{i-1}) \cup \theta(M_i)$. If in a given move M_n, $\theta(M_n) = t(M_n)$, then the dialogue is complete.

The results of the productions in a move M_n are designed by $g(M_n)$, and they are obtained by applying $\mathcal{F}(\theta(M_n) \Rightarrow O)$. The possible agreements of the deliberation once the move M_n has been performed, are denoted by $G(M_n)$. They are obtained by applying $\mathcal{F}(\Theta(M_n) \Rightarrow O)$.

In this research, we assume agents have a clear order of preferences, even if they want to reach an agreement. In order to optimize the options to obtain a good deal, two very simple techniques can be carried out: *horizontal scoring* and *balance scoring*.

Horizontal scoring measures the potential index of success for each agent in a given move, if the final agreement is achieved in that move. It just calculates the average of the score for both agents in each move.

Balance scoring is a technique that calculates the possibilities of success for every one of the utterances that an agent can perform in every move. To do that, the sub-trees produced for every potential production are measured.

By means of this method we attempt to explore some mathematical properties of deliberation that can be applied to the design of strategies for the agents to achieve a good agreement. The participants in the dialogue have to calculate the convenience of having a large exchange as well as the index of success for every trajectory. The model assumes an evolution in the internal state of the agents, in the strategies of the participants and the environment where the conversation takes place.

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