On the Issue of Reinstatement in Argumentation

Martin Caminada

Institute of Information and Computing Sciences, Utrecht University
P.O. Box 80 089 3508 TB Utrecht, The Netherlands.
martinc@cs.uu.nl

Abstract. Dung's theory of abstract argumentation frameworks [1] led to the formalization of various argument-based semantics, which are actually particular forms of dealing with the issue of reinstatement. In this paper, we re-examine the issue of semantics from the perspective of postulates. In particular, we ask ourselves the question of which (minimal) requirements have to be fulfilled by any principle for handling reinstatement, and how this relates to Dung's standard semantics. Our purpose is to shed new light on the ongoing discussion on which semantics is most appropriate.

1 Introduction

Dung's abstract theory of formal argumentation [1] has been a guide for researchers in the field of formal argumentation and nonmonotonic logic for more than ten years. During this period, a significant amount of work has been done on proof procedures for Dung's various argument-based semantics [2, 3], as well as on concrete argumentation formalisms (such as [4–6]) based on Dung's theory.

One specific issue that has received relatively little attention is the nature of reinstatement. Although reinstatement as a principle is not totally uncontroversial [7], the current consensus among many researchers in formal argumentation and nonmonotonic logic is that reinstatement of arguments is an essential feature of defeasible reasoning (as is for instance expressed in [8]). Dung provides several approaches for dealing with reinstatement, like stable semantics, preferred semantics, complete semantics and grounded semantics. Our contribution is not to criticize Dung's theory but rather to strengthen it. In particular, we ask ourselves the question: "Why do these semantics actually make sense?"

In previous work, we have stated a number of postulates which, in our view, every argumentation formalism should satisfy [9]. In the current paper, we will follow the same approach and state some simple and intuitive properties for dealing with the issue of reinstatement We then show how these properties are satisfied by Dung's standard semantics and how the differences between the various semantics could be viewed. We also show that a careful examination of reinstatement postulates reveals a semantics not currently known. Based on this discussion, we then share some thoughts on which type of semantics is most appropriate.

In order to keep things concise, the proofs have been omitted from the current paper. They can be found in a seperate technical report [10]

2 Dung's Standard Semantics

A central notion in Dung's theory of abstract argumentation [1] is that of an argumentation framework, which is defined as follows.

Definition 1 (argumentation framework). *An argumentation framework is a pair* (Ar, def) *where* Ar *is a set of arguments and* $\mathit{def} \subseteq Ar \times Ar$.

Definition 2 (defense / conflict-free). *Let* $A \in Ar$ *and* $\mathcal{A}rgs \subseteq Ar$.
We define A^+ *as* $\{B \mid A \mathit{ def } B\}$ *and* $\mathcal{A}rgs^+$ *as* $\{B \mid A \mathit{ def } B \text{ for some } A \in \mathcal{A}rgs\}$.
We define A^- *as* $\{B \mid B \mathit{ def } A\}$ *and* $\mathcal{A}rgs^-$ *as* $\{B \mid B \mathit{ def } A \text{ for some } A \in \mathcal{A}rgs\}$.
$\mathcal{A}rgs$ defends *an argument* A *iff* $A^- \subseteq \mathcal{A}rgs^+$.
$\mathcal{A}rgs$ *is* conflict-free *iff* $\mathcal{A}rgs \cap \mathcal{A}rgs^+ = \emptyset$.

In the following definition, $F(\mathcal{A}rgs)$ stands for the set of arguments that are acceptable (in the sense of [1]) with respect to $\mathcal{A}rgs$.

Definition 3 (acceptability semantics). *Let* $\mathcal{A}rgs$ *be a conflict-free set of arguments and* $F : 2^{\mathcal{A}rgs} \rightarrow 2^{\mathcal{A}rgs}$ *be a function with* $F(\mathcal{A}rgs) = \{A \mid A \text{ is defended by } \mathcal{A}rgs\}$.
$\mathcal{A}rgs$ *is* admissible *iff* $\mathcal{A}rgs \subseteq F(\mathcal{A}rgs)$.
$\mathcal{A}rgs$ *is a* complete *extension iff* $\mathcal{A}rgs = F(\mathcal{A}rgs)$.
$\mathcal{A}rgs$ *is a* grounded *extension iff* $\mathcal{A}rgs$ *is the minimal (w.r.t. set-inclusion) complete extension.*
$\mathcal{A}rgs$ *is a* preferred *extension iff* $\mathcal{A}rgs$ *is a maximal (w.r.t. set-inclusion) complete extension.*
$\mathcal{A}rgs$ *is a* stable *extension iff* $\mathcal{A}rgs$ *is a preferred extension that defeats every argument in* $Ar \backslash \mathcal{A}rgs$.

3 Reinstatement Labellings

The issue of quality postulates, or axioms, has recently received some attention in the field of formal argumentation and non-monotonic logic [9, 11]. An interesting question is whether one can also provide quality postulates for dealing with the reinstatement of arguments. Although the reinstatement has to a great extent been studied by Dung [1], the issue of which postulates have to be satisfied in order for a specific criterion for reinstatement to make sense has received relatively little attention.

One possible approach would be to start labelling the arguments in an argumentation framework. We distinguish three labels: "in", "out" and "undec" (undecided).

Definition 4. *Let* (Ar, def) *be a Dung-style argumentation framework. An* AF-labelling *is a (total) function* $\mathcal{L} : Ar \longrightarrow \{\mathtt{in}, \mathtt{out}, \mathtt{undec}\}$. *We define* $\mathtt{in}(\mathcal{L})$ *as* $\{A \in Ar \mid \mathcal{L}(A) = \mathtt{in}\}$, $\mathtt{out}(\mathcal{L})$ *as* $\{A \in Ar \mid \mathcal{L}(A) = \mathtt{out}\}$ *and* $\mathtt{undec}(\mathcal{L})$ *as* $\{A \in Ar \mid \mathcal{L}(A) = \mathtt{undec}\}$.

In a *reinstatement labelling*, an argument is "in" iff all its defeaters are "out" and an argument is "out" if it has a defeater that is "in", as is stated in the following definition.

Definition 5. *Let $\mathcal{L}$ be an AF-labelling. We say that $\mathcal{L}$ is a* reinstatement labelling *iff it satisfies the following:*

- $\forall A \in Ar : (\mathcal{L}(A) = \texttt{out} \equiv \exists B \in Ar : (B\, def\, A \wedge \mathcal{L}(B) = \texttt{in}))$ *and*
- $\forall A \in Ar : (\mathcal{L}(A) = \texttt{in} \equiv \forall B \in Ar : (B\, def\, A \supset \mathcal{L}(B) = \texttt{out}))$.

The above definitions can be illustrated using the argumentation frameworks in Figure 1. Here, an argumentation framework is depicted as a directed graph, in which the vertices represent the arguments and the edges represent the defeat relation. In the leftmost argumentation framework, there exists just one reinstatement labelling ($\mathcal{L}_1$) with $\mathcal{L}_1(A) = \texttt{in}$, $\mathcal{L}_1(B) = \texttt{out}$, $\mathcal{L}_1(C) = \texttt{in}$. In the middle argumentation framework, there exist three reinstatement labellings ($\mathcal{L}_2, \mathcal{L}_3, \mathcal{L}_4$) with $\mathcal{L}_2(D) = \texttt{in}$, $\mathcal{L}_2(E) = \texttt{out}$, $\mathcal{L}_3(D) = \texttt{out}$, $\mathcal{L}_3(E) = \texttt{in}$, $\mathcal{L}_4(D) = \texttt{undec}$ and $\mathcal{L}_4(E) = \texttt{undec}$. In the rightmost argumentation framework, there exists just one reinstatement labelling ($\mathcal{L}_5$) with $\mathcal{L}_5(F) = \texttt{undec}$.

Notice that Definition 5 can actually be seen as a *postulate*, as it specifies a restriction on an AF-labelling. It turns out that different kinds of reinstatement labellings correspond with different kinds of Dung-style semantics. This is explored in the remainder of this paper.

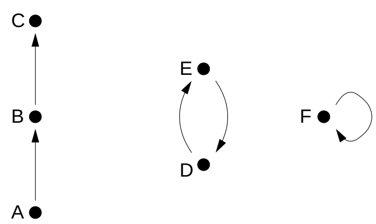

Fig. 1. Three argumentation frameworks.

4 Labellings versus Semantics

We now define two functions that, given an argumentation framework, allow a set of arguments to be converted to a labelling and vice versa. The function $\texttt{Ext2Lab}_{(Ar,def)}$ takes a conflict-free set of arguments (sometimes an extension) and converts it to a labelling. The function $\texttt{Lab2Ext}_{(Ar,def)}$ takes an AF-labelling and converts it to a set of arguments (sometimes an extension). Notice that as an AF-labelling is defined as a function (Definition 4), which in its turn is essentially a relation, it is possible to represent the labelling as a set of pairs.

In the following definition, the resulting AF-labelling does not yet need to satisfy the properties of a reinstatement labelling as stated in Definition 5.

Definition 6. *Let* (Ar, def) *be an argumentation framework,* $\mathcal{A}rgs \subseteq Ar$ *such that* $\mathcal{A}rgs$ *is conflict-free, and* $\mathcal{L} : Ar \longrightarrow \{\mathtt{in}, \mathtt{out}, \mathtt{undec}\}$ *an AF-labelling. We define* $\mathtt{Ext2Lab}_{(Ar,def)}(\mathcal{A}rgs)$ *as* $\{(A, \mathtt{in}) \mid A \in \mathcal{A}rgs\} \cup \{(A, \mathtt{out}) \mid \exists A' \in \mathcal{A}rgs : A' \mathit{def}\, A\} \cup \{(A, \mathtt{undec}) \mid A \notin \mathcal{A}rgs \wedge \neg\exists A' \in \mathcal{A}rgs : A' \mathit{def}\, A\}$*. We define* $LabToExt_{(Ar,def)}(\mathcal{L})$ *as* $\{A \mid (A, \mathtt{in}) \in \mathcal{L}\}$*.*

The fact that $\mathcal{A}rgs$ is conflict-free in the above definition makes that $\mathtt{Ext2Lab}_{(Ar,def)}(\mathcal{A}rgs)$ is indeed an AF-labelling. When the associated argumentation framework is clear, we sometimes simply write `Ext2Lab` and `Lab2Ext` instead of $\mathtt{Ext2Lab}_{(Ar,def)}$ and $\mathtt{Lab2Ext}_{(Ar,def)}$.

4.1 Reinstatement labellings without restrictions

It is interesting to notice that a reinstatement labelling coincides with Dung's notion of complete semantics.

Theorem 1. *Let* (Ar, def) *be an argumentation framework. If* $\mathcal{L}$ *is a reinstatement labelling then* $\mathtt{Lab2Ext}(\mathcal{L})$ *is a complete extension. If* $\mathcal{A}rgs$ *is a complete extension then* $\mathtt{Ext2Lab}(\mathcal{A}rgs)$ *is a reinstatement labelling.*

It is interesting to observe that, when the domain and range of `Lab2Ext` is restricted to reinstatement labellings and complete extensions, and the domain and range of `Ext2Lab` is restricted to complete extensions and reinstatement labellings, then the resulting functions (call them $\mathtt{Lab2Ext}^r$ and $\mathtt{Ext2Lab}^r$) are bijective (that is, they are both injective and surjective) and each other's inverse.

Theorem 2.
Let $\mathtt{Lab2Ext}^r_{(Ar,def)} : \{\mathcal{L} \mid \mathcal{L} \text{ is a reinstatement labelling of } (Ar, def)\} \longrightarrow \{\mathcal{A}rgs \mid \mathcal{A}rgs \text{ is a complete extension of } (Ar, def)\}$ *be a function defined by* $\mathtt{Lab2Ext}^r_{(Ar,def)}(\mathcal{L}) = \mathtt{Lab2Ext}_{(Ar,def)}(\mathcal{L})$*.*
Let $\mathtt{Ext2Lab}^r_{(Ar,def)} : \{\mathcal{A}rgs \mid \mathcal{A}rgs \text{ is a complete extension of } (Ar, def)\} \longrightarrow \{\mathcal{L} \mid \mathcal{L} \text{ is a reinstatement labelling of } (Ar, def)\}$ *be a function defined by* $\mathtt{Ext2Lab}^r_{(Ar,def)}(\mathcal{A}rgs) = \mathtt{Ext2Lab}_{(Ar,def)}(\mathcal{A}rgs)$*.*
The functions $\mathtt{Lab2Ext}^r$ *and* $\mathtt{Ext2Lab}^r$ *are bijective and are each other's inverse.*

As $\mathtt{Lab2Ext}^r$ and $\mathtt{Ext2Lab}^r$ are each other's inverse, there exists a strong similarity between complete extensions and reinstatement labellings.

4.2 Reinstatement labellings with empty `undec`

Reinstatement labellings where `undec` is empty coincide with stable semantics.

Theorem 3. *Let* (Ar, def) *be an argumentation framework. If* $\mathcal{L}$ *is a reinstatement labelling with* $\mathtt{undec}(\mathcal{L}) = \emptyset$ *then* $\mathtt{Lab2Ext}(\mathcal{L})$ *is a stable extension. If* $\mathcal{A}rgs$ *be a stable extension then* $\mathtt{Ext2Lab}(\mathcal{A}rgs)$ *is a labelling with* $\mathtt{undec}(\mathcal{L}) = \emptyset$*.*

4.3 Reinstatement labellings with maximal `in`, maximal `out` and maximal `undec`

Reinstatement labellings where `in` is maximal coincide with preferred semantics.

Theorem 4. *Let (Ar, def) be an argumentation framework. If $\mathcal{L}$ is a reinstatement labelling where $\mathtt{in}(\mathcal{L})$ is maximal then $\mathtt{Lab2Ext}(\mathcal{L})$ is a preferred extension. If $\mathcal{A}rgs$ is a preferred extension then $\mathtt{Ext2Lab}(\mathcal{A}rgs)$ is a labelling where $\mathtt{in}(\mathcal{L})$ is maximal.*

It is interesting to notice that, contrary to what one might expect, reinstatement labellings in which `out` is maximized coincide with preferred semantics, just like (as was proved earlier) labellings in which `in` is maximized. This has to do with the fact that when `in` increases, `out` also increases, and conversely. This is stated by the following lemma.

Lemma 1. *Let $\mathcal{L}$ and $\mathcal{L}'$ be two reinstatement labellings. If $\mathtt{in}(\mathcal{L}) \subsetneq \mathtt{in}(\mathcal{L}')$ then $\mathtt{out}(\mathcal{L}) \subsetneq \mathtt{out}(\mathcal{L}')$. If $\mathtt{out}(\mathcal{L}) \subsetneq \mathtt{out}(\mathcal{L}')$ then $\mathtt{in}(\mathcal{L}) \subsetneq \mathtt{in}(\mathcal{L}')$.*

Theorem 5. *Let (Ar, def) be an argumentation framework. If $\mathcal{L}$ is a reinstatement labelling where $\mathtt{out}(\mathcal{L})$ is maximal then $\mathtt{Lab2Ext}(\mathcal{L})$ is a preferred extension. If $\mathcal{A}rgs$ is a preferred extension then $\mathtt{Ext2Lab}(\mathcal{A}rgs)$ is a labelling such that $\mathtt{out}(\mathcal{L})$ is maximal.*

A reinstatement labelling with maximal `undec` coincides with grounded semantics.

Theorem 6. *Let (Ar, def) be an argumentation framework. If $\mathcal{L}$ is a reinstatement labelling where $\mathtt{undec}(\mathcal{L})$ is maximal then $\mathtt{Lab2Ext}(\mathcal{L})$ is the grounded extension. If $\mathcal{A}rgs$ is the grounded extension then $\mathtt{Ext2Lab}(\mathcal{A}rgs)$ is a reinstatement labelling where $\mathtt{undec}(\mathcal{L})$ is maximal.*

4.4 Reinstatement labellings with minimal `in`, minimal `out` and minimal `undec`

A reinstatement labelling with minimal `in` coincides with grounded semantics.

Theorem 7. *Let (Ar, def) be an argumentation framework. If $\mathcal{L}$ is a reinstatement labelling where $\mathtt{in}(\mathcal{L})$ is minimal then $\mathtt{Lab2Ext}(\mathcal{L})$ is the grounded extension. If $\mathcal{A}rgs$ is the grounded extension then $\mathtt{Ext2Lab}(\mathcal{A}rgs)$ is a reinstatement labelling where $\mathtt{in}(\mathcal{L})$ is minimal.*

A reinstatement labelling with minimal `out` coincides with grounded semantics.

Theorem 8. *Let (Ar, def) be an argumentation framework. If $\mathcal{L}$ is a reinstatement labelling where $\mathtt{out}(\mathcal{L})$ is minimal then $\mathtt{Lab2Ext}(\mathcal{L})$ is the grounded extension. If $\mathcal{A}rgs$ is the grounded extension then $\mathtt{Ext2Lab}(\mathcal{A}rgs)$ is a reinstatement labelling where $\mathtt{out}(\mathcal{L})$ is minimal.*

The last remaining case to be examined is the one of reinstatement labellings where `undec` is minimized. We show that this does not coincide with any of Dung's standard semantics.

There is a one-way relation between reinstatement labellings with minimal `undec` and preferred extensions, as is stated in the following theorem.

Theorem 9. *Let (Ar, def) be an argumentation framework and $\mathcal{L}$ be a reinstatement labelling such that* $\texttt{undec}(\mathcal{L})$ *is minimal. Then* $\texttt{Lab2Ext}(\mathcal{L})$ *is a preferred extension.*

Unfortunately, it does not work the other way around. If $\mathcal{A}rgs$ is a preferred extension, then it is not necessarily the case that $\texttt{Ext2Lab}(\mathcal{A}rgs)$ is a reinstatement labelling where $\texttt{undec}(\mathcal{L})$ is minimal. This is shown in the following example.

Example 1. Let $Ar = \{A, B, C, D, E\}$ and let A defeat B, B defeat A, B defeat C, C defeat D, D defeat E, and E defeat C (see also Figure 2). Here, there exists two preferred extensions: $\mathcal{E}_1 = \{B, D\}$ and $\mathcal{E}_2 = \{A\}$. As $\mathcal{E}_1$ is also a stable extension, it holds that $\texttt{Ext2Lab}(\mathcal{E}_1)$ yields a labelling (say $\mathcal{L}$) with $\texttt{undec}(\mathcal{L}) = \emptyset$. However, $\texttt{Ext2Lab}(\mathcal{E}_2)$ yields a labelling (say $\mathcal{L}'$) with $\texttt{undec}(\mathcal{L}') = \{C, D, E\}$. So, even though $\mathcal{E}_2$ is a preferred extension, $\texttt{Ext2Lab}(\mathcal{E}_2)$ is not a reinstatement labelling in which $\texttt{undec}$ is minimal.

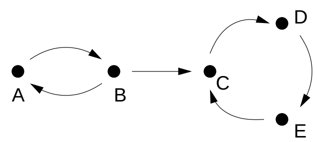

Fig. 2. A preferred extension does not necessarily imply minimal `undec`.

Labellings in which `undec` is minimized can be seen as produced by an agent that is eager to take a position (`in` or `out`) on as many arguments as possible. It is not too difficult to specify what these would look like as a Dung-style semantics.

Definition 7. *Let (Ar, def) be an argumentation framework and $\mathcal{A}rgs \subseteq Ar$. $\mathcal{A}rgs$ is called a* semi-stable extension *iff $\mathcal{A}rgs$ is a complete extension where $\mathcal{A}rgs \cup \mathcal{A}rgs^+$ is maximal.*

The following theorem states that semi-stable semantics indeed coincides with reinstatement labellings in which `undec` is minimal.

Theorem 10. *Let (Ar, def) be an argumentation framework. If $\mathcal{L}$ is a reinstatement labelling where* $\texttt{undec}(\mathcal{L})$ *is minimal then* $\texttt{Lab2Ext}(\mathcal{L})$ *is a semi-stable extension. If $\mathcal{A}rgs$ is a semi-stable extension then* $\texttt{Ext2Lab}(\mathcal{A}rgs)$ *is a reinstatement labelling where* $\texttt{undec}(\mathcal{L})$ *is minimal.*

An interesting property is that when there exists at least one stable extension, the semi-stable extensions coincide with the stable extensions. This is because a stable extension lables every argument `in` or `out`, without labelling any argument `undec`. As for this stable extension, the set of `undec` labelled arguments is empty, every labelling in which `undec` is minimized must then also have the set of `undec` labelled arguments empty, and is therefore also a stable extension.

Theorem 11. *Let (Ar, def) be an argumentation framework. If there exists a stable extension, then the semi-stable extensions coincide with the stable extensions.*

It should be mentioned that Theorem 11 does not hold when semi-stable semantics is replaced by preferred semantics. That is, it is *not* the case that if there exists a stable extension, the preferred extensions coincide with the stable extensions (see Figure 2 for a counterexample). Semi-stable semantics is thus very close to stable semantics (closer than, for instance, preferred semantics) without the traditional disadvantage of stable semantics (the potential absence of extensions).

The idea of semi-stable semantics is not entirely new. It is quite similar to Verheij's concept of an *admissible stage extension*, which fits within Verheij's approach of using *stages* to deal with the reinstatement of arguments [12].

Definition 8 ([12], condensed). *An* admissible stage extension *is a pair $(\mathcal{A}rgs, \mathcal{A}rgs^+)$ where $\mathcal{A}rgs$ is an admissible set of arguments and $\mathcal{A}rgs \cup \mathcal{A}rgs^+$ is maximal.*

Theorem 12. *Let (Ar, def) be an argumentation framework and $\mathcal{A}rgs \subseteq Ar$. $(\mathcal{A}rgs, \mathcal{A}rgs^+)$ is an admissible stage extension iff $\mathcal{A}rgs$ is a semi-stable extension.*

4.5 Overview

From the previous discussion, it is clear that there exists a connection between the various forms of reinstatement labellings on one hand and the various Dung-style semantics on the other hand. This connection is summarized in Table 1.

restriction reinst. labellings	Dung-style semantics	linked by Theorem
no restrictions	complete semantics	1
empty `undec`	stable semantics	3
maximal `in`	preferred semantics	4
maximal `out`	preferred semantics	5
maximal `undec`	grounded semantics	6
minimal `in`	grounded semantics	7
minimal `out`	grounded semantics	8
minimal `undec`	semi-stable semantics	10

Table 1. Reinst. labellings versus Dung-style semantics.

There also exists a partial ordering between the various Dung-style semantics. Every stable extension is a semi-stable extension, every semi-stable extension is a preferred extension, every preferred extension is a complete extension, and every grounded extension is a complete extension. This is graphically depicted in Figure 3.

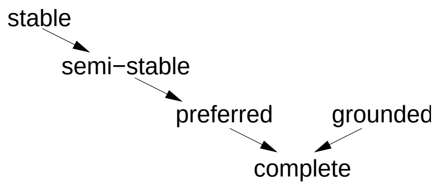

Fig. 3. An overview of the different semantics.

5 Semantics Revisited

In essence, a reinstatement labelling can be seen as a subjective but reasonable point of view that an agent can take with respect to which arguments are `in`, `out` or `undec`. Each such position is internally coherent in the sense that, if questioned, the agent can use its own position to defend itself. It is possible for the position to be disagreed with, but at least one cannot point out an internal inconsistency. The set of all reinstatement labellings thus stands for all possible and reasonable positions an agent can take. This can be seen as a good reason for applying complete semantics, as reinstatement labellings coincide with complete extensions (as was explained in section 4.1). In the remainder of this section, we compare the approach of applying complete semantics with alternative approaches (in particular with preferred semantics).

When determining the overall justified arguments, two approaches are possible: the sceptical and the credulous one. Under the credulous approach, an argument is justified iff there is at least one reasonable position (= reinstatement labelling) where it is labelled `in`. Under the sceptical approach, an argument is justified iff it is `in` in every reasonable position; that is, a reasonable agent cannot deny that the argument is `in`.

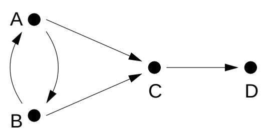

Fig. 4. A floating argument.

As an example, consider the argumentation framework of Figure 4. Here there are three reinstatement labellings, as stated in Figure 5. When all reinstatement labellings are taken into account (such is the case in complete semantics) then A, B and D are credulously justified, whereas no arguments are sceptically justified.

It is interesting to compare this approach with preferred semantics, which has been the subject of much recent research [2, 13, 14]. As was explained earlier, a preferred extension coincides with a reinstatement labelling in which the set of

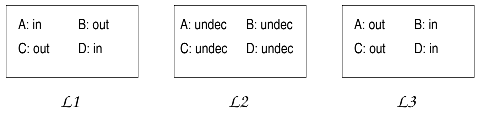

Fig. 5. Three reinstatement labellings.

arguments labelled `in` is maximal. In case of Figure 4, for instance, the relevant labellings are only $\mathcal{L}_1$ and $\mathcal{L}_3$; thus, $\mathcal{L}_2$ is ruled out (see Figure 6).

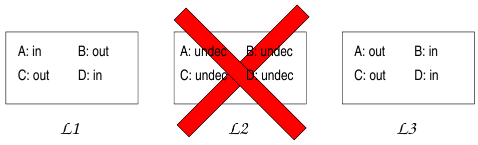

Fig. 6. Preferred semantics rules out particular labellings.

What preferred semantics essentially does is to rule out zero or more reinstatement labellings before determining which arguments are credulously or sceptically justified. Under the sceptical approach, this can lead to more conclusions becoming justified. In the case of Figure 4, for instance, argument D is sceptically justified under preferred semantics but not under complete semantics.

The fact that under preferred semantics, reinstatement labelling $\mathcal{L}_2$ is ruled out can be seen as odd. $\mathcal{L}_2$, after all, is a perfectly valid reinstatement labelling. The fact that it is ruled out under preferred semantics means that those who defend preferred semantics must have some reason to justify this. This reason should state why $\mathcal{L}_2$ is "wrong" or "irrelevant", thus making it possible to ignore $\mathcal{L}_2$. One such reason could be (Theorem 4) "$\mathcal{L}_2$ should be ignored because the set of `in`-labelled arguments is not maximal." This reason does not appear to be a very strong one.

A more pragmatic reason in favor of preferred semantics is the issue of floating conclusions and floating arguments. Suppose the following information is available [15]: (1) Lars's mother is Norwegian, (2) Lars's father is Dutch, (3) Norwegians like ice-skating and (4) Dutch like ice-skating. We can now construct two arguments that defeat each other (assuming that double nationality is not possible): (A) Lars likes ice-skating because he's Norwegian and (B) Lars likes ice-skating because he's Dutch. Under sceptical complete semantics, the proposition that Lars likes ice-skating is not justified, despite the fact that, intuitively, it should be. Under sceptical preferred semantics, on the other hand, the proposition that Lars likes ice-skating *is* justified. At a first sight, this seems to illustrate a clear advantage of preferred semantics to complete semantics.

If we take a closer look, however, the situation becomes more complex. This is because the issue of whether or not Lars likes ice-skating depends on whether or not the principle of excluded middle is regarded as valid. In monotonic logic, the validity of a statement $p \vee \neg p$ depends, among other things, on the number of truth-values. Whereas in a two-valued logic (where each proposition is either `true` or `false` in a given model) the proposition $p \vee \neg p$ is usually regarded as valid, it is *not* regarded as valid in, for instance, three-valued logics [16, 17]. Similarly, for one of the two conflicting arguments A and B to be regarded as valid (or *justified*), one should require that an argument is either `in` or `out`, resulting in a two-valued reinstatement labelling (without `undec`). In section 4.2, it was shown that this essentially boils down to stable semantics. Stable semantics, however, suffers from the problem that for some argumentation frameworks, no stable extensions exist. Consequently, it is not always possible to have a reinstatement labelling with only `in` and `out`. A third possibility (`undec`) is needed. Therefore, the principle of excluded middle, as an absolute criterion, should be rejected.[1] For those who nevertheless feel that the principle of the excluded middle should perhaps not hold at all times, but at least as much as possible (thus not completely ruling out `undec` but merely *minimizing* it), semi-stable semantics would seem a more appropriate choice than preferred semantics.

Given the observation that the principle of complete semantics can be given a decent philosophical justification, it is interesting to examine how complete semantics could be implemented. Fortunately, it turns out that both sceptical and credulous complete semantics have relatively easy and well-documented proof procedures.

As for sceptical semantics, an argument is in each complete extension iff it is in the grounded extension.

Theorem 13 ([1]). *Let* $\{CE_1, \dots, CE_n\}$ *be the set of complete extensions and* GE *be the grounded extension. Let* A *be an argument. It holds that* $A \in GE$ *iff* $A \in CE_1 \cap \dots \cap CE_n$.

As for credulous semantics, an argument is in some complete extension iff it is in some admissible set.

Theorem 14. *Let* $CE_1, \dots, CE_n$ *be the set of complete extensions and* $AS_1, \dots, AS_m$ *be the set of admissible sets. Let* A *be an argument. It holds that* $\exists CE_i \in \{CE_1, \dots, CE_n\} : A \in CE_i$ *iff* $\exists AS_j \in \{AS_1, \dots, AS_m\} : A \in AS_j$.

The fact that sceptical complete semantics coincides with grounded semantics, and credulous complete semantics coincides with credulous preferred semantics is advantageous, as these have relatively straightforward and well-studied proof procedures. Proof procedures for grounded semantics are given in [4, 18], and proof procedures for credulous preferred semantics are given in [2, 3].

[1] Another issue where the principle of excluded middle does not hold in most formalisms for defeasible reasoning is in handling disjunctive information. If $\{p \vee q\} \subseteq \mathcal{P}$ and $\{p \Rightarrow r;\ \ q \Rightarrow r\} \subseteq \mathcal{D}$ then in most formalisms for defeasible reasoning, r is not justified, although intuitively it should be, if one accepts the principle of excluded middle.

6 Summary and Discussion

In this paper, we showed it is possible to describe Dung's standard semantics in terms of reinstatement labellings, which provide an intuitive and relatively simple way of dealing with the issue of reinstatement. We also showed how reinstatement labellings can be used to pinpoint the exact differences between Dung's standard semantics. Using a systematic analysis of reinstatement labellings, we were also able to specify an additional form of semantics (semi-stable semantics) and showed how this semantics fits into the overall picture (Figure 3). We then reexamined the various semantical approaches and made a case for grounded semantics for sceptical entailment and credulous preferred semantics for credulous entailment.[2]

One of the researchers who has done some work on the relation between reinstatement labellings ("status assignments") and Dung's various semantics is Prakken [15]. In particular, Prakken proves (in his own terms and particular formalization) that reinstatement labellings without `undec` correspond to stable extensions, and that reinstatement labellings with maximal `in` correspond to preferred extensions [15]. It was the work of Prakken that served as an inspiration for the more thorough analysis in this paper.

Other recent work on reinstatement labellings has been done by Jakobovits and Vermeir [19]. Their definition of a labelling, however, is different than ours. First of all, they allow for an argument to be labelled `in`, `out`, both `in` and `out`, or neither `in` or `out`. Furthermore, their main reinstatement postulate is different.

Definition 9 ([19], syntax and formulation adjusted). *$\mathcal{L}$ is a labelling iff:*

- $\forall A \in Ar : (\mathcal{L}(A) = \texttt{out} \equiv \exists B \in Ar : (B\, def\, A \wedge \mathcal{L}(B) = \texttt{in}))$ *and*
- $\forall A \in Ar : (\mathcal{L}(A) = \texttt{in} \supset \forall B \in Ar : (B\, def\, A \supset \mathcal{L}(B) = \texttt{out}))$.

The difference between Definition 9 and the earlier presented Definition 5 is that the former does not require an argument of which all defeaters are `out` to be labelled `in`. This is quite strange, since it also means that an argument that has no defeaters at all is not required to be labelled `in`. To some extent, this problem is repaired for *complete labellings*, in which each argument is labelled either `in`, `out` or both.

The overall aim of Jakobovits and Vermeir is to come up with a semantics that is different from Dung's. Jakobovits and Vermeir justify their approach by discussing a number of small examples. However, the general approach of using examples in order to justify a particular formalism has some important downsides. To illustrate our main point, consider the following example provided in [19].

[2] This also implies that we do not support the approach of sceptical preferred semantics, as is for instance examined by [13]. We reject sceptical preferred semantics for reasons discussed in the previous section. We do, however, support the approach of credulous preferred semantics, as this coincides with credulous complete semantics.

Example 2.
A: As the bacteria in the patient's blood is not of type X, it must be of type Y.
B: As the bacteria in the patient's blood is not of type Y, it must be of type X.
C: As the patient does not have bacterial infection, giving antibiotics to the patient is superfluous.
D: As it is not superfluous to give the patient antibiotics, the antibiotics should be prescribed.

Example 2 is represented in the argumentation framework of Figure 4. Jakobovits and Vermeir argue that the correct outcome should be that argument D is justified. However, it is quite easy to provide another example, with essentially the same structure, where the desired outcome is totally different.

Example 3.
A: The suspect killed the victim by stabbing him with a knife, as witness #1 says so.
B: The suspect killed the victim by shooting him with a gun, as witness #2 says so.
C: The suspect is innocent.
D: The suspect should go to jail.

This essentially gives the same argumentation framework as Figure 4. However, an analysis of this case yields a different outcome. As essentially none of the witness statements is without doubt, none of them can serve as a good reason to refute the innocence of the suspect, and the conclusion that suspect should go to jail is not an intuitive or desired one, at least not from a legal point of view.

The main point here is that some researchers try to justify a particular design decision by giving an abstract example (like Figure 4) an informal meaning (like Example 2 or Example 3) and then arguing that the outcome of the abstract example should be in line with the "intuitive" outcome of the informal example. Although this approach has been applied by various researchers in the past, it has also been criticized [20, 18] for its inherent ad-hoc nature.

It is the author's opinion that a better justification for the design of a particular logical formalism can be found in postulates, as these have a more general nature than separate examples. And for reasons explained earlier, we feel that Definition 5 can serve as a more intuitive and acceptable postulate for reinstatement than Definition 9. It is the author's firm opinion that Dung's traditional semantics have a solid basis and that one should have very good reasons for adjusting them.

References

1. Dung, P.M.: On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. Artificial Intelligence **77** (1995) 321–357
2. Vreeswijk, G.A.W., Prakken, H.: Credulous and sceptical argument games for preferred semantics. In: Proceedings of the 7th European Workshop on Logic for Artificial Intelligence (JELIA-00). Number 1919 in Springer Lecture Notes in AI, Berlin, Springer Verlag (2000) 239–253

3. Cayrol, C., Doutre, S., Mengin, J.: Dialectical Proof Theories for the Credulous Preferred Semantics of Argumentation Frameworks. In: Proceedings of the 6th European Conference on Symbolic and Quantitative Approaches to Reasoning with Uncertainty (ECSQARU-2001). Volume 2143 of LNAI., Springer-Verlag (2001) 668–679
4. Prakken, H., Sartor, G.: Argument-based extended logic programming with defeasible priorities. Journal of Applied Non-Classical Logics **7** (1997) 25–75
5. Governatori, G., Maher, M., Antoniou, G., Billington, D.: Argumentation semantics for defeasible logic. Journal of Logic and Computation **14**(5) (2004) 675–702
6. ASPIC-consortium: Deliverable D2.5: Draft formal semantics for ASPIC system (2005)
7. Horty, J.: Argument construction and reinstatement in logics for defeasible reasoning. Artificial Intelligence and Law **9** (2001) 1–28
8. Prakken, H.: Intuitions and the modelling of defeasible reasoning: some case studies. In: Proceedings of the Ninth International Workshop on Nonmonotonic Reasoning (NMR-2002), Toulouse, France (2002) 91–99
9. Caminada, M., Amgoud, L.: An axiomatic account of formal argumentation. In: Proceedings of the AAAI-2005. (2005) 608–613
10. Caminada, M.: On the issue of reinstatement in argumentation. Technical Report UU-CS-2006-023, Institute of Information and Computing Sciences, Utrecht University (2006)
11. Caminada, M.: Contamination in formal argumentation systems. In: Proceedings of the 17th Belgium-Netherlands Conference on Artificial Intelligence (BNAIC). (2005) 59–65
12. Verheij, B.: Two approaches to dialectical argumentation: admissible sets and argumentation stages. In Meyer, J.J., van der Gaag, L., eds.: Proceedings of the Eighth Dutch Conference on Artificial Intelligence (NAIC'96), Utrecht, Utrecht University (1996) 357–368
13. Doutre, S., Mengin, J.: On sceptical versus credulous acceptance for abstract argument systems. In: Proceedings of the 9th European Conference on Logics in Artificial Intelligence (JELIA-2004). (2004) 462–473
14. Dimopoulos, Y., Nebel, B., Toni, F.: Finding Admissible and Preferred Arguments Can be Very Hard. In: Proc. of the 7th Int. Conf. on Principles of Knowledge Representation and Reasoning (KR-2000). (2000) 53–61
15. Prakken, H.: Commonsense reasoning. Technical report, Institute of Information and Computing Sciences, Utrecht University (2004) Reader.
16. Urquhart, A.: Basic many-valued logic. In Gabbay, D., Günthner, F., eds.: Handbook of Philosophical Logic. Volume 2. Second edn. Kluwer Academic Publishers, Dordrecht/Boston/London (2001) 249–295
17. Hähnle, R.: Advanced many-valued logic. In Gabbay, D., Günthner, F., eds.: Handbook of Philosophical Logic. Volume 2. Second edn. Kluwer Academic Publishers, Dordrecht/Boston/London (2001) 297–395
18. Caminada, M.: For the sake of the Argument. Explorations into argument-based reasoning. Doctoral dissertation Free University Amsterdam (2004)
19. Jakobovits, H., Vermeir, D.: Robust semantics for argumentation frameworks. Journal of logic and computation **9(2)** (1999) 215–261
20. Vreeswijk, G.A.W.: Studies in defeasible argumentation. PhD thesis at Free University of Amsterdam (1993)