# I win, You lose – Computational Complexity of Verification and NonVerification in Abstract Argumentation

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**Abstract**

In the field of abstract argumentation, the acceptance of an agent's position within a discussion is usually investigated only for the agent themselves. However, a discussion always consists of at least two parties with opposing views. Therefore, an agent's position can only be accepted if the opposing position is rejected. In this paper, we investigate the problem of *Verification-NonVerification*, which asks if a set of arguments is accepted with respect to a semantics within an argumentation framework, while a different set is rejected with respect to the same semantics and argumentation framework. We show the computational complexity of the corresponding decision problem.

**Keywords**

Abstract Argumentation, Computational Complexity, Verification, Discussion games



## 1. Introduction

*Formal argumentation* [1] is concerned with models of rational decision-making based on representations of arguments and their relations. A particularly important and simple approach is that of abstract argumentation frameworks (AFs) [2], which represent argumentative scenarios as directed graphs. Here, *arguments* are identified by vertices, and an *attack* from one argument to another is represented as a directed edge. To reason over AFs *extension semantics* were proposed. These are functions that evaluate whether a set of arguments is accepted or not.

One approach to compute such acceptable sets are *discussion games* [3, 4, 5, 6, 7], where an agent (called proponent) states that one argument is accepted with respect to a semantics in the underlying AF, while another agent (called opponent) questions this acceptance by presenting counter-arguments. In turn, the proponent must defend their position by presenting counter-arguments to those of the opponent. The proponent and opponent then exchange arguments until one party concedes and loses the discussion. Caminada [3] has shown that if there exists a discussion for an argument that is won by the proponent, then the argument is accepted with respect to a semantics and the proponent has a winning strategy in the discussion game.

The fact that some AFs have multiple equally acceptable sets is often overlooked when evaluating discussion games. The goal is to identify a sequence of arguments in which the proponent presents an acceptable set. However, this does not necessarily imply that the position of the opponent is not acceptable. The opponent may also have a winning strategy representing an acceptable set. Consider an AF with two arguments $a$ and $b$ with a symmetric attack. In this case, both $\{a\}$ and $\{b\}$ are acceptable sets with respect to some semantics (for formal definitions see Section 2). Hence, there is a winning strategy for both arguments even though they are in conflict. Thus, in the context of discussion games a variation of the acceptance problem within AFs would be more appropriate.

*Does the proponent win the discussion, while the opponent loses?*

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This question essentially boils down to verifying whether a set of arguments is acceptable with respect to a semantics within an AF, while a different set is not. In this paper, we define the decision problem $\sigma$-VER-NONVER and investigate the computational complexity of this problem. It turns out that it is in **P** for $\sigma \in \{\mathsf{cf}, \mathsf{ad}, \mathsf{co}, \mathsf{gr}, \mathsf{st}\}$, but for $\sigma \in \{\mathsf{pr}, \mathsf{sst}\}$ the computational complexity rises to **DP-complete**.

The paper is structured as follows: We recall all necessary information on complexity theory and abstract argumentation in Section 2. In Section 3, we discuss the problem Verification-NonVerification in detail and investigate the computational complexity of the corresponding decision problem. Section 4 concludes the paper.

## 2. Preliminaries

In this section, we introduce the necessary background information on computational complexity and abstract argumentation.

### 2.1. Computational Complexity

We assume some familiarity with the basic concepts of *computational complexity* such as *deterministic polynomial-time reduction* or *decision problems* [8, 9]. We use the standard notations for the complexity classes and write **P** and **NP** for the sets consisting of decision problems which can be solved by a (non-)deterministic polynomial-time algorithm. For **NP**, **coNP** is the complement class, i.e. it contains the problems where a Yes-instance of the complement can be recognised by a non-deterministic polynomial-time algorithm. We define the *polynomial-time hierarchy* **PH** [10] for $k > 0$ as follows:

$$\begin{aligned}
&\Sigma_0^p = \Pi_0^p = \Delta_0^p = \mathbf{P}, \\
&\Sigma_1^p = \mathbf{NP}, \\
&\Pi_1^p = \mathbf{coNP}, \\
&\Sigma_{k+1}^p = \mathbf{NP}^{\Sigma_k^p} \text{ and} \\
&\Pi_{k+1}^p = \mathbf{coNP}^{\Sigma_k^p}
\end{aligned}$$

Papadimitriou and Yannakakis [11] have introduced the complexity class **DP**, which consist of decision problems that are the intersection of a problem in **NP** and a problem in **coNP**.

The fundamental problem in computational complexity theory is the *satisfiability* problem (SAT for short), which asks if a propositional formula is satisfiable. For a set of atoms $At$, we define the *propositional language* $\mathcal{L}(At)$. We use the usual connectives: $\wedge$ (and), $\vee$ (or) and $\neg$ (negation). An *interpretation* (or *possible world*) for $\mathcal{L}(At)$ is defined by a function $\omega : At \to \{\mathtt{true}, \mathtt{false}\}$. $\Omega(At)$ denotes the set of all interpretations. An interpretation $\omega$ *satisfies* an atom $a \in At$ ($\omega \models a$) if and only if $\omega(a) = \mathtt{true}$. We extend $\models$ to formulas as usual.

| | | |
|---|---|---|
| SAT | **Input:** | A propositional formula $\varphi$. |
| | **Output:** | Yes if $\varphi$ is satisfiable. |

The satisfiability problem was extended by Papadimitriou and Yannakakis [11] to SAT-UNSAT, which is the canonical **DP**-complete problem.

| | | |
|---|---|---|
| SAT-UNSAT | **Input:** | Two propositional formulae $\varphi, \psi$. |
| | **Output:** | Yes if $\varphi$ is satisfiable and $\psi$ is unsatisfiable. |

### 2.2. Abstract Argumentation

An abstract argumentation framework is a directed graph $F = (A, R)$ where $A$ is a (finite) set of *arguments* and $R \subseteq A \times A$ is an *attack relation* among them [2]. An argument $a$ is said to *attack* an argument $b$ if $(a, b) \in R$. We say that an argument $a$ is *defended by a set* $E \subseteq A$ if every argument

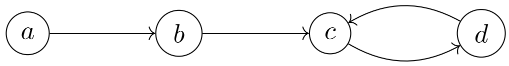

**Figure 1:** AF $F$ from Example 1.

$b \in A$ that attacks $a$ is attacked by some $c \in E$. For $a \in A$, we define $a_F^- = \{b \mid (b, a) \in R\}$ and $a_F^+ = \{b \mid (a, b) \in R\}$ as the set of arguments attacking $a$ and the set of arguments that are attacked by $a$ in $F = (A, R)$. For a set of arguments $E \subseteq A$, we extend these definitions to $E_F^-$ and $E_F^+$ via $E_F^- = \bigcup_{a \in E} a_F^-$ and $E_F^+ = \bigcup_{a \in E} a_F^+$, respectively. If the AF is clear from the context, we will omit the index. For two AFs $F = (A, R)$ and $F' = (A', R')$, we denote with $F \oplus F' = (A \cup A', R \cup R')$ the union of $F$ and $F'$. Most semantics for abstract argumentation rely on two basic concepts: *conflict-freeness* and *admissibility*.

**Definition 1.** *Given $F = (A, R)$, a set $E \subseteq A$ is:* conflict-free *iff $\forall a, b \in E$, $(a, b) \notin R$;* admissible *iff it is conflict-free, and every element of $E$ is defended by $E$.*

For an AF $F$, we use $cf(F)$ and $ad(F)$ to denote the sets of conflict-free and admissible sets, respectively. We define the remaining semantics (denoted as *extension semantics*) as proposed by [2].

**Definition 2.** *For an AF $F = (A, R)$ and a set of arguments $E \subseteq A$. An admissible set $E \subseteq A$ is:*

- *a* complete *extension (co) iff it contains every defended argument;*
- *a* preferred *extension (pr) iff it is a $\subseteq$-maximal complete extension;*
- *the unique* grounded *extension (gr) iff it is the $\subseteq$-minimal complete extension.*
- *a* stable *extension (st) iff $E_F^+ = A \setminus E$;*

For each AF, there is always at least one extension for the complete, preferred and grounded extension semantics. However, this is not necessarily the case for the stable extension semantics. Due to this, [12] proposed a novel variation of the stable extension semantics, the so-called *semi-stable* extension semantics.

**Definition 3.** *For AF $F = (A, R)$, a set $E \subseteq A$ is a* semi-stable *extension iff $E$ is a complete extension where $E \cup E_F^+$ is $\subseteq$-maximal.*

The set of semi-stable extensions coincides with the set of stable extensions when the latter is not empty [12]. The sets of extensions of an AF $F$, for the five semantics mentioned, are represented by $\mathsf{co}(F)$, $\mathsf{gr}(F)$, $\mathsf{pr}(F)$, $\mathsf{st}(F)$, and $\mathsf{sst}(F)$. These extension semantics are commonly referred to as Dung's extension semantics. We call an argument $a$, that is part of at least one $\sigma$-extension of AF $F$, *credulously accepted* with respect to extension semantics $\sigma$ in $F$ ($a \in \mathsf{cred}_\sigma(F)$). An argument $a$ is *skeptically accepted* with respect to extension semantics $\sigma$ in AF $F$, if $a$ is part of every $\sigma$ extension of $F$ ($a \in \mathsf{skep}_\sigma(F)$).

**Example 1.** *Consider the AF $F = (A, R)$ with*

$$A = \{a, b, c, d\}$$
$$R = \{(a, b), (b, c), (c, d), (d, c)\}$$

*as depicted in Figure 1. The complete extensions are $\{a\}$, $\{a, c\}$, and $\{a, d\}$, thus the preferred and stable extensions are $\{a, c\}$ and $\{a, d\}$, while $\{a\}$ is the grounded extension. Therefore $a$, $c$ and $d$ are credulously accepted with respect to complete, preferred, and stable semantics and $a$ is also skeptically accepted with respect to these semantics.*

| | cf | ad | co | gr | pr | st | sst |
|---|---|---|---|---|---|---|---|
| $\textsc{Ver}_\sigma$ | in **P** | in **P** | in **P** | in **P** | **coNP**-c | in **P** | **coNP**-c |
| $\textsc{Cred}_\sigma$ | in **P** | **NP**-c | **NP**-c | in **P** | **NP**-c | **NP**-c | $\Sigma_2^P$-c |
| $\textsc{Skep}_\sigma$ | *trivial* | *trivial* | in **P** | in **P** | $\Pi_2^P$-c | **coNP**-c | $\Pi_2^P$-c |

**Table 1**
Complexity results for Dung's extension semantics based on [19].

In abstract argumentation, we typically consider three decision problems: *verification*, *credulous acceptance* and *skeptical acceptance*. The verification problem $\textsc{Ver}_\sigma$ for extension semantics asks whether a set $E$ is a $\sigma$-extension in abstract argumentation framework $F$. Formally:

$\textsc{Ver}_\sigma$ **Input:** An AF $F = (A, R)$ and $E \subseteq A$
**Output:** Yes if $E \in \sigma(F)$, and No otherwise

For $\sigma \in \{\mathsf{cf}, \mathsf{ad}, \mathsf{co}, \mathsf{gr}, \mathsf{st}\}$ $\textsc{Ver}_\sigma$ is in **P** [2, 13, 14, 15, 16]. However, $\textsc{Ver}_{\mathsf{pr}}$ is **coNP**-complete [17], and $\textsc{Ver}_{\mathsf{sst}}$ is **coNP**-complete [12, 18].

For the two acceptance problems, we ask whether a given argument is credulously or skeptically accepted in an abstract argumentation framework with respect to an extension semantics $\sigma$.

$\textsc{Cred}_\sigma$ **Input:** An AF $F = (A, R)$ and $a \in A$
**Output:** Yes if $a \in \mathsf{cred}_\sigma F$, and No otherwise

$\textsc{Skep}_\sigma$ **Input:** An AF $F = (A, R)$ and $a \in A$
**Output:** Yes if $a \in \mathsf{skep}_\sigma F$, and No otherwise

The acceptance problems are generally harder problems than the verification problem. For instance, $\textsc{Cred}_\sigma$ for $\sigma \in \{\mathsf{ad}, \mathsf{co}, \mathsf{pr}, \mathsf{st}\}$ is **NP**-complete. Note that for $\textsc{Skep}_{\mathsf{ad}}$, the answer is trivially always No, since the empty set is always admissible.

The complexity results for the extension semantics $\sigma \in \{\mathsf{cf}, \mathsf{ad}, \mathsf{co}, \mathsf{gr}, \mathsf{pr}, \mathsf{st}, \mathsf{sst}\}$ are recalled in Table 1. For a deeper discussion on computational complexity in abstract argumentation and more problems, we refer the reader to [19].

## 3. Verification-NonVerification

Within an argumentation framework, multiple different sets of arguments can be accepted with respect to the same semantics. In Example 1, the sets $\{a, c\}$ and $\{a, d\}$ are both preferred extensions, even though arguments $c$ and $d$ are mutually attacking. In the preferred discussion game by Caminada et al. [20], two agents (proponent and opponent) argue amongst themselves about the acceptance of an argument. The proponent argues in favour of accepting an argument, while the opponent argues against it. The agents then take turns to present arguments and their acceptance status. All arguments of the proponent have to be accepted, while all arguments of the opponent have to be rejected. The proponent wins if they can ensure that the opponent cannot take another turn without contradicting themselves. This winning outcome coincides with a preferred extension. For instance, in Example 1 the proponent wants to show that $c$ is accepted, so they present $c$. The opponent responds with $b$, which will be attacked by $a$, winning the discussion for the proponent and showing that $\{a, c\}$ is a preferred extension. Therefore, the proponent has a winning strategy within the preferred discussion game, as described in [20], to prove that argument $c$ is credulously accepted with respect to preferred semantics. However, for the same AF, an agent also has a winning strategy to demonstrate that $d$ should be accepted with respect to preferred semantics. Thus, there is a winning strategy for two conflicting arguments.

In the context of discussion games, a variation of the acceptance problem would be more appropriate. We ask:

Can an agent win a discussion, while their opponent loses the discussion?

This question is equivalent to asking whether there is a set of arguments that is acceptable with respect to an semantics within an AF, while a different set of arguments is not acceptable within the same AF and semantics. The corresponding decision problem is:

| | | |
|---|---|---|
| $\sigma$-VER-NONVER | **Input:** | AF $F = (A, R)$ and $E, E' \subseteq A$, $E \neq E'$. |
| | **Output:** | Yes if $E \in \sigma(F)$ and $E' \notin \sigma(F)$. |

**Example 2.** *Continuing with Example 1, consider the preferred semantics, then the pair $\{a, c\}$ and $\{b\}$ is a Yes-instance of* pr*-VER-NONVER, since $\{a, c\}$ is a preferred extension, whereas $\{b\}$ is not. The pair $\{a, c\}$ and $\{a, d\}$ is a No-instance of* pr*-VER-NONVER, because both sets are preferred extensions.*

Note that for $E = E'$, $\sigma$-VER-NONVER is always a No-instance, since a set cannot be simultaneously be accepted and rejected by a semantics.

If the verification problem for an extension semantics $\sigma$ is efficiently decidable, then we can verify whether both sets $E$ and $E'$ are accepted with respect to $\sigma$ or not. For the complete, grounded and stable semantics, we show that $\sigma$-VER-NONVER is in **P**.

**Proposition 1.** *$\sigma$-VER-NONVER is in* **P** *for $\sigma \in \{\mathsf{cf}, \mathsf{ad}, \mathsf{co}, \mathsf{gr}, \mathsf{st}\}$*

*Proof.* Consider AF $F = (A, R)$, $E, E' \subseteq A$, and extension semantics $\sigma \in \{\mathsf{cf}, \mathsf{ad}, \mathsf{co}, \mathsf{gr}, \mathsf{st}\}$. We check if $E \in \sigma(F)$ and $E' \in \sigma(F)$. These checks are the verification problem $\text{VER}_\sigma$ and are solvable with a polynomial time algorithm [19]. If both checks return Yes, then $\sigma$-VER-NONVER returns No since $E'$ is a $\sigma$-extension. If both checks return No, then $\sigma$-VER-NONVER returns No as well. In the case that $E \notin \sigma(F)$ and $E' \in \sigma(F)$, $\sigma$-VER-NONVER returns No. If $E \in \sigma(F)$ and $E' \notin \sigma(F)$, then $\sigma$-VER-NONVER returns Yes. Thus, the upper bound of the complexity of $\sigma$-VER-NONVER boils down to the complexity of deciding if $E \in \sigma(F)$, and this problem is the verification problem $\text{VER}_\sigma$ and solvable with a polynomial time algorithm. □

For the preferred and semi-stable semantics, the verification problem is **coNP**-complete [19], thus the corresponding complement problem of deciding that a set of arguments is not accepted with respect to these two semantics is **NP**-complete. Deciding whether a set of arguments is accepted with respect to these two semantics involves combining a **coNP**-complete and a **NP**-complete problem, which is characteristic of problems in **DP**.

**Proposition 2.** *$\sigma$-VER-NONVER is* **DP**-complete *for $\sigma \in \{\mathsf{pr}, \mathsf{sst}\}$*

*Proof.* Consider AF $F = (A, R)$, $E, E' \subseteq A$, and extension semantics $\sigma \in \{\mathsf{pr}, \mathsf{sst}\}$. We check if $E \in \sigma(F)$ and $E' \notin \sigma(F)$ holds. The first check is possible in **coNP** and the second part is possible in **NP**. If both these checks return Yes, then $\sigma$-VER-NONVER returns Yes as well, thus $\sigma$-VER-NONVER is in **DP**.

Next, we present a reduction from SAT-UNSAT to $\sigma$-VER-NONVER based on the *standard translation* by [19]. Consider two propositional formulae $\varphi$ and $\psi$ in CNF given by the set of clauses $C = C_\varphi \cup C_\psi$ over atoms $Z = X \cup Y$ with $X = \{x_1, \ldots, x_n\}$ and $Y = \{y_1, \ldots, y_m\}$. We define the corresponding AF $F_{(\varphi,\psi)} = (A, R)$ as follows:

$$
\begin{aligned}
A =& \{a, b, \varphi, \bar{\varphi}, \psi, \bar{\psi}\} \cup C \cup Z \cup \bar{Z} \\
R =& \{(x, \bar{x}), (\bar{x}, x) \mid x \in X\} \cup \{(y, \bar{y}), (\bar{y}, y) \mid y \in Y\} \cup \\
& \{(x, c) \mid x \in c, c \in C\} \cup \{(\bar{x}, c) \mid \bar{x} \in c, c \in C\} \cup \\
& \{(y, c) \mid y \in c, c \in C\} \cup \{(\bar{y}, c) \mid \bar{y} \in c, c \in C\} \cup \\
& \{(c, \varphi) \mid c \in C_\varphi\} \cup \{(c, \psi) \mid c \in C_\psi\} \cup \\
& \{(c, c) \mid c \in C\} \cup \\
& \{(\bar{\varphi}, x) \mid x \in X\} \cup \{(\bar{\varphi}, \bar{x}) \mid x \in X\} \cup
\end{aligned}
$$

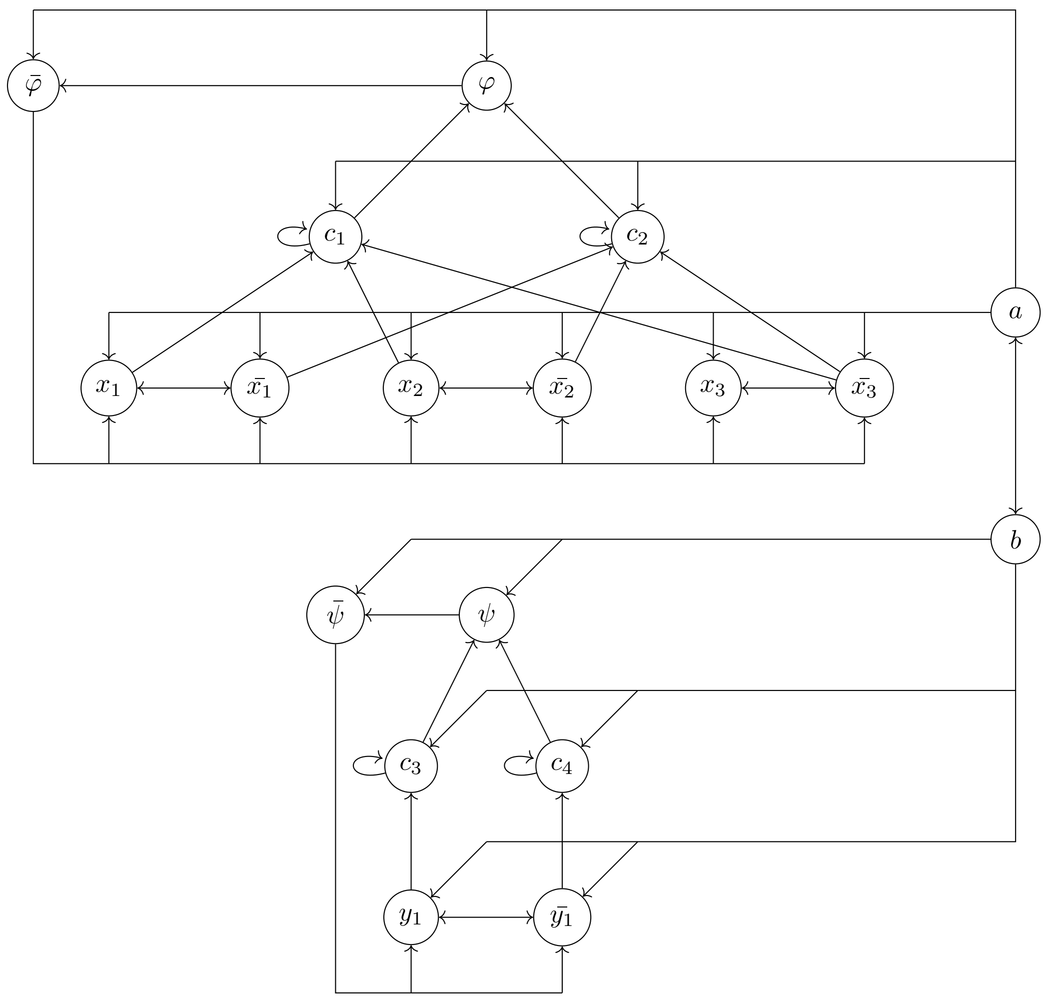


**Figure 2:** Example reduction for **DP**-hardness of $\sigma$-Ver-NonVer. $F_{(\varphi,\psi)}$ for propositional formulae $\varphi = (x_1 \vee x_2 \vee \bar{x_3}) \wedge (\bar{x_1} \vee \bar{x_2} \vee \bar{x_3})$ and $\psi = y_1 \wedge \bar{y_1}$.

$$
\begin{aligned}
&\{(\bar{\psi}, y) \mid y \in Y\} \cup \{(\bar{\psi}, \bar{y}) \mid y \in Y\} \cup \\
&\{(\psi, \bar{\psi}), (\varphi, \bar{\varphi})\} \cup \\
&\{(a, x_\varphi) \mid x_\varphi \in \{\varphi, \bar{\varphi}\} \cup X \cup \bar{X} \cup C_\varphi\} \cup \\
&\{(b, y_\psi) \mid y_\psi \in \{\psi, \bar{\psi}\} \cup Y \cup \bar{Y} \cup C_\psi\} \cup \\
&\{(a, b), (b, a)\}
\end{aligned}
$$

where $X$ contains the atoms of $\varphi$ and $Y$ contains the atoms of $\psi$. With $\bar{Z}$ we denote the negations of the atoms $Z$. An example reduction for $\varphi = (x_1 \vee x_2 \vee \bar{x_3}) \wedge (\bar{x_1} \vee \bar{x_2} \vee \bar{x_3})$ and $\psi = y_1 \wedge \bar{y_1}$ is depicted in Figure 2.

We show that if $I(X, Y)$ is a Yes-instance of Sat-Unsat, then $F_{(\varphi,\psi)}$ with $E = \{a\}$ and $E' = \{b\}$ is a Yes-instance of $\sigma$-Ver-NonVer for $\sigma \in \{\mathsf{pr}, \mathsf{sst}\}$. If $I(X, Y)$ is a Yes-instance of Sat-Unsat, then $\varphi$ is satisfiable and $\psi$ is unsatisfiable. Thus, there is an assignment $I(X)$ of $X$ such that every clause of $\varphi$ is satisfied. It was shown in [19] that this induces a $\sigma$-extension for the $\varphi$ part, i.e. $S \cup \{\varphi\}$ is a $\sigma$-extension, where $S = \{x_i \mid I(x_i) = true\} \cup \{\bar{x_i} \mid I(x_i) = false\}$ for $F_\varphi = (A_\varphi, R \cap (A_\varphi \times A_\varphi))$ with $A_\varphi = \{X \cup \bar{X} \cup C_\varphi \cup \{\varphi, \bar{\varphi}\}\}$. As $b$ attacks every argument in $A \setminus A_\varphi \cup \{b\}$, $S \cup \{\varphi\} \cup \{b\}$ is a $\sigma$-extension for $F_{(\varphi,\psi)}$. Thus, $E' = \{b\}$ cannot be a $\sigma$-extension of $F_{(\varphi,\psi)}$ if $\varphi$ is satisfiable.

If $\psi$ is unsatisfiable, then in [19] it was shown that there is no non-empty $\sigma$-extension in $F_\psi = (A_\psi, R \cap (A_\psi \times A_\psi))$ where $A_\psi = \{Y \cup \bar{Y} \cup C_\psi \cup \{\psi, \bar{\psi}\}\}$. For every assignment $I(Y)$ of $Y$ there is at least one clause of $\psi$ not satisfied, this implies that for every possible set $S' = \{y_i \mid I(y_i) = true\} \cup \{\bar{y_i} \mid I(y_i) = false\}$ induced by these assignments there is at least one clause argument

$c_i \in C_\psi$ not attacked by $S'$, thus $\psi$ cannot be defended and $\bar{\psi}$ is not defeated. Hence, none of the arguments out of $Y \cup \bar{Y}$ can be part of any $\sigma$-extension. For $\bar{\psi}$ to be part of any $\sigma$-extension, $\psi$ has to be defeated, which is not possible, since every attacker of $\psi$ is self-attacking. Thus, $\emptyset$ is the only $\sigma$-extension of $F_\psi$. Argument $a$ attacks every argument in $A \setminus A_\psi \cup \{a\}$, hence $\{a\}$ is a $\sigma$-extension if $\psi$ is unsatisfiable.

So, $E \in \sigma(F_{(\varphi,\psi)})$ and $E' \notin \sigma(F_{(\varphi,\psi)})$ if $I(X,Y)$ is a Yes-instance of Sat-Unsat.

If $I(X,Y)$ is a No-instance of Sat-Unsat, then either $\varphi$ is unsatisfiable or $\psi$ is satisfiable. If $\varphi$ is unsatisfiable, then $\{b\}$ is a $\sigma$-extension of $F_{(\varphi,\psi)}$, to show this, we follow the reasoning of the $\psi$ case from above. Thus, $F_{(\varphi,\psi)}$ with $E = \{a\}$ and $E' = \{b\}$ is a No-instance of $\sigma$-Ver-NonVer for $\sigma \in \{\mathsf{pr}, \mathsf{sst}\}$. If $\psi$ is satisfiable, then $\{a\}$ is not a $\sigma$-extension of $F_{(\varphi,\psi)}$, to show this, we use the reasoning for the $\varphi$ case from above. Thus, $F_{(\varphi,\psi)}$ with $E = \{a\}$ and $E' = \{b\}$ is a No-instance of $\sigma$-Ver-NonVer for $\sigma \in \{\mathsf{pr}, \mathsf{sst}\}$.

We have shown that $\sigma$-Ver-NonVer for $\sigma \in \{\mathsf{pr}, \mathsf{sst}\}$ is **DP**-complete. □

If the verification problem is tractable for an extension semantics, then the Verification-NonVerification problem also remains tractable. But, if the problem is not tractable, then the computational complexity of the Verification-NonVerification problem increases.

## 4. Conclusion

In this paper, we discuss the problem Verification-NonVerification, which asks if a set of arguments is acceptable with respect to a semantics within an AF, while a different set is not. We have shown that the computational complexity of the corresponding decision problem is in **P** for $\sigma \in \{\mathsf{cf}, \mathsf{ad}, \mathsf{co}, \mathsf{gr}, \mathsf{st}\}$, and for $\sigma \in \{\mathsf{pr}, \mathsf{sst}\}$ the computational complexity rises to **DP-complete**.

Examining the computational complexity of verification is one of the first steps taken when investigating newly defined semantics. For instance, Thimm [21] investigated a new procedure for defining extension semantics, with the first listed decision problem being a verification variation. All other decision problems rely on verification, so checking whether a set is acceptable while rejecting a different set is a natural continuation of the investigation. Although the computational complexity of decision problems was already investigated in 1996 by Dimopoulos and Torres [13], other complexity classes have received attention in recent years: *Counting problems*, i.e. questions like: How many preferred extensions does an AF have?, have been investigated by Fichte et al. [22, 23]. *Approximation problems*, i.e. problems that check how close a solution is to the optimal one, were discussed by Thimm [24] as well as by Skiba and Thimm [25]. Thus, investigating the computational complexity of problems remains an intensively researched topic in formal argumentation.

Since the decision problem for Verification-NonVerification is efficiently decidable, we can define for some extension semantics a new class of discussion games. These games are more in line with the interpretation that the loser of a discussion game should not have a winning strategy for their position. A full discussion of these new discussion games will be part of future work.

## Declaration on Generative AI

During the preparation of this work, the author used Claude (Sonnet 5) for grammar and spell checks. After using the tool, the author reviewed and edited the content as needed and takes full responsibility for the publication's content.

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