Argumentative Reasoning with ABEL

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Abstract. Most formal approaches to argumentative reasoning under uncertainty focus on the analysis of qualitative aspects. An exception is the framework of probabilistic argumentation systems. Its philosophy is to include both qualitative and quantitative aspects through a simple way of combining logic and probability theory. Probabilities are used to weigh arguments for and against particular hypotheses. ABEL is a language that allows to describe probabilistic argumentation systems and corresponding queries about hypotheses. It then returns arguments and counter-arguments with corresponding numerical weights.

1 Introduction

In the last couple of years, *argumentation* has gained growing recognition as a new and promising research direction in artificial intelligence. As a consequence of this increasing interest, different authors have investigated argumentation and its application in various domains. By looking at today's literature on this subject, one realizes that argumentation is understood in fairly different ways. The common feature of most approaches is their restriction to particular types of logic. As a consequence, they are all limited in the way they combine arguments for and against a particular hypothesis.

The approach we present in this paper is known as *probabilistic argumentation systems* (PAS) [8]. The idea of the PAS framework goes back to the concept of *assumption-based truth maintenance systems* (ATMS) [5]. It is also closely related to *abduction* [4, 9]. The idea is to understand argumentation as a deductive tool that helps to judge *hypotheses*, that is open questions about the unknown or future world, in the light of the given uncertain and partial knowledge. From a qualitative point of view, the problem is to derive *arguments* in favor and *counter-arguments* against the hypothesis of interest. Every argument is a defeasible proof built on uncertain *assumptions*. In other words, arguments are chains of true or false assumptions that make the hypothesis true. Efficient algorithms are obtained by focusing the search on the most relevant arguments [6, 7].

In a second step, a quantitative judgement of the situation is obtained by considering the probabilities that the arguments are valid. The credibility of a hypothesis can then be measured by the probabilities that it is supported or defeated by at least one argument. Conflicts are handled through conditioning. The resulting *degrees of support* and *possibility* correspond to *belief* and *plausibility*, respectively, in the Dempster-Shafer theory of evidence [11, 12, 10]. Although a qualitative judgement may be valuable in many ways, a quantitative judgement is often more useful and helps to decide whether a hypothesis can be accepted, rejected, or whether the available knowledge does not permit to decide.

A system called ABEL [2, 3] is an example of implementing probabilistic argumentation systems (check out `http://www2-iiuf.unifr.ch/tcs/ABEL`). It includes an appropriate modeling and query language, as well as corresponding inference mechanisms. Problems from a broad spectrum of application domains show that the ABEL system is very general and powerful [1]. It has an open architecture that permits the later inclusion of further or more advanced deduction techniques. The aim of this paper is to provide a short introduction to ABEL. Our hope is to increase the recognition of PAS as a legitimate formal model and ABEL as powerful tool for reasoning under uncertainty.

2 Probabilistic Argumentation Systems

The basic ingredients for probabilistic argumentation systems (PAS) are *propositional logic* and *probability theory*. More formally, we require two disjoint sets $P = \{p_1, \ldots, p_n\}$ and $A = \{a_1, \ldots, a_m\}$ of propositional symbols. The elements of P are called *propositions* and the elements of A *assumptions*. With $\mathcal{L}_{A \cup P}$ we denote the corresponding propositional language that consist of elements of $A \cup P$ only. Furthermore, we require a propositional sentence $\xi \in \mathcal{L}_{A \cup P}$ that expresses the qualitative part of the given knowledge. The formula ξ is called *knowledge base*. Finally, a set $\Pi = \{p(a_i) : a_i \in A\}$ of independent probabilities is required to expresses the quantitative knowledge. Note how the connection between propositional logic and probability theory is established through the assumptions. A quadruple (P, A, Π, ξ) is called *probabilistic argumentation system* (PAS).

The knowledge base ξ is usually assumed to be satisfiable. Note that ξ is often given as a conjunction $\xi = \xi_1 \wedge \cdots \wedge \xi_r$ of sentences $\xi_i \in \mathcal{L}_{A \cup P}$. In such a case, it is useful to consider the corresponding set $\Sigma = \{\xi_1, \ldots, \xi_r\}$ and to call Σ knowledge base.

Example 1. Let $P = \{X, Y, Z\}$ and $A = \{a_1, a_2, a_3, a_4, a_5\}$ be the sets of propositions and assumptions, respectively. Furthermore, suppose that

$$\Pi = \{p(a_1) = 0.2,\ p(a_2) = 0.4,\ p(a_3) = 0.8,\ p(a_4) = 0.3,\ p(a_5) = 0.3\}$$

are the probabilities of the assumptions and

$$\begin{aligned}\xi = (a_1 \rightarrow X) \wedge ((a_2 \vee \neg a_3) \rightarrow Y) \wedge ((X \wedge Y) \rightarrow Z) \wedge (\neg a_4 \rightarrow Z)\\ \wedge ((a_5 \wedge Y) \rightarrow \neg Z)\end{aligned}$$

the given knowledge base. This forms a probabilistic argumentation system (P, A, Π, ξ). Note that the knowledge base ξ is a conjunction that can be represented more easily as a set of five individual formulas:

$$\Sigma = \{a_1 \rightarrow X,\ (a_2 \vee \neg a_3) \rightarrow Y,\ (X \wedge Y) \rightarrow Z,\ \neg a_4 \rightarrow Z,\ (a_5 \wedge Y) \rightarrow \neg Z\}.$$

The question now is how to use a PAS for the purpose of analyzing and answering queries about *hypotheses*. A hypothesis h is usually expressed by simple a expression that includes symbols of $A \cup P$. To be most general, we consider arbitrary propositional formulas $h \in \mathcal{L}_{A \cup P}$. The approach we promote is to construct arguments and counter-arguments based on the set of assumptions A and to weigh them with the aid of the given probabilities Π. For corresponding formal definitions and descriptions of appropriate inference techniques we refer to the literature [8, 6, 7].

3 ABEL

Working with ABEL typically involves two sequential steps. First, the given information is *modeled* using the command `tell`. It is used to define the two sets A and P, the probabilities Π, and the knowledge base ξ. Second, queries about the knowledge base are expressed using the command `ask`.

An ABEL model usually starts with the declaration of the sets P, A, and Π. The distinction between the elements of P and A is made by using two distinct commands `var` and `ass`. Look below how it's done for the example introduced in the previous section. Assumptions with different probabilities must be defined on different lines. The keyword `binary` means that only two values are allowed (*true* and *false*). Note that ABEL also supports variables with more than two values [2, 3, 1].

The knowledge base ξ is then described using a LISP-like prefixed language. If ξ is given as a set of statements Σ, then every individual statement is written on a separate line. Again, consider the example of the previous section and look how it's done.

```
(tell
  (var X Y Z binary)
  (ass a1 binary 0.2)
  (ass a2 binary 0.4)
  (ass a3 binary 0.8)
  (ass a4 a5 binary 0.3))
```

```
(tell
  (-> a1 X)
  (-> (or a2 (not a3)) Y)
  (-> (and X Y) Z)
  (-> (not a4) Z)
  (-> (and a5 Y) (not Z)))
```

Note that the statements can also be distributed among different `tell`-commands. Furthermore, it is also possible to mix variable declarations and statements about the knowledge base. The only rule is that every variable must be declared before it is first used.

ABEL supports different types of queries. In the context of argumentative reasoning, the most important commands are `sp` (support), `dsp` (degree of support), and `dps` (degree of possibility). Suppose Z is the hypothesis of interest in Example 1. Observe how `sp` can be used to compute arguments and counter-arguments for Z.

```
? (ask (sp Z))
  53.3% : (NOT A4) (NOT A5)
  24.0% : A1 A2 (NOT A5)
  18.7% : A1 (NOT A3) (NOT A5)
   4.0% : A3 (NOT A2) (NOT A4)
```

```
? (ask (sp (not Z)))
  56.3% : A2 A4 A5 (NOT A1)
  43.7% : A4 A5 (NOT A1) (NOT A3)
```

In this simple case, we have four arguments and two counter-arguments. The first argument for Z is $\neg a_4 \wedge \neg a_5$. Note that $\neg a_4$ alone is not an argument for Z (because $\neg a_4$ together with a_5 produces a conflict). To get a quantitative evaluation of the hypothesis, we can compute corresponding degrees of support and possibility.

```
? (ask (dsp Z))              ? (ask (dps Z))
  0.695                        0.958
```

The above numerical results tell us that the hypothesis Z is supported by a relatively high degree. At the same time, there are only few reasons against Z which leads to a degree of possibility close to 1.

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