Argumentation and decision making: a position paper

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Abstract. This paper summarises our position on the use of symbolic methods for reasoning under uncertainty, and argumentation in particular. Our view is that argumentation offers a complement to numerical methods for reasoning about belief, and a general framework within which many competing approaches can be understood. In applications we have found that argumentation offers a variety of benefits for practical reasoning systems. The presentation is historical, emphasising the reasons which motivated the development of the argumentation framework, drawing primarily on work carried out by researchers at the Imperial Cancer Research Fund since about 1980.

1 The need for symbolic decision making

Work on argumentation at the Imperial Cancer Research Fund arose out of a series of studies on medical decision making, including work on modelling human diagnostic reasoning [9] and comparisons of the relative merits of numerical and symbolic inference techniques in clinical decision making [11, 16, 22]. These studies strongly suggested, contrary to the assumption prevalent at the time, that numerical methods were not the only sound and practical means of making decisions under uncertainty.

The first line of work was in an empirical tradition, concerned with how people make decisions and the strengths and weaknesses of the decision making process. One study investigated diagnostic decision making by medical students and compared two computational models of decision making on a simulated medical diagnosis problem [10]. The models were implemented as sets of production rules, one implementing a statistical model and one a knowledge-based, semi-qualitative model. The results strongly suggested that the latter model gave a better account of human reasoning under uncertainty. This is consistent with a well established finding from psychological research that people do not manage uncertainty in ways which closely resemble normative probabilistic reasoning.

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Classical decision theorists have strongly criticised human judgement precisely on the grounds that people do not comply with the requirements of probability theory. In contrast some cognitive scientists have questioned the force of this observation by emphasising the flexibility and other virtues of human reasoning (e.g. [24]). This observation was reinforced by a study which investigated the performance of an expert system based on a model of human reasoning [11]. In a realistic diagnostic problem in gastroenterology it was found that the diagnostic accuracy of the expert system was very similar to that of a Bayesian diagnostic system though the expert system achieved this level of performance using only half the information provided to the probabilistic system.

Other empirical studies suggest that, notwithstanding the quantitative precision of probabilistic evidence analysis, much practical medical decision making can be successfully carried out without precise numerical data. For example [16], a rule-based system for leukaemia diagnosis was developed using the EMYCIN expert system shell. The accuracy of the system, as compared with the decisions of a domain expert, was 64%. When the CFs were limited to just two values, 1.0 or 0.5 (loosely "certain" or "uncertain") a 5% *increase* in correct diagnoses was observed! In another study, decision making using a semiqualitative decision procedure was compared with a probabilistic procedure using data regarding the admission of 140 patients to a coronary care unit. It was found that the symbolic decision model performed at least as well as the probabilistic model as determined by an ROC analysis [22]. Other independent studies have confirmed the finding that practical decision making can be carried out successfully without depending upon precise quantitative data (e.g. [4]).

2 A model for reasoning under uncertainty

Having established these results, the motivation for further work was an interest in building decision support systems which would have a number of advantages over conventionally available technologies:

- They would not depend upon the availability of objective statistical data (which are frequently not available in complex domains like medicine)
- They could make use of other kinds of reasoning than statistical inference (e.g. causal, functional and temporal reasoning) which might be more intuitive than quantitative reasoning.
- They could support all phases of decision making, not just evidence analysis, such as recognising when a decision is needed, what the decision options are, what information is relevant to the choice and so forth.

An initial framework for "symbolic decision theory", using first-order logic for much of the deductive reasoning required and argumentation for the management of uncertainty, was proposed [12, 14], and evidence for the practicality of the theory came from its use in the Oxford System of Medicine (OSM) [13]. This is a decision support system aimed at general practitioners which provides a generic decision procedure for a range of medical decision tasks. Evidence that the symbolic decision theory is very versatile comes from the wide range of possible applications that have now been developed [8].

In addition, however, it was agreed, in accordance with the view generally held by decision theorists, that any decision procedure which is to be used for practical applications, particularly those like medical applications which have safety implications, must be given a sound theoretical underpinning. While the symbolic approach might be "inspired" by observations of human flexibility, people make mistakes and it is clearly not desirable to emulate those mistakes!

3 Formalising the model

The most contentious element of symbolic decision theory is the use of argumentation as the basic framework for reasoning under uncertainty. The central idea in argumentation is that of a *tentative proof* of a proposition. The fact that a proposition can have arguments for and against it suggests a divergence between argumentation and classical first order logic in which propositions are true or false. Furthermore, as pointed out in [2], argumentation has many commonalities with intuitionistic logic, suggesting that argumentation might be given a sound basis in category theory since this is possible for intuitionistic logic. The first steps in providing this basis are detailed in [2] which identifies the structure of the space of arguments, along with the kind of operations possible over them. The rest of the formalisation is provided in [1], which also highlights the link between argumentation and Dempster-Shafer theory.

With this semantics in mind, it is possible to define a logic LA in which the consequences of a database are a set of arguments, and this is the subject of [3] and [19]. In this work logical formulae are augmented with their proofs and when formulae are combined, the proofs are handled in an appropriate manner. This means that it is possible to determine the validity of formulae derived in the logic based upon the strength of the arguments for and against individual formulae, and that the way in which this is done is in accordance with the category-theoretic semantics. This process has been automated in the Argumentation Theorem Prover [20], and a summary of the formal model is recorded in [18].

4 A general model of reasoning

In addition to the arguments for argumentation as a symbolic model of decision making, we can argue [15] that it is a model of "practical reasoning" of the kind that humans indulge in every day. It captures many of the modes of commonsense reasoning—finding support for ideas, attacking other ideas, and trying to attack the support of other ideas. It handles contradictions, and should also enable the resolution of conflicting arguments at the meta-level. Furthermore, there is a strong case that argumentation provides a general framework for unifying many methods for reasoning under uncertainty, such as possibility and probability [23] theories. In this role argumentation is less a formalisation of human reasoning than a tool that can enable the use of other formalisms. Argumentation provides a general way of combining logical reasoning with Bayesian probability by using it to construct a network of influences between relevant variables. Indeed, argumentation is sufficiently general as to underlie symbolic as well as quantitative formalisms [21].

However, it is possible to do more with argumentation than just provide a framework for using established formalisms, instead, as is discussed in [6], it is possible to handle inconsistent information. That is, it is possible to have certain arguments for both a proposition p and its negation $\neg p$. This inconsistency enables LA to provide a ranking over the propositions for which arguments may be proposed. In particular, arguments for propositions are allocated different classes of acceptability [5, 7], the allocation depending on factors such as whether an argument is based on a consistent database or whether there are any counter-arguments. This approach can be used to give a purely logical approach to uncertainty that ranks propositions only on the structure of the arguments for them, and it can be augmented by the use of preference relations over subsets of the database.

5 Summary

To summarise, empirical evidence for the usefulness of a symbolic theory of decision making has led to the development of a formal model based on first-order logic combined with the use of argumentation for handling uncertainty. The versatility of the model is suggested by its wide practical applicability, while the justification for the use of argumentation is based upon its proven practical flexibility and its well-developed formal semantics.

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