On the Relationship with Toulmin Method to Logic-Based Argumentation

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Abstract. Toulmin presents a model of argumentation, in which claims can be justified in response to challenges. The model replaces the traditional concepts of 'claim' and 'premise' with new concepts of 'claim', 'data', 'warrant', 'qualifier', 'rebuttal', and 'backing'. Due to the significance of Toulmin's argumentation, this work investigates its relationship to our recently introduced logic-based argumentation [14]. We show that Toulmin's idea does not only give a visual interpretation of the logic-based argumentation, but also yields a human-understandable form. Finally, the paper wraps up the investigation's result and formalizes a novel 2-Tier argumentation framework, that combines the advantages of both Toulmin's model and the logic-based argumentation system.

Keywords: Toulmin model of argumentation · Formal argumentation · Deductive logic · Explainable artificial intelligence

1 Introduction

Argumentation is an important aspect of human intelligence. When humans are making decisions, they always search for pros and cons of arguments as well as their consequences to understand facing situations. This kind of argumentative reasoning can be formalized by utilizing a logical language for the premises and an appropriate consequence relation for showing that claims logically follow from the premises (*a.k.a. logic-based argumentation*) [14].

There are a number of proposals for logic-based formalization of argumentation (*cf.* [1,3,22] for the existing literature). These works allow the representation of arguments for claims, the representation of counterarguments against them, and the relationships between the arguments. Despite the diversity, an argument in logic-based argumentation is commonly defined as a pair of which the first item is a set of formulae that proves the second item (*i.e.* a logical formula). There have been several investigations of and success with the use of proof techniques in logic. For instance, Prakken and Sartor [13] developed proof procedures to find acceptable arguments in Dung's semantics from a defeasible logic knowledge-base. As an example in propositional logic knowledge-base, Efstathiou and Hunter [5] proposed to generate arguments and counterarguments using the resolution principle and connected graph [10,11].

Unfortunately, these existing approaches do not offer computational content of an argument in a form that is understandable by naive users. This is a vital aspect of

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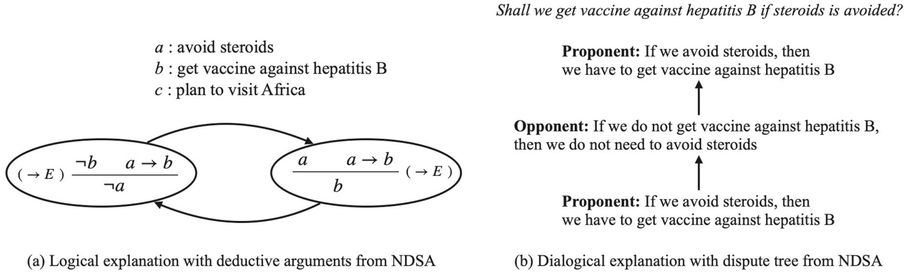

Fig. 1. Logical (a) and dialogical (b) explanations from the NDSA framework.

developing explainable artificial intelligence (XAI) systems; reasoners should provide human-understandable explanations in order to facilitate the process of evolving the theory between explainers and explainees (*i.e.* a group of people who receive the explanations). To fill this gap, Racharak and Tojo [14] recently argued for the use of natural deduction (ND) [6], taken as a mean to identify an argument's structure from the proof, and demonstrated that the pattern represented by ND is close to what humans can perceive as an argument drawing a conclusion from any conjunction that it contains. This investigation results in the development of a novel logic-based framework called "natural deduction-based structured argumentation (NDSA)". Informally, NDSA allows to indicate explanations for any decisions made by deductive arguments computed in the framework and an argumentative dialogue that defends for its oppositions.

Figure 1 illustrates two types of explanation made by the recently introduced NDSA framework. Figure 1-(a) depicts an example of NDSA-based logical explanation with natural deduction. Since the hypotheses in natural deduction only appear on the top layers, this gives a benefit for yielding human-friendly arguments, compared with other deductive formalisms. For instance, a Hilbert-style axiomatization requires us to supply many axioms in the midst of a proof tree. As for the analytic tableau method, we need to show our goal to prove first on the top line, that is against our objective. Gentzen's sequent calculus [9] might be the most polished style of deduction; however, each sequent becomes a long and messy sequence of formulae and is thus difficult for proof's visualization. Furthermore, Fig. 1-(b) depicts an example of NDSA-based dialogical explanation with a dispute tree, allowing to visualize potential conflicts in reasoning.

It is worth mentioning that current studies on logic-based argumentation have mostly concerned on exploiting logic for modeling structured argumentation such as [1]; however, how it contributes to the development of explainable artificial intelligence (XAI) systems is not fully investigated yet. This paper is an extended study of [14], where the relationship between the proposed NDSA and the Toulmin's method is analyzed. Note that Toulmin's method is a classical approach in modern argumentation theories. Understanding its relationship to NDSA is valuable on offering human-interpretation in argumentative reasoning.

This work is organized as follows. Section 2 describes the background knowledge of the Toulmin's argumentation model and the NDSA framework recently introduced

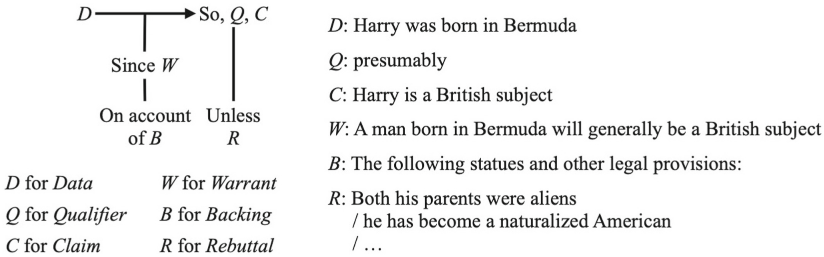

Fig. 2. Toulmin's layout of arguments with an example [15, pp. 104–5].

in [14]. Section 3 shows the manner in which the Toulmin's model provides an alternative interpretation of NDSA, yielding different viewpoints of explanation for adopted XAI systems in logic-based argumentation. Our related works and the conclusion are discussed in Sects. 4 and 5, respectively.

2 Preliminaries

2.1 Toulmin Model of Argumentation

This subsection reviews the basics of Toulmin's model of argumentation [15,16]. In his philosophical viewpoint, there exist other arguments than the formal ones, which offer more argument variants and different perspectives of interpretation.

Toulmin is perhaps most often read because of the simple representation of his argument diagram (cf. Fig. 2) [20]. While a formal logical argument often employs the dichotomy of premises and conclusions when formulating arguments, Toulmin's formalization breaks down each argument into six components: Data, Claim, Qualifier, Warrant, Backing, and Rebuttal. Figure 2 illustrates an intuition of each component with the Toulmin's classic example of arguing whether Harry, who may or may not, be a British subject.

When someone claims (C) that Harry is a British subject, apropos to Toulmin's view, it is natural to ask "what does this claim stand on?". An answer to this question can provide the data (D) on which the claim rests. For instance, "Harry was born in Bermuda". In addition, a further important question needs to be asked, *i.e.*, "why do you think that the datum gives support for your claim?". In other words, we need to use a warrant. In our example, it is "A man born in Bermuda will generally be a British subject". Warrants generally take the form of rule-like statements as illustrated in the example. A point to keep in mind here is that warrants are not necessary to be universal. As the example shows, the warrant is not that 'each' man born in Bermuda is a British subject, but merely that a man born in Bermuda will 'generally' be a British subject. As a result, the claim becomes that 'presumably' (Q) Harry is a British subject.

When the datum, qualified claim, and warrant are made explicitly, a further question has to be asked, *i.e.*, "why do you think that the warrant holds?". An answer to this question will supply the backing (B) for the warrant. In our example, Toulmin refers to the existence of statutes and other legal provisions (without specifying them) that can provide the backing of the warrant, *i.e.*, any person who is born in Bermuda will generally be a British subject. The final component of Toulmin's is Rebuttal (R) which indicates any counterarguments against the claim or any exception to it. In the example, the rebuttals might be "harry's parents could be aliens" or "he could have become a naturalized American". Note that Toulmin also distinguishes between a datum and the negation of a rebuttal; both of them are directly relevant to the claim in different ways. Here, the datum establishes a presumption of the British nationality, whereas by showing a negation of the rebuttal can confirm the presumption thereby created.

In sum, Toulmin distingiushes six kinds of elements in any arguments as follows. Firstly, claim is the starting assertion and must be justified when challenged. Secondly, datum provides the basis of the claim in response to the question: "what does the claim stand on?". Thirdly, warrant gives the connection between datum and claim. It is a general, hypothetical statement that authorizes the step of which an argument commits. Fourthly, qualifier indicates the strength of the step from datum to claim. Fifthly, backing shows why a warrant holds. Finally, rebuttal indicates circumstances in which the general authority of the warrant would have to be set aside, or exceptional circumstances which might be capable of defeating or rebutting the warranted conclusion.

2.2 NDSA: Natural Deduction for Structured Argumentation

Here, we suppose that a knowledge-base Δ is represented by classical propositional logic (PL); thereby proof theories in PL are investigated for construction of arguments and counterarguments from Δ. In [14], it is argued that reading a natural deduction (ND) proof from top to bottom yields a natural human-interpretable argument, initiating the formal development of the natural deduction for structured argumentation (NDSA) framework as follows.

Definition 1 **([14]).** *Given a PL knowledge-base Δ, an* argument *for claim α supported by $\Phi \subseteq \Delta$ (denoted by $\langle \Phi, \alpha \rangle$) is a ND proof tree such that α is derivable (backwards) from α to Φ and $\neg\alpha$ is not derivable from Φ.*

Set Φ is called *supports* or assumptions; and also, α is called the *claim* of an argument. Note that the above definition imposes the consistency constraint to avoid the construction of illogical arguments (such as via *ex falso quodlibet*).

Example 1 Consider the Toulmin's classic example on Fig. 2, let a knowledge-base $\Delta_1 := \{(born\_in\_bermuda \wedge \neg arguably) \rightarrow british\_subject; born\_in\_bermuda; aliens\_parent \rightarrow arguably; become\_american \rightarrow arguably\}$, where a semicolon (;) separates each logical formula in Δ_1 and $\neg$ denotes the classical negation. In the following, we show that $\{\neg arguably\} \cup \Delta_1 \vdash british\_subject$, where $\vdash$ indicates the derivation and $\{\neg arguably\}$ is an (uncancelled) hypothesis denoted by $[\cdot]$:

$$\dfrac{\dfrac{born\_in\_bermuda \quad [\neg arguably]}{born\_in\_bermuda \wedge \neg arguably} \quad (born\_in\_bermuda \wedge \neg arguably) \rightarrow british\_subject}{british\_subject}$$

Following Definition 1, we can say that $\langle \{\neg arguably\} \cup \Delta_1, british\_subject \rangle$ is an argument that supports the claim $british\_subject$.

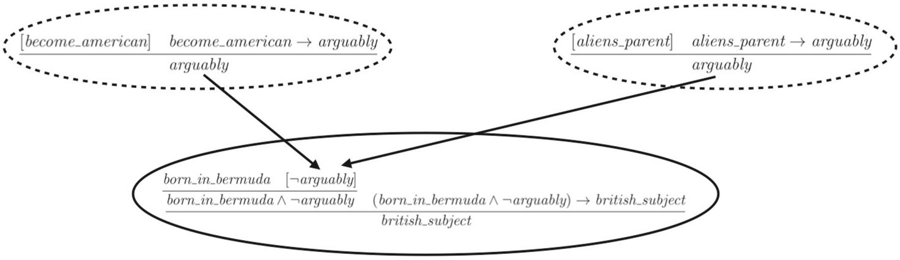

Fig. 3. An argumentation framework instantiated by the NDSA for Example 1.

Definition 2 **([14]).** *Let* $A := \langle \Phi, \alpha \rangle$ *and* $B := \langle \Psi, \beta \rangle$ *be arguments. Then, we say that argument* A attacks *argument* B *iff* $\exists \phi \in \Psi$ *such that* $\alpha \equiv \neg\phi$.

From Example 1, it is worth observing that uncancelled hypotheses can be regarded as attacked points of an argument. For instance, in order to withdraw the claim $british\_subject$, one has to show that this claim is arguable (*cf.* Fig. 3), *i.e.*, by proving with the evidence that either the parents are aliens ($aliens\_parent$) or Harry has become an American ($become\_american$).

Definition 3 **(NDSA [14]).** *A NDSA framework is a triple* $\langle \mathcal{L}, \Delta, \vdash_{ND} \rangle$*, where* $\mathcal{L}$ *is a PL language,* Δ *is a knowledge-base modeled based upon language* $\mathcal{L}$*, and* $\vdash_{ND}$ *is a consequence relation represented by the natural deduction calculus.*

As investigated in [14], Definition 3 exploits the natural deduction because it enables to construct human-interpretable arguments in a sense that hypotheses appear on the top level of each argument and the claim appears on its leaf. Figure 3 illustrates an example of the argument and (potential) counterarguments in NDSA, initiating from the classic Toulmin's example in Sect. 2.1, in which the solid round indicates a valid logical argument, dashed rounds indicate potential counterarguments, and arrows indicate attack relations between arguments.

3 The Reception and Refinement of Toulmin's Model in Logic-Based Argumentation

Observe that the Toulmin's layout of arguments (Fig. 2) looks very resemblant to arguments instantiated from the NDSA framework (Fig. 3). In particular, each argument in an argumentation framework instantiated from NDSA corresponds to a Toulmin's argument and each of its attacking arguments corresponds to a rebuttal condition pointed out by the Toulmin's diagram.

In particular, there exists historical account of AI work taking up Toulmin's idea [20]. Specifically, Toulmin's idea, that logic should be regarded as a generalized form of jurisprudence, is taken up seriously in the 1990 s s in the field of artificial intelligence and law. Influenced by logic-based knowledge representation and Toulmin's method, Prakken and Sartor [12] used an adapted first-order language as the basis of their formalism. In their system, arguments are built by applying Modus Ponens to rules, yielding an operationalization of Toulmin's idea. Prakken and Sartor also modelled specific kinds of rebuttal, namely by the attack of weakly negated assumptions and on the basis of rule priorities.

Hage [8] proposed another refinement of Toulmins's idea which is similar to Prakken and Sartor's work [12]. In Hage's approach, rules were formalized using predicates. For instance, the fact that the rule specifying thieves are punishable is formalized as 'Valid(rule(theft1, thief(x), punishable(x)))'. Here, 'theft1' corresponds to the name of a rule, 'thief(x)' the rule's antecedent, and 'punishable(x)' its consequent. A further refinement of Toulmin's view was given by Verheij *et al.* [21], which formalized two kinds of warrants, *i.e.*, legal rules and legal principles.

The key to the translation of Toulmin's model in the above works is to provide expressions in a concrete manner that a datum leads to a claim and a claim can be attacked from rebuttal. Furthermore, argument evaluation is defined in terms of winning strategies in dialogue games: an argument is called *justified* when it can be successfully defended against an opponent's counterarguments. The following subsections continue to analyze the reception and refinement of Toulmin's idea under the lens of logic-based argumentation.

3.1 Reasoning on NDSA and Admissible Sets

How does the NDSA framework relate to Toulmin's view? Obviously, similar to [8, 12, 21], NDSA has offered a precise explication on each part of Toulmin's view. This result is a direct consequence of using formal logic to formulate arguments, whereas Toulmin's only exists in the form of an informal philosophical expression. Moreover, it is shown in [14] that a formal elaboration of warrants and of rebuttals can be given in the form of the ND calculus and the notion of attack (Definition 2), yielding a systematic account of logical arguments' construction.

Indeed, a proposition is the claim of any Toulmin's argument if it can be logically derived using the ND proof calculus. Here, data of the claim is a set of hypotheses (but not uncancelled ones) used in the derivation, and warrants are the logical implication used by the rule ($\rightarrow E$) for the derivation. Consider the solid circle in Fig. 3, the claim is $british\_subject$, the datum is $born\_in\_bermuda$, and the warrant is the implication $(born\_in\_bermuda \wedge \neg \textit{arguably}) \rightarrow british\_subject$.

As investigated by Toulmin, warrants can be either universally or presumably qualified. NDSA explicitly handles this two sorts of qualifiers at the granularity of the implication formulae, *i.e.*, if such formulae contain uncancelled hypotheses, those warrants are presumably and uncancelled ones can be attacked. Otherwise, they are universally qualified. Following this principle, the formula $(born\_in\_bermuda \wedge \neg \textit{arguably}) \rightarrow british\_subject$ in Fig. 3 is classified as the presumption qualifier and $\neg \textit{arguably}$ is opened to challenge. Note that, according to Definition 2, this challenge will be achieved if there exist arguments showing the contrary of such uncancelled hypotheses as its attacks. In Fig. 3, each arrow indicates an attack, where the head associates with an attacked argument, the tail associates with an attacking argument, and each uncancelled hypothesis denotes a challenged proposition (the rebuttal in the Toulmin's

Table 1. The relationship of Toulmin's and NDSA-based Arguments.

Toulmin's Element	NDSA's Element
Data	Hypotheses of natural deduction argument
Claim	Claim of natural deduction argument
Warrant	Implication rules used to derive the claim with the hypotheses
Qualifier	*Presumably* if there are uncancelled hypotheses, or *universally* otherwise
Backing	Maximal sub-proofs used to derive the warrants in natural deduction argument
Rebuttal	Other natural deduction arguments that derive the contrary of uncancelled hypotheses

idea). As the backings are simply reasons for the warrants in the Toulmin's, they are referred to the maximal sub-proof of each implication used to derive the claim in ND.

The above discussion explains how NDSA can provide explicitly a formal representation for the Toulmin's diagram. NDSA does not only provide a formal representation as it formalizes the Dung's abstract argumentation [4]. In fact, it also concerns a genuine extension of what Toulmin had in mind. The key idea is that an extension of an argumentation framework instantiated by NDSA can be thought of as a set of accepted arguments that defend all of the rebuttal. This set of arguments is called an *admissible* set in Dung's words. Note that Dung has studied three types of subsets of the set of admissible arguments for an argumentation framework: *stable*, *preferred*, and *grounded* extensions. Therefore, the recently introduced NDSA framework can significantly extend and provide the modelling of Toulmin's concept of rebuttal in a formal manner. Table 1 summarizes the relationship with Toulmin method to NDSA accordingly.

3.2 2-Tier AF: Two-Tier Argumentation Framework

Motivated by the relationship investigated previously, this subsection presents a further refinement of NDSA based on the Toulmin's structure, called a *2-tier argumentation framework* (2-Tier AF). Our main goal is to exploit the interpretability and readability of Toulmin's for lay people. Due to the obvious translation shown in Table 1, the 2-Tier AF is naturally defined as follows.

Definition 4. *Each Toulmin's diagram is an* argument *in the 2-Tier AF.*

Definition 4 obviously follows from the analysis that each derivation in NDSA corresponds to an argument based on the Toulmin's view. Next, we adopt the same understanding from our analysis to define an attack between arguments.

Definition 5. *Given a notion of* contrary *of claim in an argument, we say that an argument A* attacks *an argument B if the claim of argument A is the contrary of a datum of argument B and argument B is presumably.*

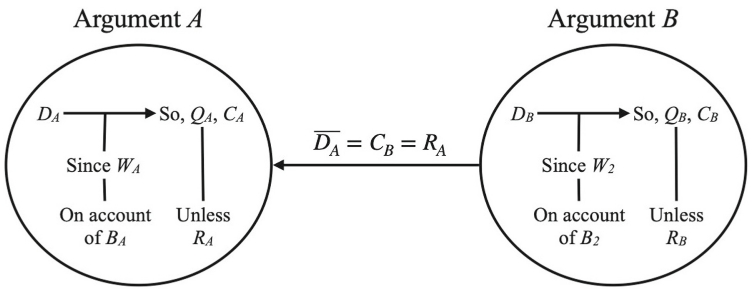

Fig. 4. An argumentation framework instantiated by a 2-Tier AF.

As in NDSA [14], the notion of attack between arguments in a 2-Tier AF depends only on attacking ('undercutting') uncancelled hypotheses. To complete the above definitions of argument and attack, we formally introduce the definition of 2-Tier argumentation framework as follows.

Definition 6 (2-Tier AF). *A 2-Tier argumentation framework is a septuple* $\langle \mathcal{D}, \mathcal{Q}, \mathcal{C}, \mathcal{W}, \mathcal{B}, \mathcal{R}, ^{-} \rangle$ *in which*

- *Datum* $D \in \mathcal{D}$*, Qualifer* $Q \in \mathcal{Q}$*, Claim* $C \in \mathcal{C}$*, Warrant* W*, Backing* $B \in \mathcal{B}$*, and Rebuttal* $R \in \mathcal{R}$ *are elements of the Toulmin's diagram,*
- $^{-}$ *is a partial mapping from the set* $\mathcal{D}$ *of data into the set* $\mathcal{C}$ *of claims, where* $\overline{D}$ *is called the* contrary *of* $D \in \mathcal{D}$*.*

Note that $^{-}$ is defined as a partial mapping due to the fact that not every argument can be attacked. As in our analysis on NDSA, an argument is open for attack if it involves uncancelled hypotheses for deriving the claim. Figure 4 illustrates an example of an argumentation framework instantiated by a 2-Tier AF, where an attack is formalized by the contrary of datum D_A of argument A and the contrary is derivable on argument B, *i.e.*, $\overline{D_A} = C_B = R_A$.

Obviously, the introduced 2-Tier AF is an instance of the Dung's abstract argumentation (AA), as in NDSA. Thus, all semantic notions for determining the 'acceptability' of arguments in AA are also applied to arguments in 2-Tier AF. This connection does not only provide benefits on the interpretability of logic-based arguments computed from the NDSA framework, but also gives potential for AI adoptions especially argument mining due to the available datasets [2].

4 Related Work

This section compares our investigation described in this paper with existing work on the relationship with the Toulmin's method for artificial intelligence.

Praken and Sartor [12] are perhaps the first researchers who are influenced by Toulmin's idea and applied it in the area of artificial intelligence and law. In their approach, an adapted first-order language was used as the basis of their formalism. The following illustrates a formal version of the rule that someone has legal capacity unless he can be shown to be a minor (taken from [12]):

$$r_1 : \sim x \text{ is a minor} \Rightarrow x \text{ has legal capacity}$$

Here, r_1 is the name of the rule, which can be used to refer to it. In addition, 'x is a minor' and 'x has legal capacity' are unary predicates. The tilde represents so-called *weak negation*, indicating that the rule's antecedent is fulfilled when it cannot be shown that x is a minor. It is not difficult to perceive that this mechanism corresponds to the presumably qualifier in the Toulmin's sense. If ordinary negation is used (*i.e.* $\neg x$ is a minor), the fulfillment of the antecedent would require to show that x is not a minor.

Hage's approach [8] is similar to the work of Prakken and Sartor. In [8], rules were first-and-foremost to be thought of as things with properties. Thus, each rule was formalized as a predicate. For instance, the same example would be expressed as 'Valid(rule(r_1, ∼minor(x), legal_capacity(x)))' in Hage's. In addition, Hage distinguished the validity of a rule from its applicability, in which the rule validity corresponded to the Toulmin's warrant.

A formal reconstruction of Toulmin's diagram is studied by Verheij [19]. In his study, the abstract argumentation logic DefLog [17] was employed to formulate each element of Toulmin's model except the notion of qualifier. Apropos to the analysis, Verheij has realized that the treatment of Toulmin's rebuttal is ambiguous as it associates with multiple kinds of attack, namely defeating (or rebutting) the warranted conclusion and undercutting in the sense of Pollock's argumentation. A side effect of his reconstruction was that arguments modelled according to Toulmin's diagram could be formally evaluated. A similar reconstruction of Walton's argumentation schemes was also studied by Verheij in [18].

Our result of this research is similar to Verheij's works [18,19] where a formal reconstruction of Toulmin's scheme is analyzed and explicitly explained. Indeed, our result differs from Verheij's in two perspectives. Firstly, our work analyzes the connection of Toulmin's idea to logic-based argumentation especially the recent NDSA framework. Unlike [18,19] which is specifically based on DefLog, NDSA can be utilized by any deductive logic with an appropriate consequence relation, providing with greater potential to be adopted. Secondly, we present an obvious translation between arguments instantiated by NDSA and Toulmin's arguments. Consider on the availability Toulmin-based annotation for argument mining [2,7], this contribution can enable researchers from both Knowledge Representation and Reasoning and Natural Language Processing to connect together and make further progress towards the automated argument reasoning.

5 Conclusion and Future Direction

This work extends the proposal in our previous paper [14]. Indeed, the reception and refinement of Toulmin's ideas in AI is investigated and analyzed under the lens of the NDSA framework. We show that when an argumentation framework is instantiated by NDSA, there exists an obvious translation from each instantiated argument to an argument in Toulmin's view and the attack between arguments is indicated through the contrary of each argument's claim.

More importantly, we demonstrate that the proposed 2-Tier argumentation framework (2-Tier AF) is an instance of the renowned Dung's abstract argumentation. Therefore, arguments modelled according to Toulmin's diagram can be formally evaluated through the mathematics of Dung. For instance, assuming that datum and warrant hold, but not a rebuttal, then the claim follows; when also a rebuttal is assumed, the claim does not follow. In addition, a rebuttal of a rebuttal can be shown to reinstate a claim. These illustrated circumstances can be formally evaluated through the notion of admissibility in Dung's sense, while retaining the original flavor of Toulmin's method.

Considering the available datasets [2,7] annotated in Toulmin's method, we plan to develop machine learning models to automatically indicate each element of Toulmin's argument from text. Indeed, we are under the development of these systems and aim at integrating with our proposal in [14] towards an implementation of automated argument reasoning in future.

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