A Gradual Semantic to Model Opinion using Bipolar Argumentation Graphs

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Résumé

L'argumentation abstraite est une méthode de formalisation des discussions argumentatives largement utilisée dans la représentation des connaissances et la construction de protocoles multi-agents. Les sémantiques graduelles ont récemment été proposées comme une extension des sémantiques classiques, permettant une évaluation plus fine des arguments. Dans cet article, nous proposons une structure générale pour représenter l'opinion des agents à partir de graphes d'argumentation bipolaires valués et caractériser cette opinion grâce à l'application d'une sémantique graduelle. Nous identifions certaines propriétés désirables d'une telle sémantique, en particulier les propriétés d'ouverture d'esprit et de dualité, et proposons une nouvelle sémantique graduelle qui les vérifie, que nous comparons à l'*Euler based semantic* de Amgoud et al. [1]. Nous discutons également des conséquences de l'application de cette nouvelle sémantique à notre structure d'opinion. Ce travail ouvre la voie à une analyse plus fine des dynamiques argumentatives dans les protocoles multi-agents utilisant les outils de l'argumentation abstraite.

Abstract

Abstract argumentation is a method for formalizing argumentative discussions which is widely used in the representation of knowledge and the construction of multi-agent protocols. Gradual semantics have recently been proposed as an extension of classical semantics, allowing a finer evaluation of arguments. In this article, we propose a general structure to represent the opinion of agents extracted from valued bipolar argumentation graphs thanks to the application of a gradual semantic. We identify some desirable properties of such a semantic, in particular open-mindedness and duality properties, and propose a new gradual semantic that verifies them, which we compare to the Euler based semantic of Amgoud et al. [1]. We also discuss the consequences of applying this semantic to our opinion framework. This work opens the way to a finer analysis of argumentative dynamics in multi-agent protocols which uses the tools of abstract argumentation.

Introduction

Abstract argumentation is a method for formalizing argumentative discussions. By representing debates in the form of graphs, it becomes possible to formally define the acceptability of arguments from the perspective of a rational agent. The simplicity and flexibility of this representation makes it an ideal tool for the representation of knowledge, and the construction of multi-agent protocols.

Many works use abstract argumentation to study dynamics that are explicitly argumentative : [12] model a strategic game of persuasion of an audience, [4] develops a protocol inspired by debates conducted on online platforms. Other works use abstract argumentation because it allows for a finer modeling of exchanges between agents, with the emergence of more varied opinion dynamics [21]. The use of argumentation to model the reasoning process of agents is justified by the recent advancements in cognitive psychology by Mercier and Sperber [14] and their theory of argumentative reasoning, which states that our reasoning abilities are derived from our capacity to produce arguments. The growing interest in these models justifies the enhancement of abstract argumentation with new tools, such as gradual semantics.

The semantics introduced by Dung [8] are functions that determine the set of acceptable arguments within an argumentation graph. Recently, a new type of semantic called *gradual* has been proposed [13, 2, 1] : these semantics assign an acceptability score to each argument, allowing for a more nuanced evaluation of the acceptability of the arguments. The inherent expressiveness of gradual semantics makes them highly valuable for the development of multi-agent protocols, as they enable precise analysis of argumentative dynamics. For instance, [9] creates a multi-agent model where the opinion of the agents is a number obtained through the application of a gradual semantic, which makes it possible to study the dynamics of the agents' opinions. In this work, we seek to build a tool which would enable similar analyses in the case of bipolar argumentation graphs.

Indeed, the first works on abstract argumentation consider only one relation between the arguments : the attack. Bipolar graphs are an extension of classical abstract argumentation graphs which consider an additional relation, that of *support* [5]. These graphs are more expressive and have been validated by empirical experiments as more representative of the way in which humans actually reason [16]. In most cases, these graphs are *weighted*, which means that arguments are equipped with a weight ; which can represent their intrinsic strength, trust in their source, or support in the form of a vote. Several gradual semantics for weighted bipolar graphs have been proposed [1, 19].

Building upon the work of [9], we present a general framework that enables the representation of agents' knowledge in the form of a bipolar graph, and the characterization of their opinion with the application of a gradual semantic. This leads us to identify some desirable properties of such semantics : in particular, the properties of open-mindedness and duality identified by Potyka [17, 18]. We propose a new semantic which verifies these principles.

The first section of this article presents an overview of the fundamental concepts of abstract argumentation frameworks and gradual semantics. Subsequently, in the second section, we introduce a general framework that effectively represents agents' opinions using argumentation graphs. This framework serves as a foundation for the exploration of various desirable properties of semantics in the subsequent third section. To address these properties, the fourth section introduces a novel gradual semantics that ensures, among others, the presence of open-mindedness and duality. Moreover, we delve into the implications of applying this semantics to our opinion framework within this section.

1 Abstract Argumentation and Gradual Semantics

1.1 Bipolar Graphs

Abstract argumentation, introduced by Dung [8], is a method for formalizing argumentative discussions that considers arguments as abstract objects and focuses on the relations that link these arguments together. Since the introduction of abstract argumentation frameworks, or graphs, the attack relation which was considered originally has been supplemented by a *support* relation, giving rise to **bipolar argumentation graphs** [5].

A very common extension of bipolar argumentation graphs consists in equipping each argument with a "weight", which corresponds to an intrinsic quality of the argument. Thus, we can define weighted bipolar argumentation graphs.

Definition 1 (Weighted Bipolar Argumentation Graphs) *A weighted bipolar argumentation graphs B is a quadruple $B = \langle A, R, S, W\rangle$ where A is a finite set of arguments, $R \subseteq A \times A$, $S \subseteq A \times A$ are two binary relations on arguments, respectively attack and support, and W is a function from A to* $[0, 1]$.

In this article, we will also focus on a subclass of these graphs, namely non-weighted bipolar graphs.

Non Weighted Bipolar Graphs correspond to the case $B = \langle A, R, S, W\rangle$ where W is a constant function. This amounts to choosing a base weight w_{base} such that $W(a) = w_{base}$ for all $a \in A$.

In order to simplify notations, we will use $B \setminus A'$ with $A' \subset A$ to denote graph B without the arguments of A' and the attack and support relations featuring these arguments. We now also define the set of attacker and supporters of an argument.

Definition 2 (Set of attackers and supporters) *Let $B = \langle A, R, S, W\rangle \in G$ a weighted bipolar graph and $a \in A$ an argument from this graph. The set of attackers and supporters of a in B are respectively defined as $Att(B, a) = \{b \in A | (b, a) \in R\}$ and $Supp(B, a) = \{b \in A | (b, a) \in S\}$.*

1.2 Gradual Semantics

A major challenge of abstract argumentation is the characterisation of the *acceptability* of arguments based on the information contained in an argumentation graph. **Gradual semantics** are functions which evaluate the acceptability of arguments through an *acceptability score*. In this work, we only consider gradual semantics whose image set is an interval of $\mathbb{R}$: it is a necessary condition to define the relevant properties presented in Section 3. This restriction enables us to consider all the gradual semantics for bipolar graphs proposed by [1, 15].

Definition 3 (Gradual Semantic) *Let G the set of all weighted bipolar graphs, $B = \langle A, R, S, W\rangle \in G$, and D an interval of $\mathbb{R}$. A gradual semantic on B is a function $\sigma : G \times A \to D$ and for all $a \in A$, $\sigma(B, a)$ denotes the acceptability score of a in B.*

We have a specific focus on a particular type of gradual semantic known as **modular** semantics, as identified by Mossakowski et al. [15]. These semantics consist of two functions : one aggregates the scores of the attackers and supports of a given argument, and the other determines their influence on the base weight of this argument. Consequently, the various semantics proposed for bipolar argument graphs in existing literature can be analyzed as combinations of an aggregation function and an influence function.

Definition 4 (Modular Gradual Semantic) *Let* $B = \langle A, R, S, W\rangle \in G$*, and* D *an interval of* $\mathbb{R}$*. A modular gradual semantic on* B *is a function* $\sigma : G \times A \rightarrow D$ *where* $\sigma(B, a) = \iota(\alpha(B, a))$ *with* α *and* ι *respectively the aggregation function and influence function.*

In the rest of this article, we will only consider modular gradual semantics, which will simplify the definition and verification of their properties. As noted by [15], all the gradual semantics for weighted bipolar graphs presented in the literature are modular.

2 Opinion Model

In this section, we place ourselves within the framework of an argumentative discussion between agents, and we define a way to characterize the opinion of the agents through a bipolar graph, their **opinion graph**. We don't specify a multi-agent protocol governing what actions are performed each turn, so we use the terminology "framework" or "structure". Our goal is to create a flexible model that can serve as a basis for the creation of various multi-agent protocols, whose specific characteristics would make it possible to study various phenomena.

The opinion graph can be interpreted either as the agent's knowledge base, or the arguments that she takes into account in her evaluation of a debate. Here, we favor the first interpretation, and say that an agent *knows* an argument when it belongs to her opinion graph.

Following the methodology of [4] and [9], all of the opinion graphs contain an argument with a special status, the *issue*, which constitutes the focus of the debate. These graphs are **issue-oriented**, which means that all the arguments of a graph belong to a path of supports and attacks directed towards the issue. Furthermore, we consider the opinion of the agents to be a real number, which belongs to the image set of the gradual semantic that we use (in most case, this interval is $[0, 1]$), and represent their opinion *about the issue*. This focus on a single issue is warranted by the context of argumentative discussions, although this framework could easily be extended to include multi-dimensional opinions about several issues. Many seminal opinion dynamics models represent the opinion of agents as a real number in the interval $[0, 1]$: such is the case of the *bounded-confidence* type models [10, 7]. These models make the assumption that the opinion of agents can be represented as a real number for the sake of simplicity, citing the example of "an expert who has to assess a certain magnitude" [10]. In our case, as we are studying argumentative discussions, one natural interpretation of the opinion is a **degree of belief** of the agent in the acceptability of the issue.

We distinguish two cases, the one where the graph is not weighted and the one where it is. It is important that our structure takes into account the cases where the arguments are equipped with weights because it enables greater expressiveness : for example a protocol could aggregate votes coming from agents and transform them into weights as described in [13]. The non-weighted case is also necessary, because it allows for a simplification of the multi-agent protocol. Indeed, according to the KISS approach (*Keep it Simple, Stupid!*) [3], multi-agent protocols must be as simple as possible, and use a minimum number of parameters. As we will see later, the need to accommodate weighted and non-weighted cases is a non-trivial constraint on the semantic used.

We can now formally define our framework, starting with opinion graphs.

Definition 5 (Issue Oriented Bipolar Graphs) *Let* $B = \langle A, R, S, W\rangle$ *a weighted bipolar graph.* B *is* ***issue-oriented*** *if there exists* $i \in A$ *such that for all* $a \in A$*, there is a path from* a *to* i*.*

Suppose we have a semantic for weighted bipolar graphs $\sigma : G \times A \rightarrow D \in \mathbb{R}$. We can then define the opinion of agents as the evaluation of the acceptability of the issue by the gradual semantic σ applied to their opinion graph.

Definition 6 (Opinion of an agent) *Let an agent* k *equipped with an issue-oriented bipolar graph of issue* i*,* $B_k = \langle A, R, S, W\rangle \in G$ *and* $\sigma : G \times A \longrightarrow D \in \mathbb{R}$ *a modular gradual semantic well defined on* B_k*. We define the* ***opinion*** *of agent* k *as* $O_k = \sigma(B_k, i)$*.*

The main contribution of our framework is that the agents' opinions are derived from graphs forming their knowledge base, using gradual semantics which can express certain ideals of rationality. With an accurate choice of image set D for the semantic as $[0, 1]$, the results of multi-agent protocols built using our framework could be directly compared with that of the bounded-confidence type models.

We can see that the semantic used plays a major role in the evaluation of the agents' opinions. The following section describes necessary and desirable properties of a semantic for this framework.

3 Desirable properties

3.1 First principles

Amgoud et al. [1] carry out an extensive study of gradual semantics for weighted bipolar graphs. The authors identify twelve desirable properties that can be verified by such semantics. Table 1 offers an intuitive explanation of each of these principles. We refer the reader to the original article for a complete formalization.

The authors compare existing semantics for weighted bipolar graphs based on these principles. They propose a novel semantic called *Euler Based Semantic* (EBS) and show that it is the only semantic that verifies their twelve principles.

3.2 EBS and non-weighted graphs

The model for representing agents' knowledge and opinions presented in Section 2 gives rise to constraints on the semantic used. In particular, a semantic must be defined for the type of graph considered, depending on whether it is weighted or not. These properties are not trivial : despite the fact that it satisfies many desirable principles, we show here that the EBS semantic is not appropriate for a protocol using non-weighted graphs.

Most of the gradual semantics for bipolar graphs proposed in the literature are defined for weighted graphs. The underlying logic is that of "Whoever can do the most can do the least.", i.e. a semantic capable of accommodating an additional level of complexity can *a fortiori* deal with simpler cases, here non-weighted graphs. It would suffice to choose the base weight well to obtain a semantics that behaves correctly. This is a method successfully applied for attack (and support) gradual semantics : thus, the h-categorizer [13] semantic can be adapted to non-weighted attack graphs and retains desirable properties [18]. We will see that this is not the case with EBS.

Let us define formally the Euler base semantic introduced by [1]. This semantic is defined exclusively in the case of acyclic bipolar graphs and is based on a quantity, the energy, which aggregates the scores of the supports and direct attackers of an argument.

Definition 7 (Energy of an argument) *Let* $B = \langle A, R, S, W \rangle \in G$ *a weighted bipolar graph. For an argument* $a \in A$*,* $Supp(B,a)$ *and* $Att(B,a)$ *are respectively the set of argument attacking and supporting a in B. The energy E is defined as the function* $E : G \times A \to \mathbb{R}$ *such that for all* $a \in A$ *:*

$$E(B,a) = \sum_{x \in Supp(B,a)} \sigma(x) - \sum_{x \in Att(B,a)} \sigma(x)$$

Definition 8 (*Euler Based Semantic* (EBS)) *Let* $B = \langle A, R, S, W \rangle \in G$ *an acyclic weighted bipolar graph.* $Ebs(B)$ *is the score function* $\sigma : G \times A \to [0,1]$ *recursively defined as : For all* $a \in A$ *of weight* w_a

$$\sigma(B,a) = 1 - \frac{1 - w_a^2}{1 + w_a e^{E(B,a)}}, \qquad (1)$$

If one wishes to apply EBS to non-weighted graphs, it is necessary to choose a base weight w_{base} for all the arguments, which will correspond to their evaluation when they are neither attacked nor supported (a natural choice for such a weight would be 0.5 for example). However, as noted in

Table 1 – Principles defined by [1] which can be verified by a gradual semantic for weighted bipolar graphs.

Property	**Intuition**
Anonymity	The score of an argument is independant from its identity.
Bivariate Independance	The score of an argument is independant from every argument that is not linked to it.
Bivariate Directionnality	Only the relations directed towards the argument influence its score, and not relations directed away from it.
Bivariate Equivalence	The score of an argument only depends on its base weight and on the score of its direct attackers and supporters.
Stability	If an argument is neither attacked nor supported, its score must be equal to its weight.
Neutrality	Attackers and supporters of score equal to zero have no effect on their targets.
Bivariate Monotony	If an argument a is as much or less attacked than an argument b, and as much or less supported than b, then the score of a must be at least as great as that of b.
Bivariate Reinforcement	An argument's score increases if the quality of its attackers is reduced and the quality of its supports is increased.
Resilience	If an argument's weight is positive, its score cannot be reduced to zero by attacks. If the weight is lower than 1, it cannot reach 1 with supports.
Strict Franklin	Attacks are as important as supports.
Weakening / Strengthening	If attacks are greater than supports, the score of the argument is lower than its weight, and conversely.

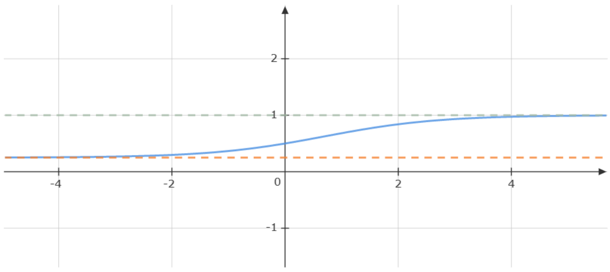


FIGURE 1 – Variation of the score of an argument according to EBS (y-axis) against its energy $E(B, a)$ (x-axis), in the case $w_{base} = 0.5$. We see that the value of the score is between 1 (grey line) and $w^2_{base} = 0.25$ (orange line).

[18], the acceptability score of an argument evaluated by EBS cannot be less than the square of the weight of the argument. Thus, this semantic adapted to a non-weighted graph would no longer affect a score between 0 and 1 but in the interval $[w^2_{base}, 1]$. Figure 1 illustrates this situation in the case of $w_{base} = 0.5$. We see that using EBS for a protocol using non-weighted graphs would amount to limiting the opinions of the agents to the interval $[w^2_{base}, 1]$, which among other things limits the possibilities of comparison with *bounded confidence* type models [1].

Another consequence of this behavior is that the impacts of supports are proportionally greater than those of attacks, regardless of the weight of the argument.

3.3 Open Mindedness and Duality

Potyka's works [18, 17] define two other properties of gradual semantic for bipolar graphs : open-mindedness and duality.

Intuitively, open mindedness corresponds to the fact that the score of an argument can vary freely between the limits of interval D, whatever its base weight : for instance, it may approach as closely as we want 0 or 1 as long as we add enough attacks and supports.

Definition 9 (Open Mindedness) *Let $\sigma : G \times A \to D$ a semantic for weighted bipolar graphs on an interval D. The semantic is open-minded for all graph $B = \langle A, R, S, W\rangle$ if for all argument $a \in A$ and all $\epsilon > 0$, the following condition is satisfied : there exists a number $N \in \mathbb{N}$ such that if we add N new arguments whose base score is maximal : $A_N = a_1, .., a_N$, $A \cap A_N = \emptyset$, then :*

1. *For graph $B_{att} = \langle A \cup A_N, R \cup \{(a_i, a) | 1 \leq i \leq N\}, S, W'\rangle$, we obtain $|\sigma(B_{att}, a) - min(D)| < \epsilon$*
2. *For graph $B_{supp} = \langle A \cup A_N, S \cup \{(a_i, a) | 1 \leq i \leq N\}, S, W'\rangle$, we obtain $|\sigma(B_{supp}, a) - max(D)| < \epsilon$*

where $W'(b) = W(b)$ for all $b \in A$ and $W'(a_i) = max(D)$ for $i \in [\![1, N]\!]$.

Potyka [17] also defines a property which illustrates the intuitive notion of symmetry between the actions of attacks and supports : duality. To illustrate, let's take the example of EBS : the asymmetric nature of this semantic causes an imbalance between the action of attacks and supports. One would expect symmetrical actions of attacks and supports when the initial weight is 0.5. On the other hand, when the initial weight is greater or less than 0.5, we cannot expect perfect symmetry because the weight of the argument is now closer to one of the limits of the interval [0, 1]. [17] generalizes this symmetry intuition in the following way : suppose that the initial weights of a and b are shifted relative to 0.5 by in different directions, and that the attackers of a have the same strength as the supports of b and vice versa. Then if the application of a dual semantics to a transforms its weight into a score shifted by δ, the score of b should be shifted by $-\delta$ with respect to its base weight. We define this property, duality, in the context of modular gradual semantics.

Definition 10 (Duality) *Let $\sigma : G \times A \to D$ be a modular semantic for weighted bipolar graphs, with α its aggregation function and ι its influence function. The semantic σ verifies **duality** for all $B = \langle A, R, S, W\rangle$ if and only if it verifies the following property :*

Let $a, b \in A$ such that $w_a = 0.5 + \epsilon, w_b = 0.5 - \epsilon$ for an $\epsilon \in [0, 0.5]$, and the supporters and attackers of a and b are such that :

$$\alpha(B \setminus Att(B, a), a) = -\alpha(B \setminus Supp(B, b), b)$$
$$\alpha(B \setminus Att(B, b), b) = -\alpha(B \setminus Supp(B, a), a)$$

then $\sigma(B, a) - w_a = w_b - \sigma(B, b)$.

These two properties are not necessary ; however, depending on the context, they may be very important. Concerning open-mindedness, apart from not being very elegant, real problems can emerge from a situation where the entirety of the opinion space is not accessible to agents. For instance, if one wanted to create an argumentative model studying epistemic communities where, like in Hegselmann's work [11], the success of the agents if measured by a distance between their opinion and a truth value, it would be very important that the opinion of the agents could approach any value of the interval [0, 1]. Similar problems would arise if we wanted to study extremism, another phenomenon investigated in bounded-confidence type models [6]. Duality, on the other hand, imposes a form of symmetry between the actions of attacks and supports. If it is not verified, the dynamics may differ from one side of the opinion space to another, which could be problematic for certain protocols.

EBS verifies neither open-mindedness, nor duality. In the following section, we propose a novel semantic which verifies both of these properties.

1. Note that by choosing a base weight of 0, we would ensure an opinion interval of [0, 1] but that in this case, all the scores of the arguments would be equal to 0.

4 Novel Semantic

We define a modular gradual semantic by combining the *energy* aggregation function with a modified logistic influence function. Like EBS, our semantic is defined exclusively for acyclic graphs.

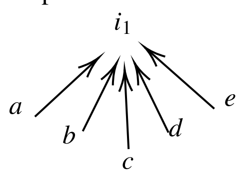
Definition 11 (*Logistic Sum Semantic* (LSS)) *Let $B = \langle A, R, S, W\rangle$ be an acyclic bipolar graph. LSS is the score function $\sigma : G \times A \to [0,1]$ recursively defined by : For all $a \in A$ of weight w_a,*

$$\sigma(B,a) = 1 - \frac{1}{1 + e^{E(B,a)+b(w_a)}}, \quad b(w_a) = ln(\frac{1}{1-w_a} - 1) \tag{2}$$

Property 1 *The LSS semantic verifies the twelve principles defined by [1] (see Table 1).*

Property 2 *The LSS semantic verifies open mindedness and duality.*

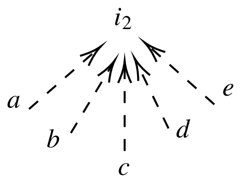
The following example compares the behavior of LSS and EBS on two simple argumentation graphs, and illustrates open-mindedness and duality.



Graph B_1

$\sigma_{EBS}(B_1,\ i_1) = 0.28$

$\sigma_{LSS}(B_1,\ i_1) = 0.08$



Graph B_2

$\sigma_{EBS}(B_2,\ i_2) = 0.89$

$\sigma_{LSS}(B_2,\ i_2) = 0.92$

Consider the above graphs B_1 and B_2, where we use full arrows to indicate attack relations and dotted arrows to indicate supports. The issue of B_1 is attacked by 5 arguments, and the issue of B_2 is supported by 5 arguments. We fix all of the weights of the arguments at 0.5, thus the aggregation of the attackers of i_1 is equal to the inverse of the aggregation of the supporters of i_2 (using the energy function).

The example illustrates the problem mentioned above, which is that EBS is limited to the interval $[0.25, 1]$. Indeed, the value of i_1 is 0.28 according to EBS, while LSS is able to assign a lower value of 0.08. We can also note that if we were to add attacks to i_1, EBS would not show much modification because the score of i_1 is already close to the limit of 0.25, while LSS would be more expressive, but on the other hand their evaluations of i_2 are much more similar.

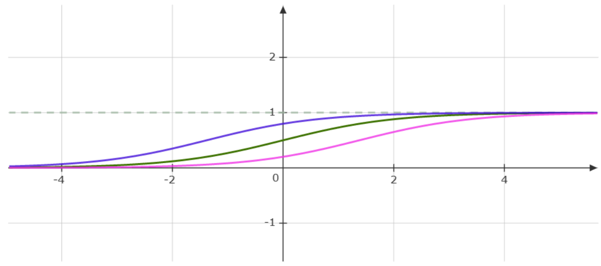


FIGURE 2 – Variation of the score of an argument according to LSS (y-axis) against its energy $E(B,a)$ (x-axis), for three basic weights $w_a = 0.2, 0.5$ and 0.8 respectively in pink, green and blue. We see that the value of the score is between 1 (grey line) and 0 and that when $E(B,a) = 0$, the score is equal to the base weight.

In this context, duality is verified if the sum of the evaluation of i_1 and i_2 is equal to 1, and we can see that it is verified by LSS and not by EBS.

Another illustration of these two properties in the case of LSS can be found on Figure 2, where we represent the score of an argument against its energy for three different weights. We see that in all three cases, open mindedness is verified as the score covers the whole interval. We can see that the purple and the pink curve, which corresponds to the acceptability score of an argument with a weight of 0.8 and 0.2 respectively, exhibit a central symmetry around the point $(0, 0.5)$. This symmetry corresponds to duality : if we take two arguments a and b with $w_a = 0.8$ and $w_b = 0.2$, and if their energies are inverse from each other, then the sum of their acceptability scores will be equal to the sum of their weights, which is 1.

4.1 Convergence of Opinions

Let us now place ourselves in the general framework defined in Section 2 : consider agents equipped with an opinion graph and let us use the LSS semantic. Suppose that two agents communicate by exchange of arguments, what can be said about their respective opinions ?

This question is important because it will allow us to compare directly any protocol built with our framework to the bounded confidence type models, where any communication between agents automatically results in a convergence of their opinions.

[9] show that in the case of attack graphs, with the h-categorizer semantic, the communication between agents does not automatically result in a convergence of their opinions. However, their simulations show an empiric convergence when many interactions take place.

In order to study this problem, we need to formally define what we mean by communication through exchange of arguments. For this, we make a number of simplification assumptions.

- The opinion graphs of the agents are acyclic.
- When agents are aware of the same arguments, they are also aware of the same attack and support relations between them.
- Agents all agree on the base weights of their shared arguments.

The initial assumption enables the use of our LSS semantic. The other two assumptions, which are aligned with [9], are rather restrictive and allow us to define communication as a strict exchange of arguments without requiring a merging mechanism for attacks, supports, and weights. It is worth noting that these constraints, within which a wide variety of protocols can still be constructed, could be relaxed within our framework given that we ensure the existence of a compatible semantic and establish a process for merging argumentation graphs.

In accordance with the idea that opinion graphs are agent's knowledge bases, we say that an agent *learns* an argument when she adds it to her opinion graph.

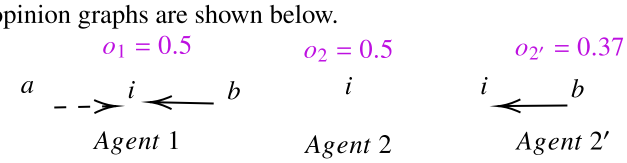
Definition 12 (Learning an argument) *Let an agent k equipped with opinion graph $B_k = \langle A, R, S, W\rangle$, and (a, R_a, S_a, w_a) a tuple composed of an argument a, relations R_a and S_a such that $R_a = \{(a, x)|x \in A_0 \subset A\} \cup \{(x, a)|x \in A_1 \subset A\}$ and $S_a = \{(a, x)|x \in A_2 \subset A\} \cup \{(x, a)|x \in A_3 \subset A\}$, and a base weight $w_a \in [0, 1]$. Agent k **learns** argument a by transforming her opinion graph to $B'_k = \langle A \cup \{a\}, R \cup R_a, S \cup S_a, W'\rangle$ with $\forall x \in A, W' : x \longrightarrow W(x)$ and $W'(a) = w_a$.*

We suppose that the attack and support relations R_a and S_a that link argument a to the arguments of the opinion graph of agent k are known. Depending on the specifics of the protocol, they could be obtained from another agent's opinion graph, or generated dynamically. Thus, we can define communication between agents as the learning of arguments from other's opinion graphs.

Under these constraints, we show the following property.

Property 3 *In our opinion model with LSS semantic, the opinion of two agents does not necessarily converge when they exchange arguments from their opinion graphs.*

It is easy to generate an example that illustrates (and proves) Property 3. Consider two agents 1 and 2 whose opinion graphs are shown below.



When applying the LSS semantic on their initial opinion graphs, their opinions are the same : $o_1 = o_2 = 0.5$. Consider what happens if Agent 2 adds one of the arguments of Agent 1 to her opinion graph : this is the situation denoted Agent $2'$ above. Her opinion $o_{2'} = 0.37$ is now further from that of agent 1, even though their opinion graphs are now more similar [2].

Property 3 is also verified when using the EBS semantic. Therefore, it seems that gradual semantics exhibit non-trivial properties that justify the interest of their study in the context of multi-agent models.

5 Conclusion

We proposed a general structure which represents the knowledge and the opinion of agents with weighted bipolar argumentation graphs and a gradual semantic. We have discussed various desirable properties for such a semantic, in particular the principles of open-mindedness and duality, and proposed a new gradual semantics that verifies them. We would like to continue to study this semantic, in particular its behavior on bipolar graphs which may include cycles. Finally, we have identified that the use of this semantic within the framework of our opinion model gives rise to non-trivial dynamics : the opinions of agents do not necessarily converge when they communicate. Knowing the similar result obtained by [9], we are convinced that this behavior is not limited to our semantic. A natural extension to this work would be to characterize a minimal set of properties that must be checked by a gradual semantic to guarantee this behavior. We also plan an empirical study of the impact of various semantic on the dynamics of agents' opinions.

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