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# An argumentation system for defeasible reasoning[☆,☆☆]

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ABSTRACT

Rule-based argumentation systems are developed for reasoning about defeasible information. They take as input a *theory* made of a set of *facts*, a set of *strict rules*, which encode strict information, and a set of *defeasible rules* which describe general behavior with exceptional cases. They build *arguments* by chaining such rules, define *attacks* between them, use a *semantics* for evaluating the arguments, and finally identify the *plausible conclusions* that follow from the theory.

*Undercutting* is one of the main attack relations of such systems. It consists of blocking the application of defeasible rules when their exceptional cases hold. In this paper, we consider this relation for capturing all the different conflicts in a theory. We present the first argumentation system that uses only undercutting, and show that it satisfies the rationality postulates proposed in the literature. Finally, we fully characterize both its extensions and its plausible conclusions under various acceptability semantics. Indeed, we show full correspondences between extensions and sub-theories of the theory under which the argumentation system is built.

## 1. Introduction

Argumentation is a promising approach for reasoning with conflicting information [2]. It consists of generating *arguments*, defining *attacks* between them, evaluating the arguments using a *semantics*, then identifying *plausible conclusions*.

In the computational argumentation literature, there are two families of semantics: *extension* semantics, initiated in [3], and *ranking* semantics, introduced in [4]. The first family looks for sets of arguments, called extensions, that are acceptable together. Then, an *absolute* acceptability degree (accepted or rejected) is assigned to each argument on the basis of its extensions membership. Ranking semantics look for rank-ordering arguments from the most to the least acceptable ones. The ranking may come from the comparison of pairs or sets of arguments, or from degrees assigned to arguments, etc. Gradual semantics from [5] are a sub-class of ranking semantics. In this paper, we focus on extension semantics, in particular those proposed in [3].

Dung proposed in [3] various semantics at an abstract level, i.e., without taking into account the structure of arguments or the nature of attacks. His abstract framework was instantiated by several scholars. The idea is as follows. Start with

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[☆] This paper extensively develops the content of the conference paper [1]. Indeed, it investigates the properties of the new system under two additional semantics, and characterizes the outcomes of the system under those semantics.

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a *knowledge base* whose elements are encoded in a logical language, generate arguments using the consequence operator attached to the language, identify the attacks and apply Dung's semantics for the evaluation task. There are two major categories of instantiations for this abstract framework. The first category uses *deductive logics* (such as propositional logic [6,7] or any Tarskian logic [8]) whereas the second category uses *rule-based languages*.

Rule-based argumentation systems, which use rule-based languages, are developed for reasoning about *defeasible* information. As a major feature, they take as input a *theory* made of three types of information: *facts*, *strict rules*, which encode general strict information, and *defeasible rules* which describe general behavior with exceptional cases. They build *arguments* by chaining such rules, define *attacks* between them, use a *semantics* for evaluating the arguments, and finally identify the *plausible conclusions* that follow from the theory. Examples of such systems are ASPIC [9], its extended version ASPIC+ [10], DeLP [11] and the systems developed in [12–15]. Some of these systems satisfy the rationality postulates proposed in [16]. However, their plausible conclusions have never been characterized. In other words, they have never been expressed in a way that clarifies how they are chosen among all the possible conclusions that follow from the theory. Thus, despite the wide use of these systems, their outputs are still unknown.

The system DeLP uses *rebuttal* as attack relation. Rebuttal captures the fact that the conclusions of two arguments are conflicting. Systems like ASPIC [9] and Pollock's system [17] use, in addition to rebuttal, *undercut* which blocks the application of defeasible rules in particular contexts. Let us illustrate this relation by an example borrowed from [17]. Consider the following argument $A$:

*The object is red* $(or)$ *because it looks red* $(lr)$.

The argument $A$ uses the defeasible rule $lr \Rightarrow or$ (meaning that generally, if an object looks red, then it is red). Assume now the following argument $B$:

*The defeasible rule* $lr \Rightarrow or$ *is not applicable because the object is illuminated by a red light.*

The argument $B$ undercuts $A$ and the conclusion $(or)$ of $A$ does not hold. Undercut deals with the *exceptions* of defeasible rules. Indeed, every exception of a defeasible rule gives birth to an attack from any argument concluding the exception toward any argument using the rule. In the example, being illuminated by a red light is a specific case where the rule $lr \Rightarrow or$ cannot be applied.

In this paper, we show that undercut can do more than dealing with exceptions of defeasible rules. It can also perfectly play the role of rebuttal and assumption attack [18], and deals thus with inconsistency in a theory. The basic idea is the following: any defeasible rule $x \Rightarrow y$ should be blocked when $\neg y$ follows from the theory. We propose the first rule-based argumentation system that uses undercutting as its single attack relation. We show that it satisfies the rationality postulates discussed in [16] under naive, complete, grounded, stable and preferred semantics. From a conceptual point of view, this system is much simpler than existing ones that combine rebuttal and undercut. Indeed, in order to satisfy the postulates, ASPIC requires one variant of rebuttal per semantics: *unrestricted rebut* is used under grounded semantics and *restricted rebut* is used under complete and preferred semantics. Our system satisfies the postulates under all semantics. Moreover, restricted rebut is based on an assumption which is not intuitive. Indeed, this relation compares only the rules whose heads are inconsistent, and neglects the remaining structure of the arguments. For instance, it considers that the argument $(x_1, x_1 \Rightarrow y_1, y_1 \rightarrow z)$ attacks the argument $(x_2, x_2 \rightarrow y_2, y_2 \Rightarrow \neg z)$ since $z$ follows from a strict rule while $\neg z$ follows from a defeasible one. Note that the converse is not true even if the first rule of the first argument is defeasible while that of the second argument is strict. Our system does not make such assumptions.

The second main contribution of the paper consists of providing the first and full characterizations of the extensions as well as the set of plausible conclusions of our system under all the semantics proposed in [3]. Indeed, we show one-to-one correspondences between extensions and sub-theories of the theory over which the argumentation system is built. We also show that the plausible conclusions are the formulas that follow from all the sub-theories characterizing the extensions under a given semantics. These correspondences ensure the correctness and completeness of the outcomes of the proposed system.

The paper is organized as follows: Section 2 defines the rule-based system we are interested in. Section 3 analyzes its properties, namely it shows that the system satisfies the existing rationality postulates as well as a new one. Section 4 characterizes its outputs (extensions and plausible conclusions), and Section 5 compares it with existing rule-based systems and concludes.

## 2. Rule-based argumentation system

As in any paper in defeasible reasoning (e.g. [19–21]), three kinds of information are distinguished: *Facts* representing factual information like 'Tweety is a bird', *strict rules* representing general information which do not have exceptions like 'Penguins do not fly' and *defeasible rules* describing general behaviors with exceptional cases like 'Birds fly'. In other words, any rule which has exceptions is considered as defeasible.

In what follows, $\mathcal{L}$ is a set of *literals*, i.e. atoms or negation of atoms, representing knowledge. The negation of an atom $x$ from $\mathcal{L}$ is denoted by $\neg x$. $\mathcal{L}'$ is a set of atoms used for naming rules. The two sets satisfy the constraint $\mathcal{L} \cap \mathcal{L}' = \emptyset$. Every