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Evaluation of arguments in weighted bipolar graphs ☆,☆☆

Leila Amgoud *, Jonathan Ben-Naim

CNRS – IRIT, 118, route de Narbonne, 31062, Toulouse, France

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ABSTRACT

The paper tackled the issue of arguments evaluation in *weighted bipolar argumentation graphs* (i.e., graphs whose arguments have basic strengths, and may be both supported and attacked). We introduce principles that an evaluation method (or semantics) could satisfy. Such principles are very useful for understanding the foundations of semantics, judging them, and comparing semantics. We then analyze existing semantics on the basis of our principles, and finally propose a new semantics for the class of acyclic graphs. We show that it satisfies all the principles.

1. Introduction

Argumentation is a form of common-sense reasoning consisting of the justification of claims by arguments. An argument is made of a set of *premises* (called reason), a *conclusion* (the justified claim), and the two are related with a link. An argument has also generally a basic strength which may represent different issues like the certainty degree of its premises [2], the strength of its link [3], the importance of values supported by the argument [4], or the trustworthiness of the source providing the argument [5].

Despite its explanatory power, an argument does not guarantee the validity of its conclusion. Indeed, its premises may be wrong, its link may be flawed, and in some cases the premises may be irrelevant to the conclusion. These flaws of an argument may themselves be supported by arguments, which are seen as attackers of the original one. An argument may also be supported by other arguments, which endorse either its premises, its conclusion, or its link. This leads to *weighted bipolar argumentation graphs*, i.e., graphs whose nodes represent arguments with numerical basic strengths, and edges represent attack and support relationships between pairs of arguments.

An evaluation of the overall strength of each argument is crucial for deciding whether or not one may rely on the argument's conclusion. Phan Ming Dung was the first to investigate in [6] this evaluation issue. He focused on a simple input: a set of arguments, having all the same basic strength, and an attack relation between pairs of arguments. Leaving the origin and the nature of arguments/attacks unspecified, Dung proposed several semantics specifying which sets of arguments (called extensions) are acceptable. Such graphs may have zero, one, or several extensions. A *single qualitative status* is then assigned to each argument as follows: an argument is *accepted* if it belongs to all extensions, and *rejected* otherwise. This status represents the *overall strength* of the argument.

☆ This paper extends the content of the conference paper [1].

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* Corresponding author.
E-mail addresses: amgoud@irit.fr (L. Amgoud), bennaim@irit.fr (J. Ben-Naim).

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This seminal paper has led to substantial work either on proposing new alternative semantics dealing with the same input (e.g., [7,8]), or on extending Dung's semantics for dealing with richer input, i.e., previous flat graphs with one of the following features: preferences between arguments (or basic strengths of arguments) [3,4,9], weights on attacks [10–12], or support relation between arguments [13–18]. To the best of our knowledge there is no extension semantics dealing with weighted bipolar argumentation graphs.

More recently, another family of semantics, called weighted semantics, is gaining interest (e.g., [1,5,19–21]). These semantics focus on the evaluation of individual arguments rather than sets of arguments. Furthermore, unlike extension-based semantics which assign a qualitative overall strength (accepted, rejected) to each argument, they assign a numerical value to each argument. Finally, instead of a coarse classification of arguments as accepted/rejected, weighted semantics allow fine-grained classifications. Most existing semantics deal only with *unipolar* graphs (i.e., graphs that consider either attack relation or support one but not both). Two notable exceptions are QuAD semantics [22] and DF-QuAD [23]. In [24] the authors discussed advantages of weighted semantics in case of bipolar argumentation graphs, but they did not propose concrete semantics.

While there is a consensus in the argumentation community on the role of attackers and how they should be taken into account in the evaluation of individual arguments, the situation is less clear for supporters. Indeed, different interpretations are given to support relation (deductive [17], evidence [15], necessary [18]), leading to semantics which may return completely different evaluations of arguments of the same graph. This complicates the comparison of existing semantics for weighted bipolar graphs. Another source of difficulty is the absence of formal principles that guide the well-definition and formal comparisons of semantics.

This paper focuses on the evaluation of arguments in weighted bipolar argumentation graphs. It extends our previous works on axiomatic foundations of semantics for unipolar graphs (support graphs [25] and attack graphs [26]). It defines principles that a semantics would satisfy in a bipolar setting. Such principles are very useful for judging and understanding the underpinnings of semantics, and also for comparing semantics of the same family, and those of different families. Some of the proposed principles are simple combinations of those proposed in [25,26]. Others are new and show how support and attack might be aggregated. The second contribution of the paper consists of analyzing existing semantics against the principles. The main conclusion is that extension semantics do not harness the potential of support relation. Indeed, when the attack relation is empty, the existing semantics declare all (supported, non-supported) arguments of a graph as equally accepted. Weighted semantics take into account supporters in this particular case, however they violate some key principles. The third contribution of the paper is the definition of a novel weighted semantics for the sub-class of acyclic bipolar graphs. We show that it satisfies all the proposed principles. Furthermore, it avoids the *big jump* problem that may impede the relevance of existing weighted semantics for practical applications, like dialogue.

The paper is structured as follows: Section 2 introduces basic notions, Section 3 presents our list of principles, Section 4 analyses existing semantics, and Section 5 introduces our new semantics and discusses its properties.

2. Main concepts

This section introduces the main concepts of the paper. Let us begin with the useful notion of weightings.

Definition 1 *(Weighting).* A *weighting* on a set X is a function from X to $[0, 1]$.

Next, we introduce the argumentation graphs (called frameworks in the literature) we are interested in, namely weighted bipolar argumentation graphs (wBAGs).

Definition 2 *(wBAG).* A *weighted bipolar argumentation graph* (wBAG) is a quadruple $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$, where $\mathcal{A}$ is a finite set of arguments, w a weighting on $\mathcal{A}$, $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$, and $\mathcal{S} \subseteq \mathcal{A} \times \mathcal{A}$. Let $\texttt{wBAG}$ denote the set of all possible wBAGs.

Given two arguments a and b, $a\mathcal{R}b$ (resp. $a\mathcal{S}b$) means a *attacks* (resp. *supports*) b, and $w(a)$ is the *basic strength* of a. The latter may represent various issues like the certainty degree of the argument's premises, trustworthiness of the argument's source, ...

We turn to the core concept of the paper. A semantics is a function transforming any weighted bipolar argumentation graph into a weighting on the set of arguments. The weight of an argument given by a semantics represents its *overall strength*. It is obtained from the aggregation of its basic strength and the overall strengths of its attackers and supporters. Arguments that get value 1 are *extremely strong* whilst those that get value 0 are *worthless*.

Definition 3 *(Semantics).* A *semantics* is a function $\mathbf{S}$ transforming any $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle \in \texttt{wBAG}$ into a weighting $\texttt{Deg}^{\mathbf{S}}_{\mathbf{A}}$ on $\mathcal{A}$. Let $a \in \mathcal{A}$, $\texttt{Deg}^{\mathbf{S}}_{\mathbf{A}}(a)$ denote the *overall strength* of a.

Let us recall the notion of *isomorphism* between graphs.

Definition 4 *(Isomorphism).* Let $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$, $\mathbf{A}' = \langle \mathcal{A}', w', \mathcal{R}', \mathcal{S}' \rangle \in \texttt{wBAG}$. An *isomorphism* from $\mathbf{A}$ to $\mathbf{A}'$ is a bijective function f from $\mathcal{A}$ to $\mathcal{A}'$ such that the following hold: