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Summary

The subject of this thesis is argumentation. We consider argumentation as a process in which arguments supporting a conclusion are taken into account. During the process of argumentation, a conclusion originally justified by some argument can become no longer justified. This is the result of the *defeasibility* of arguments, a term introduced by Hart in 1948 (cf. Loui, 1995a). Our central theme is how argumentation and the defeasibility of arguments can be formally modeled.

The purpose of our research is to find answers to two groups of research questions.

- What is the role of rules and reasons in argumentation with defeasible arguments? What properties of rules and reasons are relevant for argumentation and defeat? How do these properties relate?
- What is the role of process in argumentation with defeasible arguments? How is the defeat of an argument determined by its structure, counterarguments and the argumentation stage?

Trying to answer these groups of questions, we study argumentation and defeat from two angles, resulting in formalisms of different nature, Reason-Based Logic and CumulA.

Reason-Based Logic is a model of the nature of rules and reasons, which are at the basis of argumentation. We investigate the properties of rules and reasons that are relevant for the argumentation and defeat, and how these properties relate to each other.

CumulA is a model of argumentation in stages. We investigate how the structure of an argument is related to defeat, when arguments are defeated by counterarguments, and how the status of arguments is affected by the argumentation stage.

The thesis has five goals:

- Providing a model of rules and reasons, Reason-Based Logic, focusing on properties that are relevant for the defeasibility of arguments.
- Demonstrating the usefulness of the model by providing examples in the field of law.
- Discussing how Reason-Based Logic relates to previously proposed models.
- Providing a model of argumentation, CumulA, that focuses on the process of constructing arguments, and shows how the status of an argument is determined

by the structure of the argument, the counterarguments and the stage of the argumentation process.

- Demonstrating how CumulA can be used to analyze other models of argumentation.

Each of these goals corresponds to a chapter. In chapter 2, we describe Reason-Based Logic. We determine types of facts concerning rules and reasons that are relevant for the defeasibility of arguments, and show their relations. Using this semantics of rules and reasons, we determine some intuitively attractive modes of reasoning. However, these lead to the difficulties of nonmonotonic reasoning. We show how the ideas of Reiter (1980, 1987) can be used to define rigorously which conclusions nonmonotonically follow from a given set of premises.

Chapter 3 contains a series of examples of Reason-Based Logic, taken from the field of law. We give applications of Reason-Based Logic to the theory of legal reasoning: we describe three different ways of reconstructing reasoning by analogy, and provide an integrated view on rules and principles, which seem fundamentally different (cf. Dworkin, 1978, p. 22ff. and 71ff.).

In chapter 4, we survey other models of rules, and compare them to Reason-Based Logic. We do this by treating a number of issues concerning the formalization of rules, and discussing various approaches to deal with these issues.

In chapter 5, the second part of the thesis starts with a discussion of CumulA. It is a formal model of argumentation with defeasible arguments, focusing on the process of taking arguments into account. The main ingredients of the formalism are arguments, defeaters, argumentation stages and lines of argumentation.

In chapter 6, we show how CumulA can be used to analyze models of argumentation. We investigate types of argument structure and of defeat, the role of inconsistency and counterarguments for defeat, and directions of argumentation. As a result, we are able to distinguish a number of existing argumentation models on formal grounds.

The thesis ends with the results and conclusions of the research (chapter 7). We also give some suggestions for future research.

The contributions of the thesis are as follows:

1. We have separated the semantics of rules and reasons, as used in argumentation with defeasible arguments, from the definition of a defeasible consequence relation. In this way, the definition of defeasible reasoning becomes less ad hoc, and is based on explicit standards (cf. chapter 2, section 6).
2. We have shown that it is advantageous to consider rules as special objects and to use a translation from sentences to terms (cf. chapter 2, section 4). In this way, it becomes possible to represent facts about rules, and to reason with them. As a result, we could keep the merits of two competing approaches: the use of rule identifiers and the use of special-purpose conditionals. Our approach enhances the ad hoc use of rule identifiers, that was introduced in order to represent facts about rules. At the same time, our approach can represent the

validity of rules, which is an advantage of the use of special-purpose conditionals in contrast with the use of rule identifiers (cf. chapter 4).

3. We have separated the generation of a reason and the generation of a conclusion, that both can occur when the condition of a rule is satisfied. First, this clarifies the relation of rules and reasons, and second this allows different levels where defeasibility can occur (cf. chapter 3, sections 5 and 6).
4. We have presented an integrated view on rules and principles, and have shown that rules and principles can be regarded as the extremes of a spectrum of hybrid rules/principles (cf. chapter 3, sections 2 and 7). This integrated view is in contrast with Dworkin's strict distinction between rules and principles (cf. Dworkin, 1978). The view is formally elaborated in Reason-Based Logic.
5. We have given three different ways of reconstructing reasoning by analogy (cf. chapter 3, section 8): (1) application of principles that underlie the original rule, (2) application of an analogous rule/principle that has the same underlying principles as the original rule, and (3) analogous application of the original rule, i.e., the application of the rule with non-standard justification.
6. We have shown how the effect of the accrual of reasons on the defeat of arguments can be dealt with in a formal model. In Reason-Based Logic, we focused on the weighing of sets of reasons (chapter 2); in CumulA, we focused on the coordination of arguments and defeat by parallel strengthening (chapter 5).
7. We have provided the model of argumentation CumulA, in which the defeat of arguments is determined by the structure of arguments, counterarguments, and the stage of the argumentation process. We have shown that CumulA's defeaters can represent a wide range of types of defeat, that were not previously integrated in one formalism (cf. chapter 5).
8. We have used CumulA to analyze argumentation models. First, we have made several formal distinctions between argumentation theories. Second, we have captured elements of a number of existing argumentation models in CumulA's argumentation theories. Third, we have applied the distinctions to the resulting argumentation theories. As a result, we were able to show similarities and differences between the argumentation theories capturing argumentation models by applying the formal distinctions above (chapter 6).

Samenvatting

Het onderwerp van dit proefschrift is argumentatie. We beschouwen argumentatie als een proces. Tijdens dit proces worden redeneringen geconstrueerd ter ondersteuning van een conclusie. Gedurende dit proces kan een conclusie aanvankelijk wel en later niet meer gerechtvaardigd zijn door een redenering. Dit komt door de weerlegbaarheid van redeneringen (Eng. defeasibility of arguments). Ons centrale thema is hoe argumentatie en de weerlegbaarheid van redeneringen formeel kan worden gemodelleerd.

Ons onderzoeksdoel is het vinden van antwoorden op de twee groepen onderzoeksvragen.

- Wat is de rol van regels en redenen in argumentatie met weerlegbare redeneringen? Welke eigenschappen van regels en redenen zijn relevant voor argumentatie en weerlegging? Hoe verhouden deze eigenschappen zich tot elkaar?
- Wat is de rol van het argumentatieproces bij argumentatie met weerlegbare redeneringen? Hoe wordt de weerlegging van een redenering bepaald door de structuur van de redenering, andere redeneringen, en het argumentatiestadium?

Ter beantwoording van de vragen bestuderen we argumentatie en weerlegging vanuit twee gezichtspunten. Dit leidt tot formalismen van verschillende aard, Reason-Based Logic en CumuLA.

Reason-Based Logic is een model van de aard van regels en redenen, die de basis vormen van argumentatie. We onderzoeken welke eigenschappen van regels en redenen relevant zijn voor argumentatie en weerlegging, en hoe deze eigenschappen zich tot elkaar verhouden.

CumuLA is een model van argumentatie in stadia. We onderzoeken hoe de structuur van een redenering zich verhoudt tot weerlegging, wanneer andere redeneringen een redenering weerleggen, en hoe het argumentatiestadium de status van een redenering beïnvloedt.

Het proefschrift heeft vijf doelen:

- Het beschrijven van een model van regels en redenen, Reason-Based Logic, gericht op eigenschappen die relevant zijn voor de weerlegging van redeneringen.
- Het aantonen van de bruikbaarheid van het model door het geven van juridische voorbeelden.

- Het laten zien van de verbanden van Reason-Based Logic met eerdere voorgestelde modellen.
- Het beschrijven van een argumentatiemodel, CumulA, dat gericht is op het proces van het construeren van rederingen en dat laat zien hoe de status van een redenering wordt bepaald door de structuur van de redenering, andere redeneringen, en het argumentatiestadium.
- Het aantonen van de bruikbaarheid van CumulA bij het analyseren van andere argumentatiemodellen.

Elk doel wordt behandeld in een hoofdstuk. In hoofdstuk 2 beschrijven we Reason-Based Logic. We bepalen feittypen voor regels en redenen die relevant zijn voor de weerlegbaarheid van argumentatie, en laten de relaties tussen de feittypen zien. Gebruik makend van deze semantiek van regels en redenen bepalen we enkele intuïtief aantrekkelijke redeneerwijzen. Deze redeneerwijzen leiden echter tot de problemen van niet-monotoon redeneren. We laten zien hoe de ideeën van Reiter (1980, 1987) kunnen worden gebruikt voor een formele definitie van de conclusies die de niet-monotone gevolgen zijn van gegeven premissen.

Hoofdstuk 3 bevat een reeks voorbeelden van Reason-Based Logic in het recht. We geven twee toepassingen van Reason-Based logic in de rechtstheorie. Ten eerste beschrijven we drie manieren om redeneren naar analogie te reconstrueren. Ten tweede geven we een geïntegreerde kijk op regels en beginselen, die fundamenteel van elkaar lijken te verschillen (cf. Dworkin, 1978, p. 22ff. en 71ff.).

In hoofdstuk 4 geven we een overzicht van modellen van regels en vergelijken ze met Reason-Based Logic. We doen aan de hand van een aantal problemen bij de formalisering van regels te en behandelen benaderingen om met deze problemen om te gaan.

In hoofdstuk 5 begint het tweede deel van het proefschrift met de beschrijving van CumulA. Het is een formeel model van argumentatie met weerlegbare redeneringen, gericht op het geleidelijk construeren van redeneringen. De belangrijkste ingrediënten van het formalisme zijn redeneringen, weerleggers (Eng. defeaters), argumentatiestadia en betogen (Eng. lines of argumentation).

In hoofdstuk 6 laten we zien hoe CumulA gebruikt kan worden voor het analyseren van argumentatiemodellen. We onderzoeken typen redeneringen en weerlegging aan de hand van de structuur van redeneringen, de rol van inconsistentie en tegenargumenten in weerlegging en argumentatierichtingen. Zo kunnen we een aantal bestaande argumentatiemodellen op formele gronden van elkaar onderscheiden.

Het proefschrift eindigt met de resultaten en conclusies van het onderzoek (hoofdstuk 7). We geven ook enkele suggesties voor toekomstig onderzoek.

De bijdragen van het proefschrift zijn als volgt:

1. We hebben de semantiek van regels en redenen, zoals die gebruikt worden in argumentatie met weerlegbare redeneringen, onderscheiden van de definitie van een weerlegbare-gevolgtrekkingsrelatie. Zo wordt de definitie van weerlegbaar

redeneren minder ad hoc en kan ze gebaseerd worden op expliciete standaarden (cf. chapter 2, section 6).

2. We hebben laten zien dat het voordelig is om regels als speciale objecten te beschouwen en een vertaling tussen zinnen en termen te gebruiken (cf. chapter 2, section 4). Zo wordt het mogelijk om feiten over regels te representeren en over regels te redeneren. Als gevolg hiervan konden de voordelen van twee benaderingen worden behouden: het gebruik van regelnamen en het gebruik van een speciale conditionele zinsstructuur. Onze benadering verbetert het gebruik van regelnamen, dat was geïntroduceerd om feiten over regels te representeren. Tegelijkertijd kan onze benadering de geldigheid van regels representeren. Dit was een voordeel van het gebruik van een speciale conditionele zinsstructuur tegenover het gebruik van regelnamen. (cf. chapter 4).
3. We hebben het ontstaan van een reden en het trekken van een conclusie van elkaar gescheiden. Beide kunnen plaatsvinden als aan de voorwaarde van een regel is voldaan. Ten eerste verheldert dit de relatie tussen regels en redenen en ten tweede kan weerlegging op verschillende niveaus voorkomen (cf. chapter 3, sections 5 and 6).
4. We hebben een geïntegreerde kijk op regels en beginselen gegeven en laten zien dat regels en beginselen beschouwd kunnen worden als de extremen van een spectrum van hybride regels/beginselen (cf. chapter 3, sections 2 and 7). Deze geïntegreerde kijk contrasteert met Dworkin's strikte onderscheid tussen regels en beginselen (cf. Dworkin, 1978). De kijk wordt formeel uitgewerkt in Reason-Based Logic.
5. We hebben drie manieren beschreven om redeneren naar analogie te reconstrueren (cf. chapter 3, section 8): (1) als de toepassing van beginselen die aan de oorspronkelijke regel ten grondslag liggen, (2) als de toepassing van een analoge regel of beginsel met dezelfde onderliggende beginselen als de oorspronkelijke regel, en (3) de analoge toepassing van de oorspronkelijke regel, d.w.z. de toepassing van de regel met niet-standaard rechtvaardiging.
6. We hebben laten zien hoe met het effect van de ophoping van redenen (Eng. accrual of reasons) op de weerlegging van redeneringen formeel kan worden omgegaan. In Reason-Based Logic waren we gericht op het wegen van verzamelingen redenen (chapter 2); in CumulA waren we gericht op de nevenschikking van redeneringen en weerlegging door parallele versterking (chapter 5).
7. We hebben het argumentatiemodel CumulA voorgesteld. Hierin wordt de weerlegging van redeneringen bepaald door hun structuur, door andere argumenten en door het argumentatiestadium. We hebben laten zien dat CumulA's weerleggers (Eng. defeaters) een breed scala van typen weerlegging kunnen representeren. Deze typen zijn nog niet eerder in een formalisme geïntegreerd (cf. chapter 5).
8. We hebben CumulA gebruikt om bestaande argumentatiemodellen te analyseren. Eerst hebben we een aantal formele onderscheidingen gemaakt voor

Cumula's argumentatietheorieën. Daarna hebben we elementen van een aantal bestaande argumentatiemodellen beschreven in Cumula's argumentatietheorieën. Tenslotte hebben we de gemaakte onderscheidingen toegepast op deze argumentatietheorieën. Op deze manier was het mogelijk om op grond van de genoemde formele onderscheidingen overeenkomsten en verschillen tussen deze argumentatietheorieën te laten zien.

Curriculum Vitae

Bart Verheij was born in Hoorn, The Netherlands, in 1967. From 1979 to 1985, he attended the Johan van Oldenbarnevelt Gymnasium in Amersfoort. He studied mathematics at the University of Amsterdam, specializing in algebraic geometry. In his final year, he was a student assistant at the Department of Mathematics. In the summer of 1991, he wrote a report on the cohomology of moduli spaces of curves, related to Witten's research in theoretical physics. In 1992, he started working as a Ph.D. researcher (in Dutch: assistent in opleiding) at the Universiteit Maastricht, then called the Rijksuniversiteit Limburg, in Maastricht, The Netherlands. He worked at the Departments of Computer Science and of Metajuridica. His research was part of the ARCHIMEDES project (SKBS/B3.A). The project was financially supported by the Foundation for Knowledge-Based Systems (SKBS). He started doing multi-media information retrieval research. Gradually his attention shifted to theoretical research on argumentation and defeat. In 1995, he co-organized the Eighth International Conference on Legal Knowledge-Based Systems (JURIX '95). He was invited to work at the Computer Science Department of the Washington University in Saint Louis (Missouri) in the summer of 1996. His stay there was sponsored by the National Science Foundation (NSF) under grant number 9503476. In 1997, he starts working in a project on the application of the recent theoretical insights into legal reasoning to the legal domain of tort. This project is sponsored by the Dutch National Programme for Information Technology and Law (ITeR).

