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Optimization of dialectical outcomes in dialogical argumentation ☆

Anthony Hunter [a], Matthias Thimm [b]

[a] Department of Computer Science, University College London, UK
[b] Institute for Web Science and Technology, University of Koblenz–Landau, Germany

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ABSTRACT

When informal arguments are presented, there may be imprecision in the language used, and so the audience may be uncertain as to the structure of the argument graph as intended by the presenter of the arguments. For a presenter of arguments, it is useful to know the audience's argument graph, but the presenter may be uncertain as to the structure of it. To model the uncertainty as to the structure of the argument graph in situations such as these, we can use probabilistic argument graphs. The set of subgraphs of an argument graph is a sample space. A probability value is assigned to each subgraph such that the sum is 1, thereby reflecting the uncertainty over which is the actual subgraph. We can then determine the probability that a particular set of arguments is included or excluded from an extension according to a particular Dung semantics. We represent and reason with extensions from a graph and from its subgraphs, using a *logic of dialectical outcomes* that we present. We harness this to define the notion of an *argumentation lottery*, which can be used by the audience to determine the expected utility of a debate, and can be used by the presenter to decide which arguments to present by choosing those that maximize expected utility. We investigate some of the options for using argumentation lotteries, and provide a computational evaluation.

1. Introduction

Computational models of argument aim to reflect how human argumentation uses conflicting information to construct and analyze arguments. There is a number of frameworks for computational models of argumentation. They incorporate a formal representation of individual arguments and techniques for comparing conflicting arguments (for reviews see [9,13]).

In abstract argumentation, a graph is used to represent a set of arguments and counterarguments. Each node is an argument and each arc from an argument α to an argument β denotes an attack by α on β. It is a well-established and intuitive approach to modelling argumentation, and it offers a valuable starting point for theoretical analysis of argumentation [26]. However, including an argument α in a graph usually means that one is sure that α is a *justifiable* argument, i.e., that it is an argument that makes sense (independently of whether it can be *accepted* after relating it to other arguments). Abstract argumentation does not explicitly consider whether (or to what degree) an argument is believed to be justifiable or whether

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E-mail address: thimm@uni-koblenz.de (M. Thimm).

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(or to what degree) an attack by an argument is believed to justifiable. It only represents the existence of arguments and counterarguments in a strict manner.

To address the need to represent and reason with (quantified) uncertainty, it has been proposed to use a probability assignment to arguments and to attacks [12]. This can be used to give a probability distribution over the subgraphs of the argument graph, and this can then be used to give a probability assignment for a set of arguments being an admissible set or extension of the argument graph [49,42,45]. The probability distribution over subgraphs denotes the uncertainty over which subgraph is the actual graph that should be used. We refer to an argument graph with a probability distribution over subgraphs as a *probabilistic argument graph*.

Consider a typical argumentation scenario for persuasion [70,11], i.e., a scenario where one or more agents are presenting arguments in front of an audience, with the aim of each participant being to persuade the audience to adopt a certain statement. We assume that each participant and the audience have some argument graph in mind but are willing to incorporate new arguments and attacks into it. In this context, we believe the following are two important applications for probabilistic argument graphs:

- **From an audience's perspective**, there may be uncertainty as to what the actual argument graph is. The audience may hear various comments in a debate, for example, but they are not sure about the exact set of arguments and attacks that are being put forward. For instance, there may be uncertainty about whether someone has put forward a complex multifaceted argument, or a number of smaller more focused arguments or there may doubt about whether some arguments are just rephrasings of previous arguments. There may be uncertainty about which arguments are meant to be attacked by some argument, which occurs frequently when enthymemes (incomplete arguments) are presented. So the audience can collate all the candidates for arguments and attacks, and construct the graph containing them all, and then identify a probability distribution over its subgraphs that reflects their uncertainty about which is the actual graph.
- **From a participant's perspective** (i.e. from the perspective of someone who is about to present arguments and/or attacks to some monological or dialogical argumentation), there may be uncertainty about what the audience regards as the argument graph. When a participant (such as a politician) considers presenting arguments to an audience, the participant might not know for sure which arguments and attacks the audience has in mind. In other words, even before a participant has started, the audience may already have an argument graph in mind and the participant will be adding to that graph in the audience's mind. To handle this, the participant may have an argument graph which he/she assumes will subsume the possibilities for the argument graph held by the audience, and then the participant might identify a probability distribution over subgraphs of the argument graph to reflect the uncertainty as judged by the participant over which is the subgraph being used by the audience.

In this paper we investigate the use of probabilistic argument graphs as the underlying knowledge representation formalism in dialogical argumentation scenarios. Besides the rich expressivity of probabilistic argument graphs, this formalism can also be used for the problem of rational action selection, i.e., which arguments to disclose in order to maximize the utility of the result of the dialogue. As we will see, we can utilize probabilistic argument graphs to determine the probability of possible outcomes of an argument graph.

We define these outcomes as formulae of an expressive logic of dialectical outcomes for reasoning about subgraphs and extensions of argument graphs. This logic allows the representation of complex statements about argument graphs—such as "there is a subgraph of the graph where all preferred extensions contain either α or β"—and can thus be used to represent desired outcomes and means to reach them. For probabilistic argument graphs, we can determine the probability of those formulae. From an audience's perspective, this gives a better understanding of the consequences of the debate that they are observing, and from a participant's perspective, it gives a better understanding of whether s/he will get the desired outcomes from his/her contributions to the argumentation.

We further exploit probabilistic argument graphs, by introducing the notion of *lotteries* for argumentation. Lotteries are an important approach to decision-making with uncertainty. In a lottery, there are a number of outcomes, and probability associated with each of them. For example, if we buy a lottery ticket for 1 Euro, with the prize being 500 Euros, and there are 1000 tickets, then we have the outcome "win" with the probability 1/1000 and the outcome "lose" with a probability of 999/1000. We can then measure the utility of each outcome. For instance, the utility of "win" could be 500 for the prize minus 1 for the cost of entering (i.e. net utility is 499), and the utility of "lose" is -1. The expected utility of buying the ticket is then $(499 \times 1/1000) + (-1 \times 999/1000)$ is $-1/2$ Euro, whereas the expected utility of not buying the ticket is 0 Euro, which suggests it is not a good decision to buy the ticket.

Assume that during a discussion, a debater wants to identify a good argument to bring into the discussion and that the audience of the discussion is considering some subgraph of G as the *true* argument graph. The debater does not know for sure which subgraph is the correct one but he can identify a probability distribution over the subgraphs. Now, suppose he is keen that arguments α and β are accepted by the audience (e.g. they are both in the grounded extension of whichever subgraph the audience is using). So the outcome we want is that α and β are included in the grounded extension. If this is not possible, then perhaps he wants the outcome where α is included and β excluded. Suppose any other outcome is inferior to these two outcomes. By using the probabilistic argument graphs, we are able to determine a probability for each of these outcomes, and we can construct a lottery containing these arguments. If we identify a utility function over

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