Abstract

Using exact formal methods to study (human) reasoning is part of a wide and interdisciplinary area of scientific research. An important characteristic of human reasoning is its defeasible nature: conclusions that are drawn at one moment may be retracted later in view of new information (e.g., when learning that the streets have been cleaned one may retract the previous inference that it rained, which was formed on the basis of seeing a wet street). There are many forms of defeasible reasoning, for example abduction, induction and default reasoning. We all apply defeasible reasoning in everyday reasoning, normative reasoning, expert reasoning, as well as in scientific reasoning.

The Formal Study of Defeasible Reasoning

In view of the fact that defeasible reasoning plays an important role in human reasoning, there are several reasons for studying it from an exact formal point of view. On the one hand, a formal account of defeasible reasoning would help to gain an understanding of correct human reasoning and rationality and to develop tools in artificial intelligence that interact with humans. On the other hand, formal tools can be of great help in explicating reasoning that underlies scientific practice as well as ethical reasoning. In order to benefit even further from the before mentioned advantages of a study with a formal approach, it is useful to have one unifying framework that captures the different reasoning forms. Firstly, because having one approach makes it possible to analyze the differences and commonalities between the different reasoning types. Secondly, implementing this one framework suffices to study various types of reasoning in an application of, for example, automated reasoning.

One of the main ideas of the research in this thesis is that defeasible reasoning is best investigated from an argumentative angle, where an argument is only warranted in case it can be defended against counterarguments. Since the introduction of abstract argumentation [100], many approaches to logical argumentation have been studied.

Sequent-Based Argumentation

In many of the chapters of this thesis, sequent-based argumentation [17, 25] is taken as the formal approach. Where arguments and attacks are abstract entities in Dung’s framework, in sequent-based argumentation, arguments are represented by Gentzen-style sequents [112] derivable in the core logic (the deductive base) of the framework.

Sequent-based argumentation is a modular and flexible method of logical argumentation, that allows to take many interesting logics as the deductive base and can be generalized in many ways. The framework as it was available at the end of 2015,
has several advantages over other structured argumentation approaches, but there are some shortcomings as well:

- Not every interesting logic has a cut-free sequent calculus, a useful requirement for a logic to be taken as the deductive base of an argumentation framework.

- It is not possible to make a distinction between defeasible and strict assumptions: all formulas in the support (the antecedent of the sequent) of an argument can be attacked.

- How to deal with preferences among formulas in the support set is still an open question, though reasoning with preferences is very common, also in the argumentation literature.

- An extensive investigation of desirable properties of the argumentation frameworks has not been carried out yet.

In this thesis papers are collected that investigate the research gaps above. The result is a modular and very flexible method. Many logics can be taken as the deductive base and it can be applied in settings with defeasible and strict premises, when there are preferences among the formulas in the support set and when the core logic does not have an attractive Gentzen-style sequent calculus (but there is an attractive hypersequent calculus for it). Sequent-based argumentation is also very expressive, since several other approaches to defeasible reasoning can be expressed in it. These properties are essential to have, when developing sequent-based argumentation further into a unifying account of defeasible reasoning.

**Main Results**

The results in this thesis can be summarized as follows:

- Two types of desirable properties were studied from a proof-theoretic perspective. One investigates relevance properties, known from relevance logic and non-monotonic logic. The other is concerned with the rationality postulates introduced for argumentation frameworks. In both cases we studied what an argumentation framework has to look like in order for the properties to be satisfied. We have found that the first set of properties is satisfied when the core logic has certain relevance characteristics. For the rationality postulates it was shown that more properties are satisfied when the argumentation framework is based on direct versions of the attack rules.

- An extensive investigation in the representation of reasoning with maximally consistent subsets was done. On the one hand in general for logical argumentation, in the form of a survey of the existing literature. On the other hand, for sequent-based argumentation, including many entailment relations of reasoning with maximally consistent subsets. From both studies it can be concluded that logical argumentation is suitable to express the underlying argumentative dynamics of reasoning with maximally consistent subsets.
• Arguments can now be represented by hypersequents, a generalized form of Gentzen’s sequents. The resulting framework allows for more core logics and several desirable properties are satisfied that under the same setting fail in sequent-based argumentation. With this study, it is shown that the representation of arguments by sequents can easily be generalized to hypersequents.

• A prioritized setting for sequent-based argumentation was introduced. A variety of possible preference orderings were studied and many desirable properties were shown to hold.

• It is possible to distinguish facts and defeasible assumptions, by adding an additional component to each sequent. This way, other approaches to reasoning with defeasible assumptions from the literature can be expressed by sequent-based argumentation. Moreover, it was shown that sequent-based argumentation can easily be generalized to a setting in which the input consists of facts and assumptions.