Capturing Critical Questions in Bayesian Network Fragments

Extended abstract

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Abstract. Legal reasoning with evidence can be a challenging task. We study the relation between two formal approaches that can aid the construction of legal proof: argumentation and Bayesian networks (BNs). Argument schemes are used to describe recurring patterns in argumentation. Critical questions for many argument schemes have been identified. Due to the increased use of statistical forensic evidence in court it may be advantageous to consider probabilistic models of legal evidence. In this paper we show how argument schemes and critical questions can be modelled in the graphical structure of a Bayesian network. We propose a method that integrates advantages from other methods in the literature.

Keywords. Argument schemes, Bayesian networks, Critical questions, Legal evidence, Legal reasoning.

1. Introduction

In legal reasoning about evidence an interest in probabilistic models has arisen. In particular the general availability of forensic evidence, such as DNA, has contributed to this effect. Bayesian networks (BNs) are well-known models for capturing uncertainty. The intuitions behind BNs can, however, at times be unclear, especially for experts not trained in probability theory. In previous work [9] we showed how arguments about legal evidence can be constructed from a BN that models this evidence. In the current paper we propose a method to translate argument schemes with critical questions to BN fragments. Argument schemes capture recurring patterns of argumentation [10]. Since these patterns usually have exceptions they are often accompanied by critical questions. A typical argument scheme is the argument from *position to know*. Based on the generalisation that "witnesses usually tell the truth", it can be argued that a given testimony is probably true. More specific versions of this scheme exist, for instance for expert or eye witness testimonies. Various other recurring argument patterns have been identified but in this paper we will focus on testimony arguments because of their importance in legal proof.

2. Background

Starting with the diagrams of Wigmore [11], various models of proof and inference have been introduced. A recurring concept in argumentation theory is that of an argument scheme [10]. Argument schemes have been identified for various types of (legal) evidence. Critical questions point towards exceptional circumstances under which the "normal" inference from the evidence to the hypothesis does not apply. In this paper we study argument schemes from position to know (after [8,6,10]):

W is in the position to know about H
W testifies that H
Therefore, presumably, H

Critical Questions:

1. Veracity: is W sincere?
2. Objectivity: Did W's memory function properly?
3. Observational sensitivity: Did W's senses function properly?

Argument schemes and critical questions can guide the construction of arguments and counter-arguments. They have been used both in formal and in informal models of argumentation. In this paper we instead apply argument schemes for the construction of BNs.

A Bayesian network (BN) [5] is a widely accepted model of a probability distribution over a number of random variables. A BN graph $G = (\mathbf{V}, \mathbf{E})$ is an acyclic directed graph, consisting of nodes $\mathbf{V}$ and directed edges $\mathbf{E}$. With every variable a conditional probability table (cpt) is associated specifying the probability of its outcomes given any combination of outcomes of its parents. Since conditional probability tables are specified for all combinations of parent outcomes there is the possibility to encode complex interactions between parents.

3. Integrating models of argument schemes with critical questions

We now propose a method in which critical questions can be explicitly modelled in BNs. As an example consider Figure 1. We adopt a *signal filtering* perspective in which the variables are consecutively weaker formulations of a claim: X is true, a witness perceived X, the witness believes he saw X, and so on. The effect on the claim becomes weaker if we observe a node lower down the chain. Such a chain that models these inferential steps can be identified on the left of the figure. In the BN, we split the uncertain inference from the evidence to the conclusion into a number of inferences. Each of these inferences expresses an assumption of normality that corresponds to one of the critical questions. This corresponds to a perspective on legal argumentation where a proof is built on top of evidence in a step-wise manner. From the testimony it is first inferred that W sincerely believes that X happened. From this it is inferred that W indeed perceived X, followed by the conclusion that X must have happened. Such a view on legal proof is, for instance, visible in the treatment of the Sacco and Vanzetti case by Schum and Kadane [6]. They make an almost one-to-one mapping from Wigmore-charts

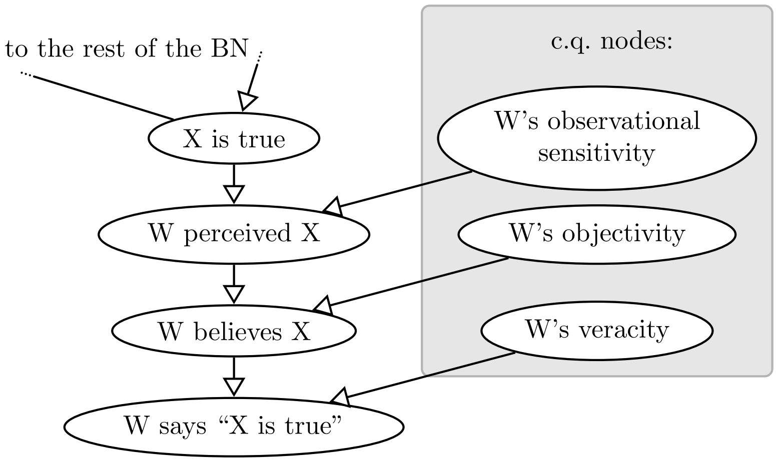

Figure 1. Modelling critical questions as a chain of exceptions.

(which model the step-by-step process of proof as we just described) to BNs, in which all arrows are simply reversed. We recognise a similar design in work by others, such as Hepler and Dawid [4] and Aitken et al. [1].

In contrast to what is commonly done in the literature, we add explicit variables for every critical question instead of leaving it implicit in the uncertainty tables of the nodes. These explicit exceptions are modelled in Figure 1 in the form of alternative explanations recognisable as head-to-head connections in the graph. The head-to-head connection through which they are connected to the inferential path from evidence to conclusion also explicitly shows that they can have an explaining away effect on that inference, as one would expect from a critical question.

The reason why we want explicit variables for critical questions is as follows. One can imagine that if the veracity of a witness becomes subject of debate, we may wish to extend the network by adding evidence nodes relating to this veracity. If veracity is modelled by a node in the BN this is easy, but implicitly modelling the veracity in a cpt makes this more difficult. A second consequence of implicit exceptions would be that the prior probabilities of critical questions are not easily identifiable in the model. If one needs to defend the correctness—or at least reasonableness—of such a BN it may be hard to explain how ones prior belief in the veracity of the witness is represented in the model.

This method requires that an ordering of the critical questions is necessary, which may not always be available. In this example the temporal order of events dictates such an order, but such a natural, intuitive ordering need not always exist.

For every additional critical question that is identified a constant number of additional parameters is added (which depends on the number of possible outcomes of the variables). In alternative BN models of testimony evidence [3,7,2], they are often attached to the same node which would result in an exponential growth of the number of parameters. Computationally our model combines the best of two worlds because there is no exponential growth in the number of parameters that need to be estimated to complete the model.

4. Conclusion

In this paper we have proposed a new way of modelling testimony evidence in BNs. We proposed a general method to capture argument schemes and critical questions in BN fragments. This can be used to guide the construction of a BN. We have argued that this model incorporates the best aspects from alternative models as presented in the literature [3,7,2,6,4,1]. We have focussed on testimony evidence arguments. We suspect that similar methods apply to other argument schemes inside and outside the legal domain but this requires further investigation.

Acknowledgement

This work is part of the project "Designing and Understanding Forensic Bayesian Networks with Arguments and Scenarios", supported by the Forensic Science research program financed by the Netherlands Organisation for Scientific Research (NWO). See `http://www.ai.rug.nl/~verheij/nwofs/`.

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