An Authority Degree-Based Evaluation Strategy for Abstract Argumentation Frameworks

Andrea Pazienza[1], Floriana Esposito[1,2], and Stefano Ferilli[1,2]

[1] Dipartimento di Informatica – Università di Bari
{*name.surname*}@uniba.it
[2] Centro Interdipartimentale per la Logica e sue Applicazioni – Università di Bari

Abstract. Abstract argumentation allows to determine in an easy, formal way which claims survive in a conflicting dispute. It works by considering claims as abstract entities, and expressing attack relationships among them. However, this level of expressiveness prevents abstract argumentation systems from being directly applied to reasoning processes where the context is relevant. An outstanding example is when a claim is supported by appealing to authority, so that the audience assigns reliability to the claim's justification based on the authority's renowned experience in the domain. To handle this, we propose to enrich the classical representation used in abstract argumentation by associating arguments with weights that express their degree of authority. The weights' values define their strength in the given domain, which in turn should affect the evaluation of their degree of justification. This paper defines a strategy to combine these weights in order to determine which arguments withstand in a dispute concerning a given domain. Such a strategy was implemented in the ARCA system, that allows to comfortably set up argumentation problems and solve them using both traditional extension-based semantics and the proposed evaluation approach. ARCA is used to illustrate the proposed strategy by means of sample use cases.

1 Introduction

Argumentation is a major component of our everyday lives, in that we are continuously faced with conflicting information and associated inconsistencies. Roughly, an argument is a bunch of information (i.e., a set of *assumptions*) from which conclusions can be drawn, based on a number of reasoning steps. The assumptions used are called the *premises* of the argument, while its *conclusion* (chosen from many possible ones) is called the *claim* of the argument. The support of an argument provides the reason (or, equivalently, a *justification*) for the claim of the argument. This structure simplifies understanding of the opinions of other people and helps in the identification of fallacies in their reasoning. People usually argue in turns, by providing arguments and counterarguments to initial arguments. The winner of the argumentation is the arguer with the last unchallenged argument.

Many strategies can be found in the literature for the identification of the successful arguments in an argumentation dispute context. Some such strategies are based on the so-called Abstract Argumentation Framework, that will be presented in the next sections. This model of argumentation takes a set of abstract arguments, i.e., arguments whose internal structure or specific interpretation is ignored. The abstract nature of the arguments, and the relationship with non-monotonic reasoning formalisms, yield a very simple and quite general model that allows to easily understand which sets of arguments are mutually compatible. Unfortunately, abstract system representations are not always suitable to depict real situations. This is because abstract systems lack of elements which can empower the representation setting so that conflicts can be automatically identified or the strength of a conflict can be determined. For example, the abstract argumentation framework does not allow to consider the weight of each argument based on the authority of the person who claims it, which may be relevant to the proper evaluation process of judging an argument.

Sometimes it may be appropriate to cite an authority to support a position. This argumentative schema is known as argument from authority, or "*argumentum ad verecundiam*" [17]. Of course, this type of argument can result in a fallacy, especially if the authority is not really such. For instance, an appeal to authority can be inappropriate if the person is not qualified to have an expert opinion on the argument. However, in general an ad verecundiam inductive argument (i.e., an argument whose conclusion is claimed to follow not with certainty but with probability) is not necessarily a fallacy, especially when the relevance of the referred authority is supported by a renowned and proved experience in the argued domain.

This work proposes a novel approach to handle these situations, that extends the abstract argumentation setting by allowing the association of arguments to weights expressing their reliability. Such weights are assigned on the basis of an *authority degree* which takes into account the reliability of the authority who states the argument in the argued domain. The objective is to overcome the low level of expressiveness that characterizes the standard abstract argumentation framework, and to make it able to handle different degrees of reliability on the arguments.

This paper is organized as follows. The next section recalls useful background information, including related works. Then, Section 3 introduces the abstract argumentation framework along with the standard evaluation strategies used in the process of justifying an argument leading to a conclusion. Section 4 describes the proposed approach and how it is embedded in the standard abstract evaluation system, and Section 5 concludes the paper and outlines future work issues.

2 Background and Related Work

As a general, informal definition, argumentation involves the identification of applicable assumptions and conclusions for a given problem under consideration. In this activity, it often faces conflicting information, which results in the need to evaluate the justification for the available conclusions. This, in turn, may involve comparing arguments, evaluating them in some aspects, and judging a set of arguments and counterarguments to consider whether any part of them can be considered as warranted according to some standard principle. In this context, it can be also safely assumed that each argument has a proponent, who is the person putting forward the argument, and that each argument has an audience, who is the group of people reached by the argument.

Probably the foundational and most important philosophical work for the development of argumentation was made by Toulmin [15]. In particular, he put forward the widely accepted definition for the structure of an abstract argument: an *argument* has a conclusion that is inferred from available data, a *warrant* that allows one to jump to conclusions, and a possible *rebuttal*, which is another argument that disagrees with the original argument. This approach is structural and, in a sense, logical. However, it does not just provide a comprehensive account of the logic of argumentation, and furthermore, it does not address many important questions about how to automate the construction or use of layouts of arguments.

In order to handle arguments systematically, a "formalization" of argumentation is needed. Many professions implicitly or explicitly explore these issues and, in facts, put the systematic use of arguments at the heart of their work. Outstanding examples can be found in the legal, medical, and journalistic professions. The study of formal argumentation started among critical thinking and practical reasoning philosophers [14, 16]. *Critical thinking* is concerned with argument identification and its evaluation by spotting the weak or missing points in arguments. *Practical reasoning* in argumentation is a type of decision making, in which the arguments are used to determine what is the best course of action in practical situations, where the knowledge of the world is incomplete.

However, the need to go beyond the systematic handling of arguments motivates the search for techniques that are able to scale up and deal with substantial and complex problems. Classical logic is appealing as a starting point for argumentation: it provides a rich representation formalism and powerful reasoning mechanism. Unfortunately, inconsistency causes problems in reasoning with classical logic [12]. And, as previously pointed out, argumentation inherently involves conflicting (i.e., inconsistent) information. If the knowledge that is available for constructing arguments is consistent, then no conflicting arguments can be obtained, and thus no recourse to argumentation is needed.

As a partial response to the issue of inconsistency arising in argumentation, three main approaches to formalization for argumentation have been proposed in the literature, namely: abstract systems [8], defeasible systems [13], and coherence systems [9]. The first two approaches use formalisms that are much less expressive (as regards both the complexity of information that can be represented and the complexity of the inferences that can be drawn) than classical logic, thereby circumventing the problem of inconsistency as manifested by the "*ex falso sequitur quodlibet*" rule. The third approach adopts a simple strategy to improve the problem of inconsistency.

In particular, abstract systems build on the seminal proposal by Dung [8]. It is based on the assumption that the structure of a set of arguments and counterarguments can be expressed by defining a set of arguments and a binary 'attack' relationship between pairs of arguments. The attack relationship captures the situation of one argument undermining the credibility of another. This setting can be represented as a graph, with each node representing an argument and each edge representing an 'attack'. Under this representation, the set of nodes in the graph is the starting point. Given such a graph, the objective is determining which subset(s) (called *extension(s)*) of its nodes (i.e., arguments) can be accepted. Providing different strategies to answer this question corresponds to defining different argumentation semantics. In other words, the idea of a semantics is, given an argumentation framework, to specify zero or more sets of acceptable arguments. Dung also provided a number of semantics, which specify different evaluation strategies ranging from the credulous to the skeptical (see next section for more details). Also Caminada proposed new extension based semantics approaches, which produce reasonable results in situations where Dung's extensions have drawbacks or don't exist [5, 4].

The argumentation literature emphasized the importance of considering additional criteria, namely *preferences*, when evaluating arguments in a framework. Preferences are expressed between arguments and reflect their relative strengths. In [1] a Preference-based Argumentation Framework (PAF) is built to handle correctly critical attacks in the framework and to refine the evaluation of arguments.

A first introduction to weighted attack relations in an argumentation framework can be found in [11], where a natural extension of Dung's model of argument systems is investigated in order to propose attacks associated with a weight indicating the relative strength of the attack. Such a model takes the name of Weighted Argumentation Framework (WAF). This model was further explored in [10] to check how much inconsistency should be tolerated in a WAF. This approach permits a much more fine-grained level of analysis of argument systems than the unweighted case, and can provide useful solutions when conventional argument systems cannot provide any. Furthermore, in [7] weights are used for relaxing extensions in order to improve the inferential power of the argumentation framework, while in [3] the authors suggest semirings as a mean to parametrically represent WAFs.

Another early extension of Dung's proposal with weights is Value-based Argumentation Frameworks (VAFs) [2]. In the VAF approach, the strength of an argument depends on the social values that it advances, and the decision about whether the attack of one argument on another succeeds depends on the comparative strength of the values advanced by the involved arguments.

A more general approach to extending Dung's proposal is that of Bipolar Argumentation Frameworks (BAFs), which take into account two kinds of interaction between arguments: a positive interaction (by which an argument can help or support another argument) and a negative interaction (by which an argument can attack another argument) [6].

3 Abstract Argument Systems

An *abstract argument system* or *Argumentation Framework* (AF for short), as introduced by Dung, is a pair $\langle A, R\rangle$ consisting of a set A, whose elements are called *arguments*, and a binary relation $R \subseteq A \times A$ on A, called *attack relation*. Given two arguments $\alpha, \beta \in A$, the relation $\alpha R \beta$ represents an attack from α against β. In general, arguments α and β are in conflict if argument α refutes argument β or if α is attacking premises supporting β. More precisely, we talk about:

- *Rebutting*, when there is an explicit contradiction between conclusions ; or
- *Undercutting*, when argument α attacks the applicability of a rule that supports β, without necessarily denying it.

An AF has a typical representation as a directed graph where nodes are arguments and edges are drawn from attacking to attacked arguments. Representing the structure and meaning of arguments at so high a level of abstraction allows to better focus on properties that are independent from any specific context, and makes it applicable to a wide variety of domains. On the other hand, this formalism lacks of expressiveness, which prevents its direct application in any specific domain. Indeed, in order to set up an AF one first needs to build an underlying knowledge base, along with mechanisms to generate the set of arguments from it and determine in which ways these arguments attack each other. Then, once the AF has been set up, a second issue is how to determine a *justification state* for the involved arguments and, in particular, how to identify which are the justified ones. Informally, an argument is considered to be justified if it survives to attack relations. Therefore, the next step is to understand which argument is not defeated from the confrontation with the others. This process, called *argument evaluation*, aims at determining the justification state of the arguments in an abstract argumentation system.

An *argumentation semantics* is the formal way of determining which arguments or statements can be considered as justified in the argument evaluation process. Two main approaches to the definition of argumentation semantics are available in the literature: the *labelling-based* one and the *extension-based* one. In the former, the idea is to define a mapping that associates each argument to one of a set of labels corresponding to the possible states of argumentsin the given context. A sensible choice for the set of labels is:

- *in* for the accepted arguments
- *out* for the rejected arguments
- *undec* for undefined (not accepted or refused) arguments.

The labeling operation can be seen as the result of the reasoning carried out by an agent which analyzes the arguments and marks them as justified, rejected or temporarily undecided. One of the benefits derived from the use of labelling-based semantics is the possibility of defining a more refined defeat-status by introducing different levels of justification and rejection (e.g., 'very acceptable', 'quite acceptable', 'not acceptable').

In the extension-based approach the idea is to derive, from an AF, an 'extension' E, that is a subset of A representing a set of argument which are considered as acceptable. These semantics can assign each node to a single status (*unique-status*) or multiple statuses (*multiple-status*). The difference is in the management of the temporarily undecided state. A multiple-status semantics can resolve a mutual attack issue by generating two hypothetical solutions in which the conflicting arguments can be alternately assumed as acceptable.

By considering the expressiveness of the two approaches to semantics, it can be observed that any extension-based semantics can be equivalently translated in a labelling-based one by adopting a set of two labels *in* and *out* that correspond to extension membership. Vice versa, in general an arbitrary assignment of labels cannot be translated in terms of extensions. This is because labellings always include a label that corresponds to the extension membership, while other labels are derivable from extension membership and the attack relation. Consequently, equivalent extension-based definitions of labelling-based semantics are in general applicable. This is the reason why extension-based semantics are more widely exploited in the literature.

A basic requirement for any extension E is derived from its interpretation as a set of arguments which can survive together. In other words, if an argument α attacks another argument β, one reasonably does not expect to have them together in the same extension. This corresponds to the concept of *conflict-free* that is at the basis of all extension-based semantics.

Definition 3.1 (conflict-free) *Given an Argumentation Framework* $AF = \langle A, R \rangle$*, a set* $S \subseteq A$ *is* conflict-free *iff* $\nexists \alpha, \beta \in S$ *s.t.* $\alpha R \beta$ *(*α *attacks* β*).*

A second requirement corresponds to the need of a set of arguments to resist the attacks it receives from other arguments by counterattacking them. This feature is based on the notions of acceptable argument and admissible set.

Definition 3.2 (acceptability) *Given an Argumentation Framework* $AF = \langle A, R \rangle$*, an argument* $\alpha \in A$ *is* acceptable *wrt a set* $S \subseteq A$ *iff* $\forall \beta \in A : \beta R \alpha \Rightarrow \exists \gamma \in S$ *s.t.* $\gamma R \beta$ *(*α *is defended by* S*).*

Definition 3.3 (admissibility) *Given an Argumentation Framework* $AF = \langle A, R \rangle$*, a set* $S \subseteq A$ *is* admissible *iff* S *is conflict-free and* $\forall \alpha \in S$ α *is acceptable wrt* S*.*

Now suppose that the attackers of an argument α are all attacked by an extension E. Then the attack suffered by α is canceled because E is 'defending' α, and α is reinstated because it should belong to E. This property takes the name of *reinstatement* and leads to the following principle:

Definition 3.4 (reinstatement principle) *Given an Argumentation Framework* $AF = \langle A, R \rangle$*, a semantics satisfies the* reinstatement principle *iff for all extensions* $E \subseteq A$ *it holds that*

$$\text{if } \alpha \text{ is acceptable w.r.t } E \text{ then } \alpha \in E.$$

3.1 Extension-Based Semantics

Since semantics provide the basis for evaluating the justification state of arguments, one may first require that the evaluation basis of an AF is not empty. Some (labelling- or extension-based) semantics may allow many alternative justification states for the arguments. Two main alternatives may be considered for the notion of justification state:

- *skeptical justification* requires that an argument is accepted in all semantics;
- *credulous justification* requires that an argument is accepted in at least one semantics.

Of course in a unique-status approach credulous and skeptical justifications coincide, but in multiple-status approaches typically the credulous justification includes the skeptical justification.

Let us now consider some approaches to determine argumentation semantics proposed in the literature.

Complete semantics The notion of complete extension is based on the principles of admissibility and reinstatement. It is a set which is able to defend itself and includes all arguments it defends.

Definition 3.5 (complete extension) *Given an Argumentation Framework* $AF = \langle A, R \rangle$*, a set* $S \subseteq A$ *is* complete extension *iff* S *is admissible and* $\nexists$ $\alpha \in A$ *such that:*

- α *is acceptable wrt* S
- $\alpha \notin S$

The following semantics build their own extensions referring to the complete extensions.

Ground semantics For each AF there exists only one *ground extension* which corresponds to the set of arguments that satisfies the conditions of admissibility and that is minimal with respect to the inclusion relation between the admissible sets of AF. Compared to complete extensions, the ground is the complete minimal one with respect to set inclusion.

Definition 3.6 (ground extension) *Given an Argumentation Framework AF* $= \langle A, R \rangle$*, a set* $S \subseteq A$ *is a* ground extension *iff* S *is admissible and* S *is a* $\subseteq$*-minimal subset of* A*.*

Preferred semantics A *preferred extension* S of an AF is the admissible set of AF which is maximal with respect to set inclusion. For each admissible set E of AF there exists at least one preferred extension S such that $E \subseteq S$ (it can be also the empty set). Compared to complete extensions, the preferred extension is the complete maximal one with respect to set inclusion.

Definition 3.7 (preferred extension) *Given an Argumentation Framework $AF = \langle A, R \rangle$, a set $S \subseteq A$ is a* preferred extension *iff S is admissible and S is a $\subseteq$-maximal subset of A.*

Stable semantics A *stable extension* of an AF is a complete extension which attacks all arguments that are not its members. Any stable extension is also a maximal conflict-free set of AF.

Definition 3.8 (stable extension) *Given an Argumentation Framework AF $= \langle A, R \rangle$, a set $S \subseteq A$ is a* stable extension *iff*

- *S is a complete extension*
- *$S \cup S_{defeated} = A$*

where $S_{defeated} = \{\beta \in A \mid \alpha \in E \wedge \alpha R \beta\}$

Semi-stable semantics A *semi-stable extension* [5] S of an AF is a complete extension which relies on the idea of maximizing not only the arguments belonging the extension but also those attacked by it. Any semi-stable extension S is also a set with maximal range with respect to the inclusion set.

Definition 3.9 (semi-stable extension) *Given an Argumentation Framework $AF = \langle A, R \rangle$, a set $S \subseteq A$ is a* stable extension *iff*

- *S is a complete extension*
- *$S \cup S_{defeated}$ is maximal wrt A*

where $S_{defeated} = \{\beta \in A \mid \alpha \in E \wedge \alpha R \beta\}$

Ideal semantics An extension of an AF is called *ideal* if it corresponds to the largest admissible set that is a subset of each preferred extension.

Definition 3.10 (ideal extension) *Given an Argumentation Framework AF $= \langle A, R \rangle$, a set $S \subseteq A$ is an* ideal extension *iff S is the admissible $\subseteq$-maximal subset of A such that $\forall S_{preferred} : S \subseteq S_{preferred}$.*

Eager semantics An *eager* extension of an AF corresponds to the largest admissible set that is a subset of each semi-stable extension. It relies on a concept that is similar to the ideal semantics, with the restriction that the admissible set must be in the intersection of semi-stable extensions.

Definition 3.11 (eager extension) *Given an Argumentation Framework AF $= \langle A, R \rangle$, a set $S \subseteq A$ is an* eager extension *iff S is the admissible $\subseteq$-maximal subset of A such that $\forall S_{semi-stable} : S \subseteq S_{semi-stable}$.*

An ordering relationship exists among the semantics described above [5]. The ground, preferred, ideal, eager, semi-stable and stable extensions can be all obtained starting from complete extensions. In particular, each stable extension is also semi-stable and each semi-stable extension is also a preferred one. Finally, by definition, a preferred extension is a complete extension too.

4 Authority Degree

The semantics shown above neglect information that, in some cases, may turn out to be of crucial importance to the argumentation. For instance, the Abstract Argumentation Framework does not distinguish between rebuttal and undercutting attacks, in order to provide more efficient computation of extensions. Also, in some cases, it would be advisable to evaluate the set of reliable arguments by taking into account the context in which the sentences are claimed, and specifically the trustworthiness of those who claim them. Adding quantitative information becomes of crucial importance when arguments have different levels of strength. Hence, adding a weight to arguments allows to give them the right strength, so as to represent real dialogues.

A first refinement to deal with this scenario could be to distinguish utterances made by domain experts from those made by novices or by outsiders of the domain of the argumentation. By domain we mean a context in which a person is skilled. The more confident a person within a domain, the higher his authority in that domain. For example, in a wine and food context, the opinion or contradiction of a mathematician has a minor significance compared to that of a winemaker of unquestionable professionalism. Conversely, in a mathematical context the winemaker level of reliability should be less than that of the mathematician. This degree of reliability might be captured in an Argumentation Framework by introducing an *authority degree* associated to nodes, such that two nodes reporting utterances made by experts in different domains will have different weights into attacking the same node. Thus, arguments are partitioned in domains which reflect the area of expertise of each arguer.

A second refinement might be to consider the number of attackers and defenders for a node in the graph. In abstract argumentation terms, the larger the number of attackers of a node, the more likely it is that it should be defeated, and, conversely, the larger number of defenders (i.e., of reinstatements) it has, the more likely it is that it may be admissible.

In general, our proposal is to associate a '*social*' weight to attack relations, preferring large admissible sets which attack external nodes and at the same time defend their members, rather smaller sets of isolated admissible nodes. In this setting, the domain-based authority degree works as '*normalizer*': it rebalances weights with the aim of avoiding over-defended conclusions. Another novelty of our approach is that the authority degree may differ depending on the intended domain. This is different than in PAFs [1], where preferences are taken into account at the semantics level. That is, instead of modifying the inputs of Dung's framework, PAFs extend semantics with preferences.

4.1 Authority Function

The setting we propose is defined through a number of functions to be used in the evaluation strategy of justification. In the following, $\langle A, R \rangle$ will indicate an argumentation framework and ϵ_α the authority degree for an argument $\alpha \in A$

in its domain Δ_α. A *domain function* allows us to focus on the most represented domains in the framework rather than on niche domains:

Definition 4.1 (domain function) $\delta\colon A \rightarrow \mathbb{R}$ *s.t.* $\forall \alpha \in A$ *:*

$$\delta(\alpha) = \frac{N_\alpha}{|A|}$$

with N_α *number of arguments having domain* Δ_α*.*

The domain function δ acts as a moderator to balance the weights of the attacking nodes within the argued context. In fact, this ensures that the arguments in support of the discussed domain have more relevance.

In the following, we propose three functions which allow to consider the strength of a group of persons involved in the same domain.

An *attacking function* returns the number of attacks launched by an argument towards other nodes.

Definition 4.2 (attacking function) $f_a\colon A \rightarrow \mathbb{N}$ *s.t.* $\forall \alpha \in A$:

$$f_a(\alpha) = |U(\alpha)|, \text{where } U(\alpha) = \{\beta \in A \mid \alpha R \beta \wedge \epsilon_\alpha \cdot \delta(\alpha) \geq \epsilon_\beta\}$$

A *defeating function* returns the number of attacks an argument suffers from other nodes.

Definition 4.3 (defeating function) $f_d : A \rightarrow \mathbb{N}$ *s.t.* $\forall \alpha \in A$:

$$f_d(\alpha) = |E(\alpha)|, \text{where } E(\alpha) = \{\beta \in A \mid \beta R \alpha \wedge \epsilon_\alpha < \epsilon_\beta \cdot \delta(\beta)\}$$

A *defending function* returns the number of attacks suffered by an argument that are not defended by other sufficiently reliable arguments.

Definition 4.4 (defending function) $f_r\colon A \rightarrow \mathbb{N}$ *s.t.* $\forall \alpha \in A$:

$$f_r(\alpha) = |D(\alpha)|, \text{where } D(\alpha) = \{\beta \in A \mid \beta R \alpha \ \wedge\ \exists \gamma \in A \ s.t.\ \gamma R \beta \wedge \epsilon_\gamma \cdot \delta(\gamma) \geq \epsilon_\beta\}$$

In the last three functions described above, the domain function δ serves to support the attacking node in order to contextualize the weight of the attack compared to the weight of the attacked node.

Now, let call us each argument $\alpha \in A$ as *authority-node* wrt an argument $\beta \in A$, that argument which launches attacks towards other nodes $\beta \in A$ such that $\epsilon_\alpha * \delta(\alpha) \geq \epsilon_\beta$. An *authority function* measures the degree of an argument $\alpha \in A$ based on the number of attacks launched as authority-node wrt $\beta \in A$ and the number of attacks suffered by other arguments being authority-nodes against it.

Definition 4.5 (authority function) *Let* $f_{authority}\colon \mathbb{N} \rightarrow \mathbb{N}$ *be a function s.t.*

$$f_{authority}(\alpha) = f_a(\alpha) - f_d(\alpha) + f_r(\alpha)$$

The more attacks launched by $\alpha \in A$ as an authority-node wrt $\beta \in A$, the higher its $f_{authority}$; the more attacks it suffers by arguments which are authority-nodes against it, the lower its $f_{authority}$. Intuitively, if the attacks suffered by a node α are defended by other authority-nodes, then its authority degree will depend only on its successful attacks (i.e. attacks towards less reliable nodes). Indeed, the suffered attacks, which decrease the value of its authority, are balanced by the number of attacks from which it is defended by authority-nodes. Hence, the authority function is used to select the 'stronger' admissible set: namely the most reliable set will be the one with the lower number of nodes such that their authority function value is maximum. In this setting, none of the classical Dung's extensions are considered, but only the collection of admissible sets, ordered according to the value of their $f_{authority}$. Then, the smallest admissible set with highest value of the authority function is chosen as more reliable justified set. Applying a more skeptical semantics may limit the aim of this paper because we would lose the sense of the domain's weight associated to nodes. In general, an attack is considered valid if the attacker's authority (decreased by a domain-dependent factor) is higher than the attacked authority.

Fig. 1 shows an example of a graph depicting an AF. Node labels indicate the level of authority. Nodes in gray belong to domain Δ' and those in white to domain Δ''. Due to space constraints, we will determine in the following the authority degree for node α only, using the above functions.

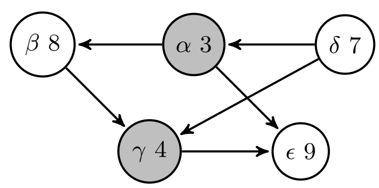

Fig. 1. AF graph example with authority degrees

Let consider the node α, it's domain value for domain Δ' is $\delta(\alpha) = \frac{2}{5} = 0.4$;
$f_a(\alpha) = 0$ because $3 \cdot 0.4 = 1.2$ s.t. $1.2 \ngeq 8$ and $1.2 \ngeq 9$;
$f_d(\alpha) = 1$ because $3 < 8 \cdot 0.6 = 4.8$;
$f_r(\alpha) = 0$ because node δ suffers no attack;
$f_{authority}(\alpha) = 0$ - $1 + 0 =$ -1.

The authority functions for the remaining nodes are calculated in the same way. Then, the smallest admissible set, having the maximum sum of authority functions values for its members, is chosen as the most reliable justified subset of arguments.

4.2 ARCA

The proposed strategy was implemented in the ARCA system (acronym for *Abstract Resolution of Conflicts in Argumentation*). ARCA includes a logic

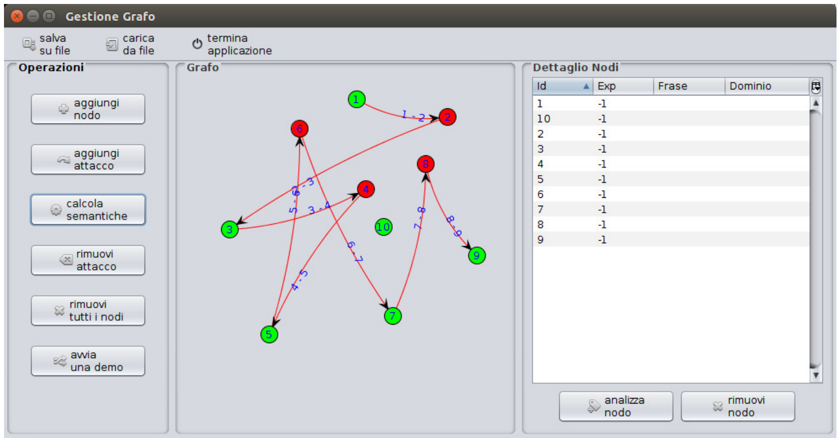

Fig. 2. ARCA

program core which can compute both the classical extension based semantics and the proposed authority degree-based evaluation of arguments. On top of it, ARCA provides a graphic tool (see Fig. 2) to enter and display arguments and attacks in an AF, and to associate to each claim a domain of origin and a degree of experience in that domain. It also allows to associate and display utterances associated to arguments and to show nodes with different colors denoting their acceptability according to the different semantics. This allows one to easily see conflicts and observe the differences between different semantic extensions.

4.3 Sample Scenario

Let us now show the various features of ARCA using a sample scenario in which some professionals olive growers are arguing about the most useful criterion of olive trees pruning. In mature trees, pruning is mainly required to renew the fruiting surface of the tree and achieve high yields, maintain vegetative growth of sprouts, maintain the skeleton structure, contain tree size, favor light penetration and air circulation inside the canopy, permit control of pests and diseases, prevent aging of the canopy, and eliminate dead wood.

Three novice croppers, Albert, John and Jack, are expressing their point of view, according their own (limited) experience:

1. Albert: "*When in doubt, less pruning is better.*"
2. John: "*Not all trees in a grove need to be pruned every year.*"
3. Jack: "*Pruning should be rapid and simple.*"

Samuel, a renowned expert olive grower, counterargues all three statements according to his large experience: "*The type of pruning must be adjusted in relation to plant age, training system, crop load, product use, environmental conditions, soil fertility, and farm structure.*" Thus, Samuel's opinion has more

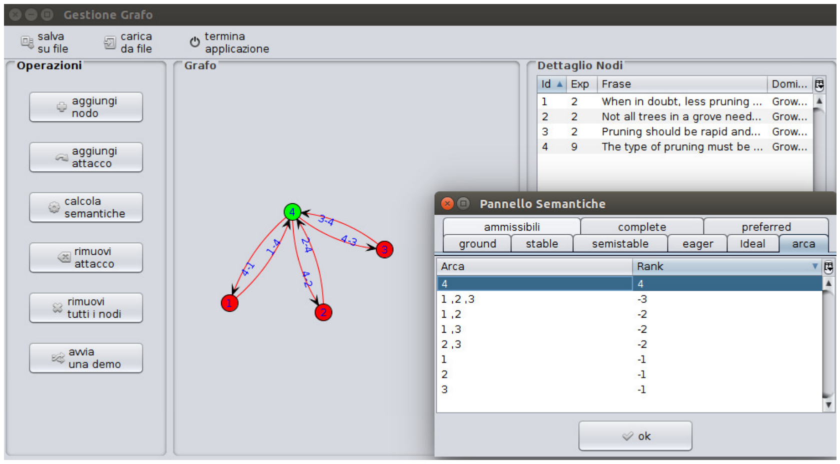

Fig. 3. Growers Argumentation

relevance than those of the three novice growers. Hence, his authority degree is such that the attacks he is suffering have no effect in the argumentation. In fact, Fig. 3 shows that, among all admissible subsets, the one with higher rank is precisely the set containing Samuel's (winning) argument.

Now, suppose Julian, an agronomist, takes part in the discussion. As a person with special knowledge in soil management and field-crop production, he explains in which direction new techniques in this domain are going and, therefore, which strategy is better to accomplish all aims: "*Current tendency is to prune olive trees as little as possible, so as to reduce costs substantially and simplify pruning management.*" This sentence attacks Samuel's claim and generates circular conflicts between Julian's claim and the novice growers' statements. Since Julian has less practical experience in pruning olive trees, his claim has less weight in the argumentation. In this situation, the evaluation of extension-based semantics and the ARCA solution are quite different. In skeptical extension-based semantics such as Semi-Stable and Stable extensions (Fig. 4 (a)), the admissible undefeated set of arguments includes both the claims of novice growers, and the agronomist's one. In the ARCA solution (see Fig. 4 (b)), the weight of the agronomist in the argumentation is such that his argument is undefeated, despite his weight is lower than Samuel's one in the argued domain.

Suppose now that Samuel counterattacks also Julian's claim with another argument: "*Pruning should be more severe on old trees and trees of low vigor than on young plants, or on trees growing in irrigated conditions and in fertile soils.* The authority weight of Samuel's last argument determines the winning arguments in the ARCA solution. Indeed, in Fig. 5 the two arguments expressed by Samuel are a subset of admissible elements which has a higher rank in the ARCA solution.

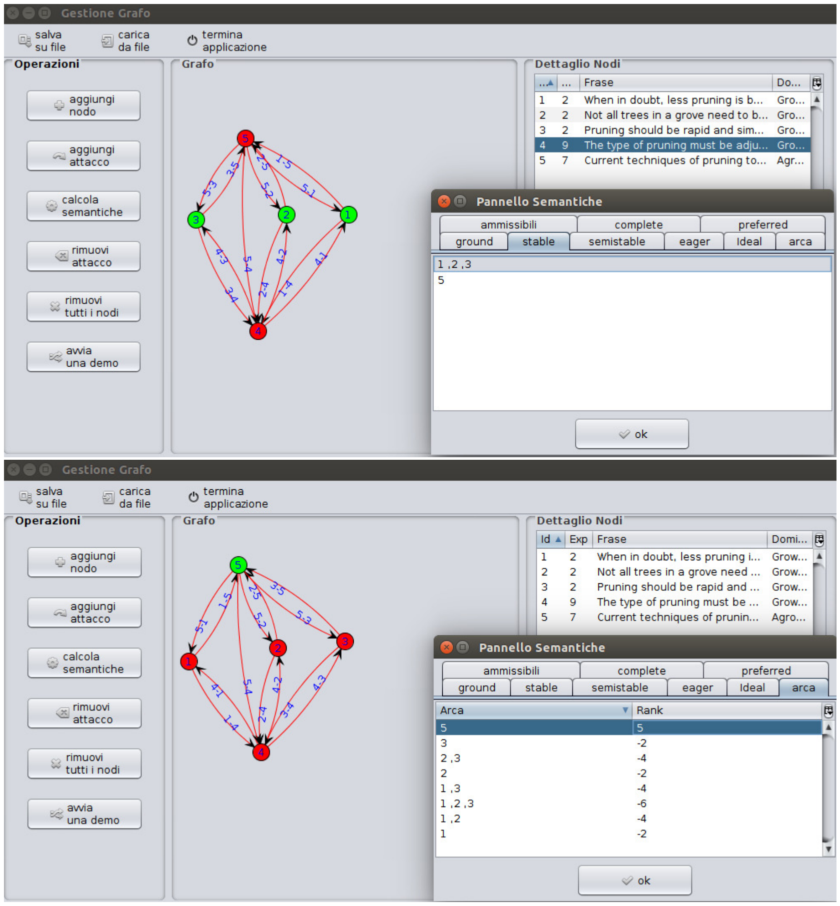

Fig. 4. Stable Extension solution (a) versus ARCA solution (b)

This sample scenario clearly shows how the weighted evaluation strategy of justified arguments may lead to more reliable and sensible results when the context domain is relevant.

5 Conclusions and Future Work

Abstract Argumentation is a formal approach to define which claims withstand in a dispute, in which the only expressed property is a binary 'attack' relation representing the rebuttal of an argument to another. The aim is determining an evaluation strategy that allows to justify conflicting arguments. While several such strategies have been defined, not always they are useful or sensible. This is due to the low level of expressiveness of abstract systems which doesn't allow to represent all relevant contextual situations. E.g., using an appeal to authority,

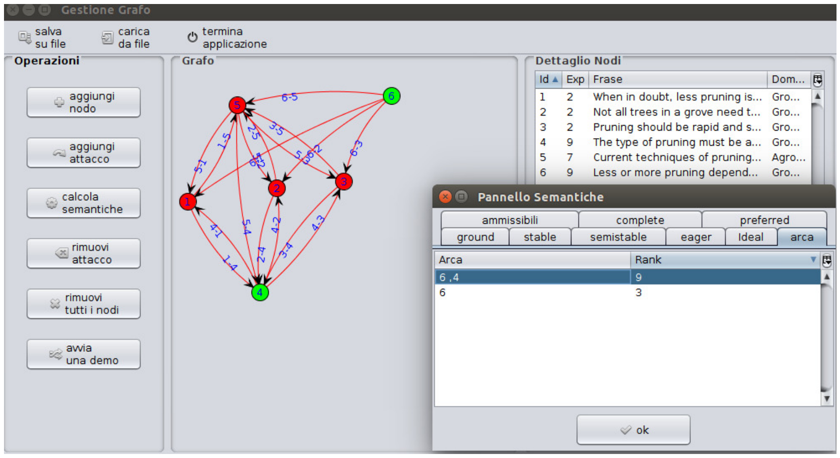

Fig. 5. Last Samuel's claim determines the winning arguments

claims may have different weights in the discourse, and justifications might be evaluated differently. In turn, the weight of a claim depends on the degree of experience (i.e., the authority) of the person expressing it in a particular domain. This work proposed a novel evaluation strategy which may take into account the authority degree of arguments in a given domain in order to understand which arguments survive in a debate. It was implemented in the ARCA system, that allows easily to set up abstract argumentation frameworks and solve justified arguments with both classical extension-based semantics and the proposed authority-weighted approach. A sample scenario is used to illustrate how ARCA works and how the proposed strategy is useful to best handle a real-world argumentation problem in which the reliability of claims is significant.

As future work, we will investigate the adoption of modal logics depending on the actor's domain membership. E.g., deontic logic in legal field or temporal logic in historical-literary field. We would also like to implement (semi-)automatic analysis of arguments expressed in natural language, so as to help the users of ARCA in setting up their argumentation frameworks. Specifically concerning the use of weights, we would like to extend the abstract model with the use of Value-based Argumentation Frameworks in which the justification of an argument depends on the social values that it advances, and the process of justification of one argument depends on the strength of the values involved in the argumentation. Also the extension to Bipolar Argumentation Frameworks will be considered, so as to distinguish the sense of 'support' to an argument from the sense of 'defense' of an argument.

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