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# Why Do They Vote That?

**Marius C. Silaghi, Roussi Roussev, Badria Alfurhood**
Florida Institute of Technology
msilaghi@fit.edu,rroussev1998@my.fit.edu,balfurhood2014@my.fit.edu

### Abstract

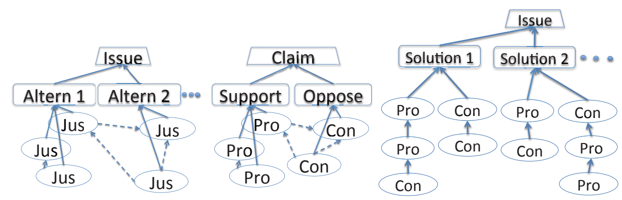
The mining of justifications to be recommended to visitors of deliberation fora used in decision making by constituents raises specific challenges. Graph-based representations can improve our understanding of the problem and enable reasoning with the available data. The addressed technical problem consists in recommending sets of texts containing comprehensive arguments supporting or opposing *poll alternatives*, as mined from submissions of opinions in electronic deliberative polls. A graphical framework is proposed to enable the development of techniques for identification of relevant/encompassing arguments in debates following the Alternative-Based Information System (ABIS) model, a competitor of the IBIS model. Bipolar argumentation frameworks are extended with votes, *enhance* relations and argument coalitions, proposing the BAPDF family of frameworks.

## Introduction

Decision making systems can be designed to provide incentives for each user to submit or support a candidate for the most comprehensive justification of the poll choice selection done by him. The justification text submitted by each user may contain the relevant worldview of the group of participants making the same selection, i.e., their view on all available poll alternatives, defining the balance that has tilted their decision in the direction selected by the group. Incentive for placing comprehensive arguments in one text submission can be provided, for example, by mechanisms where users support only one justification at a time, in conjunction with ranking schemes for texts based on support, introduced in DebateDecide.org (Kattamuri et al. 2005) and DirectDemocracyP2P.net (Silaghi et al. 2013).

Here we refer to the debate structure model introduced by DebateDecide.org as **the Alternative-Based Information System (ABIS)** model, depicted in Figure 1.a, where each justification is in support of some alternative solution to the discussed issue, while other attack and support relations may exist between them (Silaghi and Roussev 2014). This therefore differs from the Issue-Based Information System (IBIS) model (Kunz and Rittel 1970; Baroni et al. 2015) shown in Figure 1.c where some arguments oppose some alternatives without specifically supporting something. In a basic version, ABIS(2), the issue is a claim and the alternatives are *Support* and *Oppose* as in Figure 1.b.






a) ABIS b) ABIS(2) c) IBIS

Figure 1: ABIS vs IBIS debate models

We present a framework for ranking or extracting the $k$-most comprehensive justifications for each poll alternative, where $k$ is an estimation of the number of justifications that a user studies. Authors need to locate relevant justifications that others submitted for making the same choice as themselves, to identify and merge their arguments. Authors also need relevant justifications for remaining poll alternatives, to identify challenges from users making other selections, to which they can provide their group's answer. The argumentation framework we propose has classes/coalitions of arguments as a part of its definition rather than a result of some reasoning. As such these coalitions can be used as a robust support of further inferences.

## Argumentation Frameworks for Debates

Mechanisms to extract data from forum statements into some argumentation framework can profit more from exploiting metadata, despite the existence of investigations into general level forum design and ranking schemes (Hsu, Khabiri, and Caverlee 2009) Data mining and intelligent recommendation is being used for tasks such as analysis of Twitter messages (Ediger et al. 2010) and significant effort is put by research in natural language and abstract argumentation frameworks to come up with formal models of argumentation that fit debates in various venues (Aakhus and Lewiński 2011).

The research in abstract argumentation frameworks has been mainly dealing with dialectics (namely dialogues with arguments in a persuasion process to establish the truth).

Much of the current research in abstract argumentation frameworks (AAFs) is based on Dung's seminal theory of argumentation. In his approach, a (Dung) **argument** is defined as *"an abstract entity whose role is solely determined by its relations to other arguments. No special attention is paid to the internal structure of the arguments."* (Dung 1995). The examples of arguments given by Dung are the natural language statements in the exchange: "My government cannot negotiate with your government because your government doesn't even recognize my government." and "Your government is a terrorist government."

**Definition 1 (AAF)** *An argumentation framework is a pair* $\langle \mathcal{A}, \mathcal{R} \rangle$ *where* $\mathcal{A}$ *is a set of arguments, and* $\mathcal{R}$ *is a binary relation representing attacks on* $\mathcal{A}$*,* $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$*.*

The relation $\mathcal{R}(\alpha, \beta)$ between two arguments, $\alpha$ and $\beta$, represents the fact that $\alpha$ attacks $\beta$. Based on the induced graphs, Dung defined the concepts of *conflict-free* and *admissible extension* (set of arguments which defends each argument in the set, i.e. *accepting* them, by attacking whatever other argument attacks them), as well as a characteristic function $F$ that can filter admissible extensions of an input conflict-free set of arguments by retaining acceptable arguments with respect to the input. Procedures based on these concepts can infer maximal admissible extensions (aka preferred), complete extensions (fix points of $F$), stable extensions (attacking any other arguments), or the smallest complete extension (the least fix point of $F$). Each of these extensions defines a different semantic of acceptance.

The concept of *preference* can be seen as a source of attacks on attacks:

**Definition 2 (EAF (Modgil 2009))** *An Extended Argumentation Framework (EAF) is a tuple* $\langle \mathcal{A}, \mathcal{R}, \mathcal{D} \rangle$*, such that* $\mathcal{A}$ *is a set of arguments, and:*

- $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$*, showing attacks*
- $D \subseteq A \times R$*, showing arguments which defeat attacks*
- $(X, (Y, Z)), (X', (Z, Y)) \in \mathcal{D} \rightarrow (\mathcal{X}, \mathcal{X}'), (\mathcal{X}', \mathcal{X}) \in \mathcal{R}$.

A quantitative approach to preferences integrates the concept of audience:

**Definition 3 (VAF (Bench-Capon 2003))** $\langle \mathcal{A}, \mathcal{R}, \mathcal{V}, val, \mathcal{P} \rangle$ *is a value-based argumentation framework (VAF), where* $val$ *is a function from arguments* $\mathcal{A}$ *to a non-empty set of values* $\mathcal{V}$*, and* $\mathcal{P}$ *is a set* $\{a_1, ..., a_n\}$*, where each* $a_i$ *names a total ordering (audience)* $>_{a_i}$ *on* $\mathcal{V} \times \mathcal{V}$*.*

*An audience specific VAF (aVAF) is a tuple* $\langle \mathcal{A}, \mathcal{R}, \mathcal{V}, val, a \rangle$ *where* $a \in \mathcal{P}$*.*

*If* $X, Y \in \mathcal{A}$*, then* $X$ *defeats*$_a$ $Y$ *iff* $(X, Y) \in \mathcal{R}$ *and it is not the case that* $val(Y) >_a val(X)$*.*

It has already been argued, as a practical desiderata, that *"abstract argumentation frameworks (AAF) should also be studied under the assumption that they are motivated by requirements for modeling relations between locutions as used in common reasoning and debate"* (Modgil 2013), as compared to their instantiation with logical theories, to make them more suitable for modeling dialogues appearing in practice. Abstract Locution Networks (ALNs) were proposed as an alternative where nodes are locutions rather than arguments. Previous research suggested that systems should be prompting users introducing locutions to clarify the relations intended (Brewka and Woltran 2010; Modgil 2013). An abstract framework was proposed for online debating systems, to enable reasoning about argument strength using votes (Eğilmez, Martins, and Leite 2013):

**Definition 4 (ESAF)** *An extended social argumentation framework is a 4-tuple* $F = \langle \mathcal{A}, \mathcal{R}, \mathcal{V}_\mathcal{A}, \mathcal{V}_\mathcal{R} \rangle$*, where* $\mathcal{A}$ *is a set of arguments,* $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$ *is a binary attack relation between arguments,* $\mathcal{V}_\mathcal{A} : \mathcal{A} \rightarrow \mathbb{N} \times \mathbb{N}$ *stores the crowd's pro and con votes for arguments, and* $\mathcal{V}_\mathcal{R} : \mathcal{R} \rightarrow \mathbb{N} \times \mathbb{N}$ *stores the pro and con votes for attacks.*

An abstract bipolar argumentation framework (BAF) (Amgoud et al. 2008; Boella et al. 2010) introducing support relations has also been proposed:

**Definition 5 (BAF)** *An abstract bipolar argumentation framework* $\langle \mathcal{A}, \mathcal{R}_{def}, \mathcal{R}_{sup} \rangle$ *consists of a set* $\mathcal{A}$ *of arguments, a binary relation* $\mathcal{R}_{def}$ *on* $\mathcal{A}$ *called defeat relation and a binary relation* $\mathcal{R}_{sup}$ *on* $\mathcal{A}$ *called support relation: if* $A_i, A_j \in \mathcal{A}$*,* $A_i \mathcal{R}_{def} A_j$ *(resp.* $A_i \mathcal{R}_{sup} A_j$*) means that* $A_i$ *defeats* $A_j$ *(resp.* $A_i$ *supports* $A_j$*).*

Groups of arguments in a BAF that satisfy a coherence requirement define coalitions (Cayrol and Lagasquie-Schiex 2010):

**Definition 6 (Coalition of BAF)** $\mathcal{C} \subseteq \mathcal{A}$ *is a coalition of BAF iff:*
**(i)** *The subgraph of* $\mathcal{G}_{sup}$ *induced by* $\mathcal{C}$ *(the graph representing the AAF* $\langle \mathcal{A}, \mathcal{R}_{sup} \rangle$*) is connected;*
**(ii)** $\mathcal{C}$ *is conflict-free for the AF* $\langle \mathcal{A}, \mathcal{R}_{def} \rangle$*;*
**(iii)** $\mathcal{C}$ *is maximal (for* $\subseteq$*).*

Unlike in this report, the main AAF related problems addressed in literature are about finding a set of laws (rules) that are compatible and have support (Dokow and Holzman 2010), and finding the strongest chains of arguments (Amgoud and Devred 2011).

We had previously introduced concepts used in this work such as enhancements, bipartite graphs, and voting aggregation for ABIS in (Silaghi and Roussev 2014), and present instances in (Roussev and Silaghi 2017).

**Social Media** Given a graph, a number of researchers in different areas have studied how to find the set of most "important" nodes in the graph. In social networks, important nodes are influential people (Kempe, Kleinberg, and Tardos 2003). Various algorithms have been proposed for this problem (Aggarwal, Khan, and Yan 2011; Chan and Ahmadzadeh 2016).

## Proposed Framework

We introduce here the problem setting and involved terms: justification, reason, group and worldview.

**Problem Setting Specification: Poll Dialogues** We address decision supporting processes via *fora associated with electronic polls*, where a discussion is focused on a single issue/claim $Q$ (ABIS model). In polls, questions can be either open-ended or restricted to a set of allowed **alternatives** (aka **choices**): $c_1, ..., c_k$.

A statement submitted by a user can contain multiple explanations for different choices and for various audiences. Unlike for Dung's abstract arguments, we refine the term argument in the sense of minimality.

**Definition 7 (Reason)** *A* reason for a choice *is a minimal statement in support of the given choice.*

For example, we will say that the statement: *"We should keep buying US bonds because US economy is flourishing and EU is in an existential crisis"* is a *justification*, but not a *reason* (minimal argument) for the choice of *"buying US bonds"*. Examples of reasons are: (1) *"US economy is flourishing"*, and (2) *"EU is in an existential crisis"*. While Dung's definition could account for the above statement, $\alpha$, as containing one argument (given Dung's definition of argument as an opaque entity), we will count it as containing two reasons. This enables us to model and evaluate the comprehensiveness of a **portfolio of statements**.

When we talk about a **group** of users we generally refer to the set of participants selecting the same choice of the given poll. By the **worldview** of a given group with respect to a specific poll question we mean the union of the offered sets of reasons due to which members select the corresponding poll alternative.

Frequently such groups are not monolithic and the literature has looked into decomposing them further as separate audiences or groups (Lewinski and Blair 2011). Various levels of resolution in the analysis of these people could yield different sets of sub-groups. This is partly accounted in our work by the fact that we do not look to reconstruct the worldview of the group (defined by a poll choice) as a single justification, but as a portfolio of justifications. The actions a user can perform are: (1) submit an argument, (2) reply/improve to an argument with an argument, (3) vote an argument.

**Framework modeling justification content in poll debates** We introduce a new type of relation between arguments, namely *enhance*.

**Definition 8 (Enhance Relation)** *Argument $\alpha$ enhances another argument $\beta$, if $\alpha$ contains all the reasons of $\beta$, but $beta$ does not contain all the reasons of $\alpha$.*

While in practice enhancement can be just an improvement on the clarity of the description or organization of some reasons, that can still be accounted as an increase of the number of arguments (as a fraction).

**Definition 9 (Justification)** *A justification is an argument for voting a choice $c_i$ of a poll question $s$ with possible choices $c_1, ..., c_k$. It consists of a statement $\langle\Sigma, \Pi\rangle$, with the semantic $\langle\Sigma, \Pi\rangle \rightarrow (s = c_i)$, where $\Sigma = \{r_1, ..., r_k\}$ such that each $r_j$ is a set of reasons for voting choice $c_j$ of $s$, and $\Pi : r_1 \cup ... \cup r_k \rightarrow \mathcal{O}$ is a function mapping each reason to an element of a partially ordered set $\mathcal{O}$ specifying a qualitative or quantitative order of significance between reasons.*

The significance component $\Pi$ can be factored into the computation of relevance for reasons, and can be provided by meta-data or by NLP (e.g. estimating counts of reasons by number of *inference indicators*, and significance from nearby adjectives).

Different constituents/shareholders may own different amounts of shares in the corresponding organization whose decisions are debated, and votes have different *weights* (as given by the shares owned). Voting weights are non-negative real numbers. Other stakeholders and volunteer advisers can be enabled to contribute statements with zero voting weight. Now we can define a family of argumentation frameworks, that we refer to as: *Bipolar Abstract Poll Debate Frameworks (BAPDFs)*. Unlike previous extensions of Dung AAFs, we assume that authors label all their statements with meta-data specifying at least the coalition (alternative of the issue/claim $s$) that the statement supports. The BAPDFs model the new relations (e.g., enhance), besides attack and support relations available in BAF and their votes defined with ESAF. For ABIS(2):

**Definition 10 (BAPDF)** *A bipolar abstract poll debate $\mathcal{B}$ is a tuple $\langle \mathcal{J}_{end}, \mathcal{J}_{opp}, \mathcal{R}_{att}, \mathcal{R}_{enh}, \mathcal{V}_{\mathcal{A}}, \mathcal{V}_{\mathcal{R}} \rangle$ where $s(\mathcal{B})$ denotes the claim of the poll, $\mathcal{J}_{end}$ is a set of justifications for endorsing votes and $\mathcal{J}_{opp}$ is a set of justifications for opposing votes. $\mathcal{R}_{att}$ is a binary relation representing attacks between justifcations of different types. $\mathcal{R}_{enh}$ is a binary relation representing enancement between justifications of the same type. $\mathcal{V}_{\mathcal{A}} : \mathcal{J}_{end} \cup \mathcal{J}_{opp} \rightarrow \mathbb{R}_+$ stores shareholders' voting weight for each argument and $\mathcal{V}_{\mathcal{R}} : \mathcal{R}_{att} \cup \mathcal{R}_{opp} \rightarrow \mathbb{R}_+$ stores shareholders' voting weight for each relation.*

Extensions to issues with **more than two alternatives** are immediate. Namely, while described in the context of only two alternatives, the proposed techniques are focusing on one alternative at a time, and can consider remaining alternatives by merging them (their justifications), converting attack to enhance relations when both involved arguments are for merged alternatives.

When a justification for voting alternative $c$ of poll claim $s$ is studied as an opaque entity $j$, its representation from Definition 9 becomes $j \rightarrow (s = c)$. The other relations are *attack* relations between justifications of different types, denoted $j_1 \not\longrightarrow j_2$, and *enhance* relations between justifications of the same type, denoted $j_1 \rightarrowtail j_2$. The attack relation suggests that $j_1$ *contradicts* $j_2$. The enhance relation suggests that $j_1$ *includes* $j_2$. With both, we say that the relations *start at* the justification $j_1$, the one on their left-hand side, and *point to* $j_2$, being *pointed by* $j_1$.

Simplifications of the BAPDF (e.g., without enhancement relations) can be modeled as instances of ESAF, namely for a special structure on arguments. Further, BAPDF without votes can also be seen as a modification of BAF with different semantics for relations and coalitions. As such, the concepts of *admissible extensions* from AAF can be directly used with the above simplified view of BAPDFs. However, additional attacking rules can be inferred by applying four

**approximate transitivity** relations suggested by the semantics of *attack* and *enhance*. Namely, in an analogy where the target of an attack is referred to as a "victim" and the enhanced argument as a "weaker friend", we can infer with approximation that: the victim of my victim is weaker friend ($j_1 \not\longrightarrow j_2, j_2 \not\longrightarrow j_3$ then $j_1 \rightarrowtail j_3$), and the attacker of my stronger friend is my attacker ($j_1 \not\longrightarrow j_2, j_2 \rightarrowtail j_3$ then $j_1 \not\longrightarrow j_3$). From $j_1$ *enhances* $j_2$, and $j_2$ *attacks* $j_3$ ($j_1 \rightarrowtail j_2, j_2 \not\longrightarrow j_3$) it can be extracted that likely $j_1$ *attacks* $j_3$ ($j_1 \not\longrightarrow j_3$). Further, the *enhances* relation is transitive.

## Problems Enabled

We define *the most encompassing $K$ arguments* for a poll alternative answer from two different perspectives, obtaining results with different semantics:
(a) *Relevance or Representativity:* A set of $K$ arguments that together describe the reasons of a set of voting shareholders with the highest total number of shares/stock (among all sets of $K$ arguments).
(b) *Comprehensiveness:* A set of $K$ arguments that together contain the largest number of reasons for a given choice of a poll (among all sets of $K$ arguments).

A version of this problem consists in finding *the most encompassing any-time $\mathcal{K}$ ranking of justifications*:

**Definition 11 (Any-Time $\mathcal{K}$ Ranking)** *The most encompassing any-time $\mathcal{K}$ ranking of a set of justifications for a set of integers $\mathcal{K}$ is an ordering of the justifications such that for any number $K$, $K \in \mathcal{K}$, the first $K$ justifications form a most encompassing set among all possible sets of $K$ justifications.*

**Theorem 1 (Impossibility)** *A most encompassing any-time ranking of justifications does not exist for all possible BAPDFs and sets $\mathcal{K}$.*

**Proof:** A counterexample for the *comprehensiveness* semantic, implying the property also holds for the *relevance* semantic, can be built as follows. Let us consider the problem defined by the set of reasons $\{a, b, c, d, e\}$ and the set of justifications: $j_1 = \{a, b, c, d\}, j_2 = \{a, b, e\}, j_3 = \{c, d, f\}$. The single most encompassing $K = 1$ justification is $j_1$, and the single most encompassing set of $K = 2$ justifications is $\{j_2, j_3\}$. Therefore no extension of the solution for $K = 1$ is a solution for $K = 2$, and finding a most encompassing any-time ranking for $\mathcal{K} = \{1, 2\}$ is impossible. □

Solving algorithms can be designed to exploit these relations as arcs in a bipartite graph. The occurrence of bipartite graphs with reply links was previously observed from the perspective of coalition detection (Agrawal et al. 2003). These algorithms search for the best (i.e., most relevant) subsuming candidates for justifications of the opposing conclusions. The search can look directly for $K$ justifications at a time, or for a ranking, e.g., by interleaving as appropriate extractions of one justification at a time, with extractions of $\Delta K$ (increment between sequential values in $\mathcal{K}$ taken in increasing order) justifications at a time.

We formalize now the set of situations when it can be argued that a justification discusses the reasons or issues raised by a given voter, under the aforementioned interaction assumptions of this work:
(i) that a voter can sign support for a single justification which comprehensively describes his reasons,
(ii) and that a voter can also sign attack (called **attacks**) relations and/or enhances relations (called **enhances**) between his supported justification and other justifications.

**Definition 12 (Answer)** *A justification is said to* **answer** *a given* voter *if either it is signed by that voter, or if it points, by a chain of* **attacks** *or* **enhances** *relations, to some justification signed by that voter.*

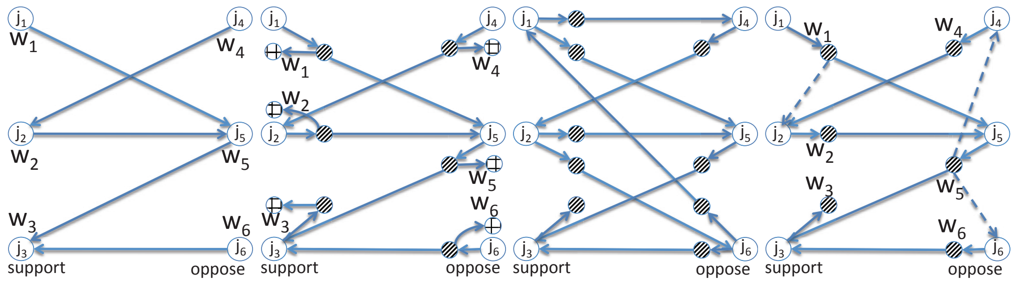
A simple version of the problem is where there exist no **enhances** relation and the **attacks** relation is functional, being specified only by the author of the justification on its left-hand side.

The Subsuming Justification Problem (SJP) is specified by a pair $\langle \mathcal{B}, K \rangle$ where $\mathcal{B}$ is a BAPDF $\langle \mathcal{J}_{end}, \mathcal{J}_{opp}, \mathcal{R}_{att}, \emptyset, \mathcal{V}_{\mathcal{A}}, \emptyset \rangle$ for a Boolean poll claim $s(\mathcal{B})$ with a functional **attacks** relation $\mathcal{R}_{att}$ and argument weight function $\mathcal{V}_{\mathcal{A}}$. The SJP problem is to find a set of at most $K$ supporting justifications that **answer** to a maximum weighted number of voters supporting $s(\mathcal{B})$, and a set of at most $K$ opposing justifications that **answer** to a maximum weighted number of voters opposing $s(\mathcal{B})$.

Note that, in SJP, for ranking endorsing justifications we are only interested in how they represent the participants approving the Boolean claim. The symmetric approach is used for ranking opposing justifications. This design is based on the principle of limiting the incentives of opponents for voting strategically on relations and justifications.

An example of a SJP's bipartite graph for 6 justifications is shown in Figure 2a. Nodes on the left represent endorsing justifications $\{j_1, j_2, j_3\}$ and those on the right represent opposing justifications $\{j_4, j_5, j_6\}$. Each node $j_i$ is shown with a weight $w_i$ representing the shares of shareholders signing justification $j_i$, $w_i = \mathcal{V}_{\mathcal{A}}(j_i)$. An alternative representation is shown in Figure 2b, based on a heterogeneous graph adding nodes for votes and nodes for voters (i.e., shareholders). It is possible to use one node per shareholder, labeled with its voting share, or one node for all shareholders with the same vote and labeled with the sum of their voting shares. The shareholders represented (answered to) by a justification are those that can be reached by traversing the obtained directed graph starting with the justification. The approximations in the assumption that each justification subsumes the justification that it attacks can be quantified by a discount factor. For example, in the given graph, if weights $w_i = i$, then the most encompassing supporting justification is $j_2$ which answers all voters represented by shares in $w_2, w_3$. Even not knowing the contained reasons, one can draw such conclusions by interpreting the agreed semantic of the arrows. The *most encompassing 2 supporting justifications* are $\{j_1, j_2\}$, answering all supporting voters. The most encompassing opposing justification is $j_4$.

A practical problem with the simplifying assumptions in SJPs is that an older justification cannot be marked as a valid attack of newer justifications without its original author's help. In the next extension with practical relevance, each




a) SJP  b) SJP (alternative)  c) WSJP  d) CSJP

Figure 2: Large circles show "justification" nodes, diagonally hatched circles show "vote" nodes, and cross hatched circles show "voter" nodes (aka "shareholder" nodes). Continuous arrows between "justification" nodes, or from "votes" to "justifications" show attack relations. Dashed arrows show enhance relations. The arrows from "justification" nodes to "vote" nodes are called "vote" arcs.

voter can specify explicitly the justification that his selected justification **attacks** (rather than inheriting the one specified at the creation of his justification).

A Weighted Subsuming Justification Problem (WSJP) is specified by a pair $\langle \mathcal{B}, K \rangle$ where $\mathcal{B}$ is a BAPDF $\langle \mathcal{J}_{end}, \mathcal{J}_{opp}, \mathcal{R}_{att}, \emptyset, \mathcal{V}_{\mathcal{A}}, \mathcal{V}_{\mathcal{R}} \rangle$ with an **attacks** relation $\mathcal{R}_{att}$, where functions $\mathcal{V}_{\mathcal{A}}$ and $\mathcal{V}_{\mathcal{R}}$ assign weights for arguments and relations. The WSJP problem is to find a set of at most $K$ supporting justifications that **answer** to a maximum weighted number of voters supporting $s(\mathcal{B})$, and a set of at most $K$ opposing justifications that **answer** to a maximum weighted number of voters opposing $s(\mathcal{B})$.

A sample graph depicting a WSJP is shown in Figure 2c. In this version of the WSJP graph we do not show "shareholder"/"voter" nodes but only "vote" nodes. A "vote" node can be labeled with the number of shares of the shareholders submitting the corresponding vote, or alternatively it can be linked with directed weighted arcs to "shareholder" nodes. Each "vote" node is pointed by a "voter" arrow from the justification $j_i$ signed by the corresponding vote, and may be linked by an outgoing "attack" arrow to another justification that is marked as attacked by $j_i$ in $\mathcal{R}_{att}$. The weight of a justification returned by $\mathcal{V}_{\mathcal{A}}$ is the sum of weights for votes on attacks from that justification, as returned by $\mathcal{V}_{\mathcal{R}}$, potentially summed with the weight of a "vote" node that does not lead to any attack. Unlike for SJPs, with WSJPs there may be multiple arrows exiting a justification. Here the contribution of a justification in terms of representativity is given by the sum of weights of "vote" nodes (or "shareholder" nodes, if shown) that can be reached from it along directed arcs. The *most encompassing supporting justifications* in this example are either $j_1$ or $j_2$, function of **discount factors** and operators used to integrate votes on attacks.

The last problem with practical relevance introduced here is the extension of the simple SJP problem where **enhances** relations are added.

The Components Subsuming Justification Problem (CSJP) is specified by a pair $\langle \mathcal{B}, K \rangle$ where $\mathcal{B}$ is a BAPDF $\langle \mathcal{J}_{end}, \mathcal{J}_{opp}, \mathcal{R}_{att}, \mathcal{R}_{enh}, \mathcal{V}_{\mathcal{A}}, \emptyset \rangle$ with a functional **attacks** relation $\mathcal{R}_{att}$, a **enhances** relation $\mathcal{R}_{att}$, and a function $\mathcal{V}_{\mathcal{A}}$ assigning weights to arguments. The CSJP problem is to find a set of at most $K$ supporting justifications that **answer** to a maximum weighted number of voters supporting $s(\mathcal{B})$, and a set of at most $K$ opposing justifications that **answer** to a maximum weighted number of voters opposing $s(\mathcal{B})$.

The example of graph showing a CSJP in Figure 2d also displays "shareholder" nodes. The main difference with the SJP in Figure 2b is that it also contains "enhance" arrows representing relations in $\mathcal{R}_{enh}$. These arrows lead from "vote" nodes to the enhanced "justification" nodes. Again, the shareholders *answered* by a justification are those reachable along directed arcs from the node of that justification.

**Theorem 2** *The SJP problem is NP-hard.*

The proof follows from the reduction of the NP-hard influence-maximization problem (Kempe, Kleinberg, and Tardos 2003). A SJP can be mapped from an influence maximization problem by interpreting the phenomena in the opposite direction. Namely we interpret that the reasons have propagated along attack relations in the opposite directions of arrows.

## Conclusion

We formalize the Alternative-Based Information System (ABIS) debate model as a competitor to the IBIS model. The BAPDF argumentation framework family is introduced here to help define problems related to retrieving the most encompassing sets of $K$ arguments, or to help generating any-time $\mathcal{K}$ rankings of arguments.

Three different types of problems relevant for the new argumentation framework have been proposed, for identifying *the most subsuming justifications* among those submitted with votes in a threaded debate focusing on a single question with the ABIS paradigm. These NP-hard problems differ from the perspective of the flexibility allowed for argument meta-data.

We have also proven that it is not always possible to generate any-time $\mathcal{K}$ rankings, namely rankings where reading the justifications in the provided order is a strategy maximizing the learning process. In these cases, algorithms can generate approximate solutions.

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