Formalization of Argument Accrual: Acceptability Semantics and Dialectical Proof Procedure

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Argumentation is a powerful paradigm able to formalize commonsense reasoning, finding application in different domains such as automated reasoning, decision making, legal dispute, automated negotiation, etc. However, most of these argumentation-based formalizations do not model the notion of *argument accrual*, which has been recently gaining importance. This thesis defines a novel formalization of argument accrual, including a declarative characterization of this notion and an associated operational characterization addressing computation. The proposed formalization makes contributions to the existing accrual approaches, mainly concerning the answers obtained, answer explanation, accrual evaluation and comparison, and efficiency of computation.

Keywords: Argumentation, commonsense reasoning, argument accrual

1. Introduction

Argumentation is a mechanism that we generally use to debate a given issue, either with other humans or subjectively with ourselves. In a general sense, it is a reasoning process in which arguments supporting different conclusions are considered. An argument for a given conclusion can be disputed or *attacked* by other arguments and then, during the argumentation process, a conclusion originally justified by an argument may cease to be accepted in the light of new arguments. The final purpose of the argumentation process is to determine which conclusions are *justified*.

Artificial Intelligence (AI) has long wrestled with the challenge of modeling commonsense reasoning, which almost always occurs in the face of incomplete and potentially inconsistent information. Several argumentation-based formalisms emerged in the AI field to address this challenge, and have been successfully applied to different artificial intelligence problems such as negotiation, decision making, legal reasoning, recommendation systems, and ontology reconciliation, among other.

This thesis [1] addresses the problem of modeling the notion of argument accrual, which is based on the intuitive idea that different reasons (arguments) supporting the same conclusion generally provide, as a set, a stronger support for the conclusion than each of the individual reasons alone. Although accrual is a natural feature of argumentation, generally affecting the final result of the argumentative process, most of the existing argumentation frameworks do not allow to naturally model it. There exist two frameworks that do: Verheij's Cummula system [7], modeling accrual through arguments as tree-like structures able to represent coordination of reasons, along with a compound notion of defeat, and Prakken's approach [6], proposing three general principles of argument accrual, and an associated formalization instantiating the traditional frameworks of abstract argumentation with a notion of accrued argument derived using labels. This thesis presents a novel formalization of argument accrual, involving a declarative characterization of this notion (acceptability semantics for accrual), and an associated operational characterization addressing com-

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putation (dialectical proof procedure). The proposed formalization conforms with Prakken's principles, and makes contributions to the other two approaches for argument accrual, mainly concerning the answers obtained, answer explanation, accrual evaluation and comparison, and efficiency of computation. Further, we demonstrate different consistency properties supporting the soundness of the proposal.

2. Contributions

The following sections summarize the main aspects of the formalization of argument accrual proposed in the thesis.

2.1. Accrued structures, partial attack and partial defeat

As the first step towards the formalization of accrual, we proposed the notion of *accrued structure* (or a-structure, for short), accounting for the aggregation of a set of arguments supporting the same conclusion. Different operations on accrued structures were defined, such as union, intersection, and difference, which simplifies subsequent formalization. Then, the notions of *partial attack* and *partial defeat* were formalized, constituting accrual versions of *attack* and *defeat* in traditional argumentation, where the qualification of "partial" indicates that only a part of the disputed a-structure may be affected. Associated with this partiality of the effect of an attack, it has been shown that a set of a-structures attacking another at different parts may combine to cause a greater defeat on the target, compared with the union of the effects (defeated parts) caused by the attacking a-structures considered individually. The effect of a combined attack against an a-structure was captured through the definition of *sequential degradation*, which directly suggests a computation procedure. The partiality of attacks and defeats is one of the main differences with the other two existing approaches, allowing acceptability to be determined by constructing only maximal accruals for each conclusion. This means that the acceptability analysis is performed on a smaller graph, leading to significant improvements in efficiency of computation and clarity of answer explanations. This proposal was published in [2,4,5].

2.2. Acceptability semantics for accrual and dialectical proof procedure

Three acceptability semantics for a-structures were presented, viz., *a-grounded*, *a-preferred* and *a-stable*, which can be seen as accrual versions of the broadly recognized semantics of *abstract argumentation*. Different desirable consistency properties associated with the proposed semantics were proved. A dialectical proof procedure associated with the a-grounded semantics was presented, which can be seen as the formalization of a discussion between two parties where each one advances a-structures by turns against an a-structure previously advanced by its opponent. An advantage of this computational approach is that the constructed *discussion tree* constitutes itself an explanation for the answer obtained. Our approach mainly coincides with Verheij's and Prakken's with respect to the answers, improving the former in some particular situations where the effect of indirect attacks is incomplete or too weak, and the latter by returning more complete (while still skeptical) answers in some indecision situations. Also, Verheij's approach does not include computational procedures. A preliminary version of this proposal can be found in [2,4,5].

2.3. Possibilistic instantiation

A possibilistic instantiation of our formalization of accrual was proposed, advancing on the issue of accrual evaluation to determine defeat; this problem is not addressed by other frameworks modeling accrual. On the one hand, this proposal allows to explicitly represent necessity degrees associated with the sentences at the object language level. On the other hand, the approach defines a mechanism to synthesize a necessity degree for a given a-structure from the degrees associated with its constituent sentences. This mechanism combines the propagation of necessity degrees when performing rule-based inference with a way of accumulating necessity values coming from different rules with the same conclusion. Additionally, as we do not want to commit ourselves to a specific way of aggregating necessity degrees, the aggregation is parameterized with respect to a user-defined function that is required to satisfy different mathematical conditions to ensure a sound instantiation. This approach was published in [3].

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