Grounded Semantics as Persuasion Dialogue

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Abstract. In the current work, we provide a formal Mackenzie-style persuasion dialogue for grounded semantics. We show that an argument is in the grounded extension iff the proponent is able to persuade a maximally sceptical opponent in the dialogue.

Keywords. grounded semantics, persuasion dialogue

1. Introduction

The field of formal argumentation can be seen as consisting of two main lines of research. One line of research is concerned with the dialectical process of two or more players who are involved in a discussion. This kind of argumentation, referred to as *dialogue theory* in the ASPIC project [1], can be traced back to the work of Hamblin [7,8] and Mackenzie [9,10]. A different line of research is concerned with arguments as a basis for nonmonotonic inference. The idea is that (nonmonotonic) reasoning can be performed by constructing and evaluating arguments, which are composed of a number of reasons that collectively support a particular claim. This line of research can be traced back to the work of Pollock [12], Vreeswijk [17] and Simari and Loui [16], and has culminated with the work of Dung [5], which serves as the basis of much of today's argumentation research.

One particular question one may ask is to what extent it is possible to create links between these two lines of research. One particular way of doing so would be to have an argument accepted (under a particular Dung-style semantics) iff it can be defended in a particular type of formal dialogue. In previous work, we observed that (credulous) preferred semantics can be reinterpreted as a particular type of Socratic dialogue [2]. That is, an argument is in at least one preferred extension iff the proponent is able to successfully defend the argument in the associated Socratic discussion game, against a maximally sceptical opponent. In the current paper we take a similar approach, this time not for preferred but for grounded semantics. Our claim is that the acceptance of an argument under grounded semantics coincides with the ability to win a particular type of dialogue, against a maximally sceptical opponent.

One of the aims of our work is to contribute to a conceptual basis for (abstract) argumentation theory. Whereas, for instance, classical logic is based on the notion of truth, it is not immediately obvious where a notion like truth would fit in when it comes to (abstract) argumentation research. Still, one would like to determine what the various

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argumentation semantics actually constitute to. An answer like "preferred semantics is about the maximal conflict-free fixpoints, whereas grounded semantics is about the minimal conflict-free fixpoint" might be technically adequate, but is still conceptually somewhat unsatisfying. We believe that formal dialogue can serve as a conceptual basis for (abstract) argumentation theory. The idea is that one infers not so much what is *true*, as is the case in classical logic, but what can be *defended in rational discussion*.

2. Formal Preliminaries

We now briefly recall some basic concepts from argumentation theory.

Definition 1. *An* argumentation framework *is pair* (Ar, att) *where* Ar *is a finite set of arguments and* $att \subseteq Ar \times Ar$.

We say that A *attacks* B (or alternatively, A is an attacker of B) iff $A\ att\ B$.

Definition 2. *Let* (Ar, att) *be an argumentation framework. An* (partial) argument labelling *is a (partial) function* $lab : Ar \rightarrow \{\texttt{in}, \texttt{out}, \texttt{undec}\}$. *A non-partial argument labelling is called a* complete labelling *iff for each argument* $A \in Ar$ *it holds that*

- *A is labelled* `in` *iff each attacker of A is labelled* `out`
- *A is labelled* `out` *iff there exists an attacker of A that is labelled* `in`

A complete labelling is called the (unique) grounded labelling *iff its set of* `in`*-labelled arguments is minimal (or equivalently, iff its set of* `out`*-labelled arguments is minimal, or iff its set of* `undec`*-labelled arguments is maximal) among all complete labellings.*

Complete labellings stand in a one-to-one relationship with complete extensions [4]. In essence, a complete extension consists of the set of `in`-labelled arguments of a complete labelling. Similarly, the grounded extension consists of the set of `in`-labelled arguments of the grounded labelling [4]. Just like it holds that an argument is in the grounded extension iff it is in every complete extension [5], it also holds that an argument is labelled `in` by the grounded labelling iff it is labelled `in` by every complete labelling, and an argument is labelled `out` by the grounded labelling iff it is labelled `out` by every complete labelling [4]. Therefore, in order to show that an argument is in the grounded extension, it suffices to show that it is labelled `in` by every complete labelling.

If one interprets a complete labelling as a reasonable position an agent can take in the presence of the conflicting information represented in the argumentation framework, then the question of whether an argument is accepted in every reasonable position (labelled `in` by every complete labelling) becomes a relevant one. From dialogue perspective, having an argument accepted in every reasonable position means that even maximally sceptical agent will have to accept the argument, once the reasons are pointed out to him dialectically. Hence, the type of dialogue is essentially *persuasion*, since the idea is to persuade an agent that he has no choice but to accept the argument.

3. A Dialogue Game for Grounded Semantics

Our proposed dialogue game consists of the following moves.

claim This is the first move in the dialogue, at which the proponent claims that a particular argument has to be labelled `in`, creating a commitment of the proponent.

why With this move, the opponent asks why a particular argument has to be labelled a particular way.

because With this move, similar to the *since* move in Mackenzie's DC, a party explains why the label of a particular argument has to be what the party stated earlier.

concede With this move, a party concedes part of the statements uttered earlier by the other party, creating new commitments at the side of the speaker. Although the act of conceding is left implicit in Mackenzie's DC, we agree with [18] that it can have advantages to explicitly represent the act of conceding.

The dialogue game is guided by the definition of complete labelling. The opponent is assumed to be maximally sceptical, conceding only if it cannot be avoided. That is, he only concedes that an argument is `in` if he is already committed that all attackers are `out` and he only concedes that an argument is `out` if he is already committed that at least one attacker is `in`. Informally, the rules of the dialogue can be described as follows.

- The proponent (P) and opponent (O) takes turns; Each turn of P contains single move `claim` or `because`; In each turn O plays one or more moves. O's turn starts with an optional sequence of `concede` moves and finishes (when possible) with a single `why` move.
- P gets committed to arguments used in `claim` and `because` moves; O gets committed to arguments used in `concede` moves.
- P starts with `claim` $\mathtt{in}(A)$ where A is the main argument of the discussion; `claim` cannot be repeated later in the game.
- In consecutive turns P provides reasons for the directly preceding `why` $\mathcal{L}$ move of O by moving `because` $\mathcal{L}'$ where $\mathcal{L}'$ is a reason of $\mathcal{L}$ [3].
- P can play `because` only if the reason given does not contain any arguments already mentioned (in P's commitment store) but not yet accepted (not in O's commitment store). We call such arguments *open issues*.
- O addresses the most recent open issue $\mathcal{L}$ ($\mathtt{in}(A)$ or $\mathtt{out}(A)$) in the discussion. If O is committed to reasons for $\mathcal{L}$ it must `concede` $\mathcal{L}$ otherwise O starts to question all reasons that O is not committed to with `why`.
- O can question with `why` just one argument at a time.
- The moves `claim`, `because` and `concede` can be played only if new commitments do not contradict a previous one.
- The discussion terminates when no more moves are possible. If O conceded the main argument then P wins, otherwise O wins.

Before laying out the precise formal rules of the dialogue game, it can be illustrative to examine some examples. Consider for instance the argumentation framework of Figure 1. Here, the discussion could go as follows.

[3] A reason for $\{(A, \mathtt{in})\}$ is $\{(B_1, \mathtt{out}) \ldots (B_n, \mathtt{out})\}$ where $B_1 \ldots B_n$ are all the attackers of A in the associated argumentation framework. A reason for $\{(A, \mathtt{out})\}$ is $\{(B_i, \mathtt{in})\}$ where B_i is one of the attackers of A in the associated argumentation framework.

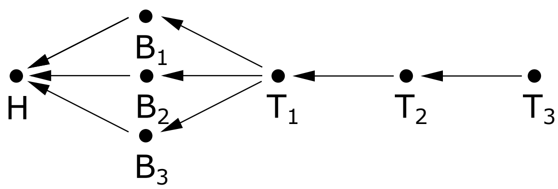

Figure 1. An argumentation framework with many paths

		Commitment			
	Moves	Proponent		Opponent	
		`in`	`out`	`in`	`out`
1	P: `claim` `in`(H)	H	-	-	-
2	O: `why` `in`(H)	H	-	-	-
3	P: `because` `out`(B_1, B_2, B_3)	H	B_1, B_2, B_3	-	-
4	O: `why` `out`(B_1)	H	B_1, B_2, B_3	-	-
5	P: `because` `in`(T_1)	H, T_1	B_1, B_2, B_3	-	-
6	O: `why` `in`(T_1)	H, T_1	B_1, B_2, B_3	-	-
7	P: `because` `out`(T_2)	H, T_1	B_1, B_2, B_3, T_2	-	-
8	O: `why` `out`(T_2)	H, T_1	B_1, B_2, B_3, T_2	-	-
9	P: `because` `in`(T_3)	H, T_1, T_3	B_1, B_2, B_3, T_2	-	-
10	O: `concede` `in`(T_3)	H, T_1, T_3	B_1, B_2, B_3, T_2	T_3	-
11	O: `concede` `out`(T_2)	H, T_1, T_3	B_1, B_2, B_3, T_2	T_3	T_2
12	O: `concede` `in`(T_1)	H, T_1, T_3	B_1, B_2, B_3, T_2	T_3, T_1	T_2
13	O: `concede` `out`(B_1)	H, T_1, T_3	B_1, B_2, B_3, T_2	T_3, T_1	T_2, B_1
14	O: `why` `out`(B_2)	H, T_1, T_3	B_1, B_2, B_3, T_2	T_3, T_1	T_2, B_1
15	P: `because` `in`(T_1)	H, T_1, T_3	B_1, B_2, B_3, T_2	T_3, T_1	T_2, B_1
16	O: `concede` `out`(B_2)	H, T_1, T_3	B_1, B_2, B_3, T_2	T_3, T_1	T_2, B_1, B_2
17	O: `why` `out`(B_3)	H, T_1, T_3	B_1, B_2, B_3, T_2	T_3, T_1	T_2, B_1, B_2
18	P: `because` `in`(T_1)	H, T_1, T_3	B_1, B_2, B_3, T_2	T_3, T_1	T_2, B_1, B_2
19	O: `concede` `out`(B_3)	H, T_1, T_3	B_1, B_2, B_3, T_2	T_3, T_1	T_2, B_1, B_2, B_3
20	O: `concede` `in`(H)	H, T_1, T_3	B_1, B_2, B_3, T_2	T_3, T_1, H	T_2, B_1, B_2, B_3

In essence, our inspiration comes from the argument game for grounded semantics as described in [15,11]. Here, a game basically consists of a proponent (P) and an opponent (O) taking turns in putting forward arguments (proponent begins). Each moved argument has to be an attacker of the previously moved argument by the other player. In order to ensure that the game terminates, the proponent is disallowed from moving the same argument twice (although the opponent does not have this restriction). A player wins if the other player cannot move any more.

Although the Standard Grounded Game, as described in [15,11], can serve fine as a basis for argument-based proof procedures, it does have some properties that deviate from what one would expect for a persuasion dialogue. In particular, where the definition of a complete labelling requires that for an argument to be `in` *all* of its attackers have to be `out`, in the Standard Grounded Game, it is only claimed that just *one* of the attackers is `out`[4] It is difficult to maintain that an agent can be persuaded that all attackers of an argument are labelled `out` when this is shown only for one of them. Therefore, the

[4]That is, if one interprets the Standard Grounded Game in terms of argument labellings, where the proponent makes `in` moves and the opponent makes `out` moves, as is done in [11].

Standard Grounded Game cannot be said to be truly about persuasion, at least not within an individual game.[5]

For the grounded game to be categorized as persuasion, it would be highly desirable to be able to evaluate, in the same game, *all* attackers of a particular argument that is claimed to be in. This, however, create a new type of problems. In the dialogue game associates with Figure 1 for instance, the proponent moves the same argument (T_1) three times. In the Standard Grounded Game, this would not be allowed, since it can lead to non-termination. Take for instance an argumentation framework consisting of two arguments A and B that attack each other. When one allows for the proponent to repeat arguments, the resulting game can be infinite.

		Commitment			
	Moves	Proponent		Opponent	
		in	out	in	out
1	P: claim in(A)	A	-	-	-
2	O: why in(A)	A	-	-	-
3	P: because out(B)	A	B	-	-
4	O: why out(B)	A	B	-	-
5	P: because in(A)	A	B	-	-
6	O: why in(A)	A	B	-	-
7	P: because out(B)	A	B	-	-
	⋮	⋮	⋮	⋮	⋮

In the Standard Grounded Game, the reason one does not have to repeat argument T_1 in the example of Figure 1 is because the lines of arguments in(H)-out(B_1)-in(T_1)-out(T_2)-in(T_3), in(H)-out(B_2)-in(T_1)-out(T_2)-in(T_3) and in(H)-out(B_3)-in(T_1)-out(T_2)-in(T_3) are considered to be distinct, constituting different discussions.[6] However, they can only be distinct because one does *not* require all attackers of an in-labelled argument to be evaluated to be labelled out in the same discussion.

Overall, what we are interested in is to define a dialogue game such that (1) all attackers of an argument that is claimed to be in can be be evaluated to be out in the same dialogue, (2) each dialogue is guaranteed to terminate, and (3) the ability for the proponent to win the dialogue coincides with membership of the grounded extension.

We now formally define the above sketched dialog game.

Definition 3 (Discussion move)**.** *A discussion move is a triple* $M = (\mathcal{P}, \mathcal{T}, \mathcal{L})$ *where* $\mathcal{P} \in \{\texttt{proponent}, \texttt{opponent}\}$ *is a player,* $\mathcal{T} \in \{\texttt{claim}, \texttt{why}, \texttt{because}, \texttt{concede}\}$ *is a move type and* $\mathcal{L}$ *is a partial labelling.*

Definition 4 (Discussion)**.** *A discussion* $\mathcal{D}$ *is a tuple* $(\mathcal{M}, \mathcal{CS})$ *where* $\mathcal{M}$ *is a finite sequence of moves* $[M_1, ..., M_n]$ *and* $\mathcal{CS}$ *is a function assigning to each player a partial labelling representing his commitment.*

Additionally we define open issues *as* $OI(\mathcal{D}) = \mathcal{CS}(\texttt{proponent}) \setminus \mathcal{CS}(\texttt{opponent})$ *and the* last open issues $LOI(\mathcal{D}) = OI(\mathcal{D}) \cap \mathcal{L}_k$ *where* $M_k = (\mathcal{P}_k, \mathcal{T}_k, \mathcal{L}_k)$ *is the last move such that* $OI(\mathcal{D}) \cap \mathcal{L}_k$ *is not empty (maximal k).*

[5] For establishing correctness and completeness with respect to membership of the grounded extension, the Standard Grounded Game relies not on an individual game, but on the presence of a winning strategy. We refer to [15,11] for details.

[6] They are essentially branches in the tree of the winning strategy [15,11].

Definition 5 (Grounded discussion)**.** *A discussion $\mathcal{D} = (\mathcal{M}, \mathcal{CS})$, $\mathcal{M} = [M_1, ..., M_{n+1}]$ is a* grounded discussion *iff the following recursive conditions (basis) or (construction) hold.*

(basis) $n = 0$ *and the following holds*

- I_1 $M_1 = (\texttt{proponent}, \texttt{claim}, \texttt{in}(A))$
- I_2 $\mathcal{CS}(\texttt{proponent}) = \texttt{in}(A)$ *and* $\mathcal{CS}(\texttt{opponent}) = \emptyset$

(construction) $n > 0$ *and* $\mathcal{D}' = (\mathcal{M}', \mathcal{CS}')$ *(where* $\mathcal{M}'$ *is* $[M_1, ..., M_n]$*) is a grounded discussion and one of the following holds:*

- W_1 $M_{n+1} = (\texttt{opponent}, \texttt{why}, \mathcal{L})$
- W_2 $M_n = (\mathcal{P}_n, \mathcal{T}_n, \mathcal{L}_n)$, $\mathcal{T}_n \neq \texttt{why}$
- W_3 $\mathcal{L} \subseteq LOI(\mathcal{D}')$, $\#\mathcal{L} = 1$
- W_4 *there is no* $\mathcal{L}' \subseteq LOI(\mathcal{D}'), \#\mathcal{L}' = 1$ *such that* $\mathcal{CS}(\texttt{opponent})$ *contains the reason for* $\mathcal{L}'$
- W_5 $\mathcal{CS} = \mathcal{CS}'$

or

- B_1 $M_{n+1} = (\texttt{proponent}, \texttt{because}, \mathcal{L})$
- B_2 $M_n = (\texttt{opponent}, \texttt{why}, \mathcal{L}')$
- B_3 $\mathcal{L}$ *is a reason for* $\mathcal{L}'$
- B_4 $\mathcal{L} \cap OI(\mathcal{D}') = \emptyset$
- B_5 $\mathcal{CS}(\texttt{proponent}) = \mathcal{CS}'(\texttt{proponent}) \cup \mathcal{L}$
- B_6 $\mathcal{CS}(\texttt{opponent}) = \mathcal{CS}'(\texttt{opponent})$

or

- C_1 $M_{n+1} = (\texttt{opponent}, \texttt{concede}, \mathcal{L})$
- C_2 $\mathcal{L} \subseteq LOI(\mathcal{D}')$, $\#\mathcal{L} = 1$
- C_3 $\mathcal{CS}'(\texttt{opponent})$ *contains a reason for* $\mathcal{L}$
- C_4 $\mathcal{CS}(\texttt{proponent}) = \mathcal{CS}'(\texttt{proponent})$
- C_5 $\mathcal{CS}(\texttt{opponent}) = \mathcal{CS}'(\texttt{opponent}) \cup \mathcal{L}$

We say that a discussion is terminated *if it cannot be extended any more. For a terminated discussion* `proponent` *wins if* `opponent` *conceded the main claim of the discussion, otherwise* `opponent` *wins.*

Observation 1. *(Grounded discussion properties)*

1. *The* `claim` *move is the first move in every discussion (I_1) and it is never repeated as it is not listed in* $construction$ *part of Definition 5.*
2. *The* `concede` *is never played after* `why` *as W_4 excludes C_3 so C_3 does not hold when* `why` *is played and also in the next move as* `why` *does not change the commitment store.*
3. *After each* `concede` *move* $\mathcal{CS}(\texttt{opponent})$ *is enlarged with one argument. Consider a partial labelling $\mathcal{L}$ that is added to* $\mathcal{CS}(\texttt{opponent})$ *during a* `concede` *move (C_5). By condition C_2 it labels exactly one argument and because $\mathcal{L} \subseteq LOI(\mathcal{D}') \subseteq OI(\mathcal{D}')$ and $OI(\mathcal{D}') \cap \mathcal{CS}(\texttt{opponent}) = \emptyset$ it was not in* $\mathcal{CS}(\texttt{opponent})$ *before.*
4. *The* `why` *move cannot be repeated directly after other* `why` *move (W_2).*
5. *Whenever a* `concede` *move can be played, by condition W_4 a* `why` *move cannot.*
6. *A* `because` *move follows directly after a* `why` *move (B_2).*
7. *After each* `because` *move* $\mathcal{CS}(\texttt{proponent})$ *is enlarged. Consider the labelling $\mathcal{L}$ that is added to* $\mathcal{CS}(\texttt{proponent})$ *during a* `because` *move (B_5). $\mathcal{L}$ is a reason for $\mathcal{L}'$ from the previous* `why` *move (B_3). By W_4 $\mathcal{L}$ is not contained in* $\mathcal{CS}(\texttt{opponent})$ *and in particular* $\mathcal{L} \setminus \mathcal{CS}(\texttt{opponent})$ *is not empty. By B_4* $\mathcal{L} \setminus \mathcal{CS}(\texttt{opponent})$ *is also not an open issue. Therefore $\mathcal{L}$ needs to contain at least one new element.*

8. *It is always the case that* $\mathcal{CS}(\texttt{opponent}) \subseteq \mathcal{CS}(\texttt{proponent})$. *It holds after the first* `claim` *move* (I_2)*, then* `opponent`*'s commitment store is only modified during* `concede` *moves when it is extended by* $\mathcal{L} \subseteq LOI(\mathcal{D}) \subseteq OI(\mathcal{D}) \subseteq \mathcal{CS}(\texttt{proponent})$.
9. *The* `because` *move cannot be played if the new commitment store defined in* B_5 *is not a partial labelling. A grounded discussion is a discussion, so the commitment stores need to be partial labellings. This rules out the possibility that the same argument is labelled both* `in` *and* `out`*. This is not a concern in case of* `concede` *as* `opponent`*'s commitment store is always subset of* `proponent`*'s store (see previous point).*

Theorem 6. *Any grounded discussion over finite argumentation framework has to terminate using a finite number of steps.*

Theorem 7. *Let* $AF = (Ar, att)$ *be argumentation framework and* $\mathcal{L}_{gr}$ *it's unique grounded labelling. For any argument* $A \in Ar$ *there exists a grounded discussion for* A *that is won by a proponent iff* $\mathcal{L}_{gr}(A) = \texttt{in}$.

It can be illustrative to examine how the earlier mentioned examples of discussion games relate to the formal definition of the grounded discussion. The discussion related to Figure 1 is in essence an instance of the formal grounded discussion although one would have to omit the $14^{th}, 15^{th}, 17^{th}$ and 18^{th} moves, since the fact that B_2 and B_3 are `out` already follows from the opponent's existing commitments, where T_1 is `in`. The second discussion, that is related to the case of two arguments attacking each other, however, is *not* a legal grounded discussion. The reason is that in the fifth step ("P: `because` $\texttt{in}(A)$") the proponent gives a reason ($\texttt{in}(A)$) that is actually an open issue, which is explicitly forbidden by rule B_4 of Definition 5.

Overall, one can observe that our approach to the grounded discussion no longer relies on an implicit tree-like structure (as was still the case in the Standard Grounded Game, in which this tree is essentially a winning strategy of lines of arguments [15,11], or in the approach of [13]) to be able to allow certain forms of desirable repetition (in different lines of arguments, as is the case in the example related to Figure 1) while at the same time ruling out certain forms of undesirable repetition (in the same line of arguments, as is the example related to two arguments attacking each other). By cleverly using the commitment store we made the desirable form of repetition unnecessary, which means that all other forms of repetition are undesirable and can simply be forbidden. We simply do not need the concept of lines of arguments anymore in order to distinguish between desirable repetition and undesirable repetition. In this way, the discussion related to grounded semantics has become in line with standard Hamblin/Mackenzie style dialogue theory, where one relies only on the notion of a commitment store, and not on all kinds of implicit mathematical structures (like trees or lines of arguments) to keep track of the status of the dialogue.

4. Summary and conclusions

In the current paper, we have examined how the notion of grounded semantics can be specified in terms of persuasion dialogue. The aim of our work, as well as that of [2] is to build a connections between two lines of argumentation research: argumentation as a basis for specifying nonmonotonic inference [5,3,14,6] and argumentation as a dialectical process of structured discussion [7,8,9,10]. The idea is that argumentation as nonmonotonic inference can be specified *by means of* different types of structured discussion.

Our theory differs from the Standard Grounded Game in that (1) we apply Mackenzie-style dialogue moves, like `claim`, `why because` and `concede`, (2) when an argument is labelled `in`, we show that *all* its attackers are labelled `out` whereas in the Standard Grounded Game this is shown for only one of the attackers (at least in a single game or line of arguments), (3) we rely on the concept of a commitment store for determining the possible moves and ensuring correctness and completeness w.r.t. grounded semantics, (4) we do not apply the notion of a discussion tree, which after all is alien to Mackenzie-style dialogue, and (5) the presence of a winning strategy is not required to establish membership of the grounded extension; instead a single game won by the proponent against a maximally skeptical opponent is sufficient, (6) the length of our dialogue is always linear w.r.t. the number of arguments in the argumentation framework, while for the Standard Grounded Game there exist examples (omitted due to lack of space) where the size of the winning strategy is exponential.

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