Follow the trace

Evaluating physical and digital forensic findings given activity level propositions using Bayesian networks

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Part II

STARTING SMALL: FROM IDIOMS TO CASE MODELS

All chapters from Part II are based on[1] Vink, M., & Sjerps, M. J. 2023. A collection of idioms for modeling activity level evaluations in forensic science. *Forensic Science International: Synergy* **6**, 100331.

Introduction to Part II

In forensic casework, many relevant questions go beyond the source of the trace. Part of these questions, known as activity level questions (Cook *et al.*, 1998), regard the manner of deposition of the trace and accordingly, the case propositions concern a dispute over an activity rather than a source. Forensic scientists must assess the likelihood of their findings concerning these activity level propositions. This assessment requires more information than source level evaluations, such as background distributions and probabilities of transfer, persistence, and recovery under different circumstances. The large amount of required information makes evidence evaluations at activity level a challenging practice. Some challenges include:

- a lack of knowledge on what variables influences the case findings
- a lack of available data on these variables
- a lack of uniformity in the evaluations, both between individual cases of the same expert and between different experts.

Evaluations given activity level propositions can be complex, but they can be invaluable for the legal process. Therefore, a more reliable and robust assessment framework is desired.

Aitken & Gammerman (1989) were one of the first to mention the use of Bayesian networks (BNs) in forensic science. Nowadays, these networks are increasingly being used to model activity level evaluations in this field. BNs are probabilistic graphical models that use Bayes' theorem to calculate event probabilities. These networks consist of nodes and directed links, which represent random variables and conditional dependencies between the variables respectively. Each node has its own conditional probability table (CPT), containing the probabilities of the various states of a variable conditioned on its parent nodes. The model can be used to derive the probability of an event occurring given all the relationships that exist within the model. For further information on BNs and probabilistic reasoning in general, we recommend Aitken and Gammerman (1989) and textbooks such as Garbolino & Taroni (2002) and Fenton & Neil (2018).

BNs are advantageous because of their ability to easily represent complex probabilistic relationships between variables. This makes them ideal for use in forensic science, where transparency and accurate results are required. Moreover, BNs are based on probability theory, which allows experts to revise probabilities for case propositions and uncertain variables. This helps them show how each piece of evidence affects their evaluation. Lastly, BNs are transparent, providing space for discussion and illustrating sources of uncertainty in the expert's reasoning.

Despite its potential benefits, the use of BNs within the legal framework has been limited. This is partly due to the complex, time-consuming and subjective nature of constructing an acceptable BN model for a legal case. And so the question is: how do we mitigate or eliminate these disadvantages?

Neil *et al.* (2000) propose an idiom-based approach to decrease the complexity of modeling Bayesian networks. The idiom-based approach divides the modeling process into smaller fragments, called idioms, that represent generic types of probabilistic reasoning (Lagnado, 2021; Neil *et al.*, 2000). They depict a set of variables and their probabilistic relationship, and can be modified and combined to form larger template or case models. Additional benefits include:

- Idioms can be constructed and reasoned about separately which makes them beneficial to the designer.
- Idioms give experts quick access to certain generic reasoning patterns, and they can choose which of these they want to integrate into a larger system.
- Idioms can easily be instantiated by transforming the node names into discipline- and case-specific variables.

- Idioms are advantageous for maintenance; modifying an idiom is much simpler than adjusting an entire template model.

- Idioms can be beneficial to (law) practitioners, as experts can explain their case model in a clear and concise manner.

Neil *et al.* (2000) state that "idioms act as a library of patterns for the BN development process." (p. 269) Research domains such as legal reasoning and medical reasoning (Kyrimi *et al.*, 2020; Lagnado *et al.*, 2013) have already developed a collection of idioms. Our goal is to present a collection of idioms particularly useful for modeling activity level evaluations in forensic casework. Chapter 2 combines a literature review of existing idioms (either generic or forensic) and our own suggestions of forensic idioms useful for activity level evaluations. Many of the perceived idioms are specified for other disciplines than forensic science. In such cases, we provide the generic version of the idiom as well as a forensic instantiation of that generic version. Furthermore, we extracted forensic reasoning patterns from template models and case models and translated them into idioms.

We provide the forensic expert with a collection of idioms consisting of five categories that are useful for evaluations given activity level propositions. In Chapter 3, we illustrate the idiom-based approach and the relevance of our collection by combining some of the presented idioms to create a larger template model. This model can be used for any kind of transfer evidence, in cases where the actor and/or the activity is disputed (Kokshoorn *et al.*, 2017). In addition, we provide concrete examples of how to use the idioms in forensic casework in Appendix B. We also refer to literature that utilizes the idioms in template models or case-specific models.