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A logic-based theory of deductive arguments ☆

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Abstract

We explore a framework for argumentation (based on classical logic) in which an argument is a pair where the first item in the pair is a minimal consistent set of formulae that proves the second item (which is a formula). We provide some basic definitions for arguments, and various kinds of counter-arguments (defeaters). This leads us to the definition of canonical undercuts which we argue are the only defeaters that we need to take into account. We then motivate and formalise the notion of argument trees and argument structures which provide a way of exhaustively collating arguments and counter-arguments. We use argument structures as the basis of our general proposal for argument aggregation.

There are a number of frameworks for modelling argumentation in logic. They incorporate formal representation of individual arguments and techniques for comparing conflicting arguments. In these frameworks, if there are a number of arguments for and against a particular conclusion, an aggregation function determines whether the conclusion is taken to hold. We propose a generalisation of these frameworks. In particular, our new framework makes it possible to define aggregation functions that are sensitive to the number of arguments for or against. We compare our framework with a number of other types of argument systems, and finally discuss an application in reasoning with structured news reports.

Keywords: Argumentation systems; Arguments; Counter-arguments; Inconsistency handling; Logic; Undercuts

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1. Introduction

In an argument, we distinguish the reasons, the conclusion and the method of inference by which the conclusion is meant to follow from the reasons. The nature of inference is diverse and includes analogical inference, causal inference, and inductive inference. We focus on deductive inference and hence on deductive arguments, i.e., the conclusion is a deductively valid consequence of the reasons. We investigate the formalisation of such arguments in the setting of classical logic. So, our starting position is that a deductive argument consists of a claim entailed by a collection of statements such that the claim as well as the statements are denoted by formulae of classical logic and entailment is identified with deduction in classical logic.

In our framework, an argument is simply a pair where the first item in the pair is a minimal consistent set of formulae that proves the second item. That is, we account for the reasons and the conclusion of an argument though we do not indicate the method of inference since it does not differ from one argument to another: We only consider deductive arguments, hence the method of inference for each and every argument is always entailment according to classical logic.

Most proposals for modelling argumentation in logic are very limited in the way that they combine arguments for and against a particular conclusion following. A simple form of argumentation is that a conclusion follows if and only if there is an argument for the conclusion and no argument against the conclusion. In our approach, we check how each argument is challenged by other arguments, and by recursion for these counter-arguments. Technically, an argument is undercut if and only if some of the reasons for the argument are rebutted. Each undercut to a counter-argument is itself an argument and so may be undercut, and so by recursion each undercut needs to be considered. Exploring systematically the universe of arguments in order to present an exhaustive synthesis of the relevant chains of undercuts for a given argument is the basic principle of our approach.

Following this, our notion of an argument tree is that it is a synthesis of all the arguments that challenge the argument at the root of the tree, and it also contains all counter-arguments that challenge these arguments and so on recursively.

Modelling argumentation has been a subject of research as long as the study of logic. They are closely intertwined topics, and modelling argumentation in logic is a natural, and important, research goal. A useful introduction to argumentation is in [23], and comprehensive recent reviews of argumentation in logic include [5,20]. The argumentation formalism that we give in this paper, including the notions of argument trees and argument structures, provides a complementary addition to the set of existing proposals for logic-based argumentation systems.

In Sections 2, 3, and 4, we provide some basic definitions for arguments, and various kinds of defeaters. This leads us to the definition of canonical undercuts which we argue are the only defeaters that we need to take into account (Section 5). We then motivate and formalise the notion of argument trees and argument structures which are a way of exhaustively collating arguments and counter-arguments (Sections 6–8). We use argument structures as the basis of our general proposal for argument aggregation. In Section 9, we compare our framework with some other logic-based argument systems. Finally, we discuss an application to argumentation with structured news report (Section 10).