Follow the trace

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

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Chapter 3

A TEMPLATE BAYESIAN NETWORK FOR THE EVALUATION OF TRANSFER EVIDENCE GIVEN ACTIVITY LEVEL PROPOSITIONS

3.1 A template Bayesian network

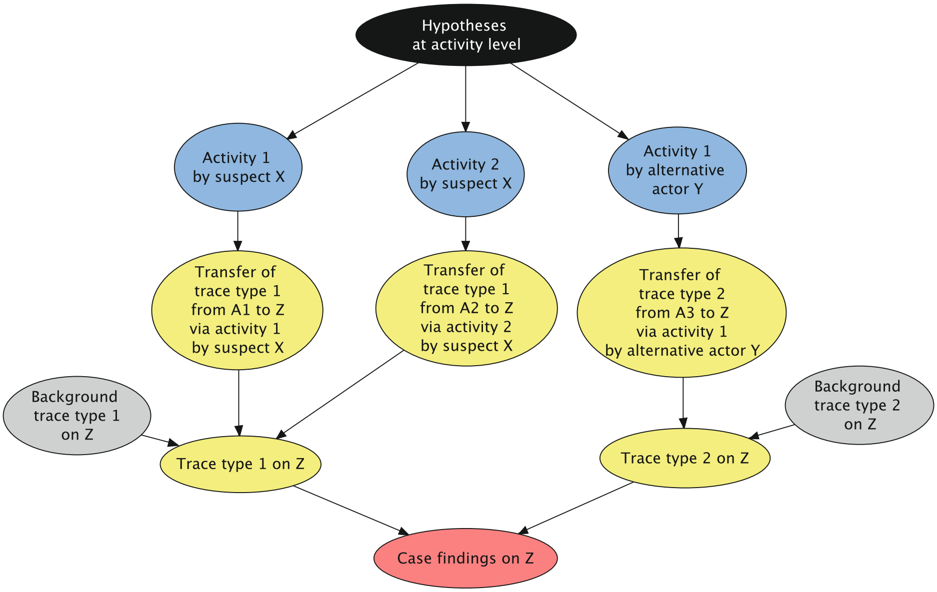

Figure 3.1: A template model for assessing the strength of transfer evidence at activity level. The template model is a combination of the hypothesis-to-transfer idiom (B.F2 in Fig. 2.6), the trace-accumulation idiom (C.F3 in Fig. 2.9), and the case-findings idiom (C.F4 in Fig. 2.9). The template Bayesian network is accessible via a QR code in Appendix A, available in both PDF and .oobn file formats.

In Chapter 2, we have discussed the collection of idioms. These can be combined to form template and case-specific models. To illustrate this approach, we present a template model in Fig. 3.1 that originates from merging the hypothesis-to-transfer idiom (B.F2 in Fig. 2.6), the trace-accumulation idiom (C.F3 in Fig. 2.9), and the case findings idiom (C.F4 in 2.9). Our template model is a generalization of the template model presented by Taylor *et al.* (2018) for constructing Bayesian networks in forensic biology cases when considering activity level propositions. The template model also incorporates the ideas in Kokshoorn *et al.* (2017) on propositions disputing the actor or activity in DNA evidence evaluation.

The template model illustrates the evaluation of transfer evidence regarding item Z by modeling the different possible pathways between trace deposition and the case findings on Z. The template model begins with a single node representing the case hypotheses, which is then divided into three activity nodes using the hypothesis-activity idiom. The hypothesis-to-transfer idiom is identical to the one illustrated in Section 2.3.2 on narrative idioms.

The template model is applicable to cases where "activity 1 by suspect X" and "activity 1 by alternative actor Y" lead to same type traces (for example in cases of indirect transfer) and to cases where these activities lead to different type of traces (i.e. DNA of suspect X and DNA of alternative actor Y respectively). Fig. 3.1 represents the latter and illustrates a case in which "activity 1 by suspect X" and "activity 2 by suspect X" lead to "trace type 1 on Z" and "activity 1 by alternative actor Y" leads to "trace type 2 on Z". The result of combining two transfer nodes into one node is the accumulation node TRACE TYPE 1 ON Z. This accumulation node is the expected evidence on Z considering the transfer activities and background material. Lastly, the case findings idiom merges all trace-accumulation nodes into a single node that summarizes the observed findings on item Z.

Our template model uses an integrated Bayesian approach to enforcing mutually exclusive hypotheses. TRANSFER OF TRACE TYPE 1 FROM A1 TO Z VIA ACTIVITY 1 BY SUSPECT X ensures that only the conditional probabilities given H_1 will follow that path. The mutually exclusive hypotheses are ensured by the CPT of CASE FINDINGS ON Z: it is only possible to observe the case findings through one of the routes. The expert may also choose to model each pathway using different BNs that are not joined (see Section 2.3.1 for further remarks on this issue).

The template model can be further expanded by including two categories: *hypothesis-conditioning* idioms from Section 2.3.4 and *evidence-conditioning* idioms from Section 2.3.5.

Traces on item Z are the central elements of the template model from Taylor *et al.* (2018) and consequently the model only considers possible pathways from activity to these traces. Item Z is automatically linked to the activities stated in the hypotheses and is considered as a relevant item in the case for at least one of the hypotheses. If Item Z is found to be irrelevant, using the model would be meaningless. The relevance of item Z can be modeled explicitly as a separate relevance node (e.g., Evett *et al.* (2002)) or as a subproposition node (e.g., De Koeijer *et al.* (2020)). The uncertain relationship between items and activities and how to model this in BNs is explored in Part III of this thesis.

3.2 An example

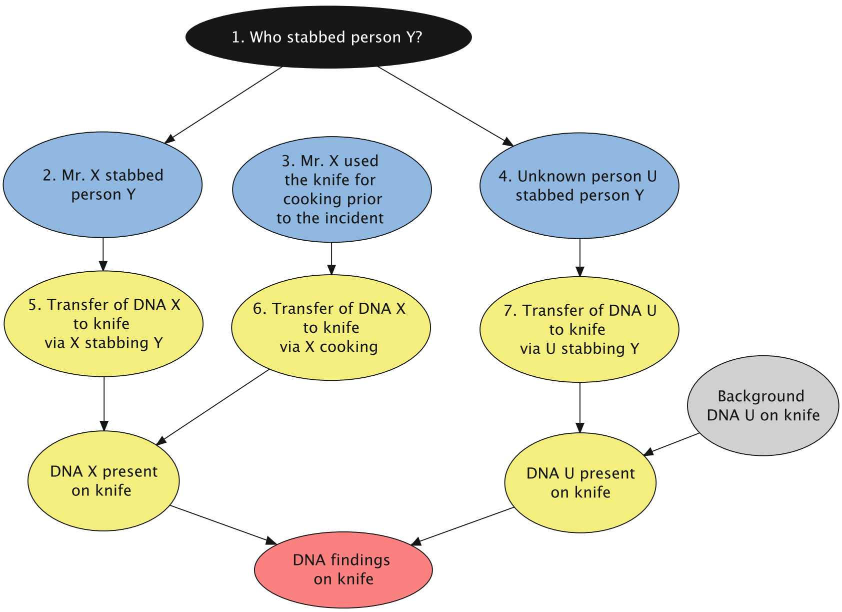

Figure 3.2: Example case model of the evaluation of DNA evidence given activity level propositions modeled using the template model.

Fig. 3.2 illustrates a case model based on our template model. The network covers a model of a simplified case example where the identity of the actor in a stabbing incident is disputed. Suppose a knife was found near the victim (hereafter: person Y) and analyzed for DNA evidence, yielding a single DNA profile matching Mr. X. Mr. X is arrested shortly after the incident and the prosecution claims that Mr. X stabbed person Y. Mr. X claims that he visits person Y regularly and that he had used the knife for cooking several days before the incident. While this is a simplified version of the case focusing only on the knife as piece of evidence, it sufficiently demonstrates how to model a Bayesian network for evaluating transfer evidence given activity level propositions.

"Activity 1 by suspect X" and "Activity 1 by alternative actor Y" are now represented as MR. X STABBED PERSON Y (2) and UNKNOWN PERSON U STABBED PERSON Y (4) respectively, while "Activity 2 by suspect X" becomes MR. X USED THE KNIFE FOR COOKING PRIOR TO THE INCIDENT (3). Since the prosecution does not dispute that Mr. X cooked with the knife, this cooking activity is considered true under both propositions. Therefore, there is no link between WHO STABBED PERSON Y? (1) and MR. X USED THE KNIFE FOR COOKING PRIOR TO THE INCIDENT (3).

The blue activity nodes are followed by yellow transfer nodes. When DNA from X transfers to the knife - whether through stabbing or cooking - it results in DNA X being present on the knife, as shown in the accumulation node DNA X PRESENT ON KNIFE (8). Since DNA from X's cooking activity is considered background DNA, the grey background node has been removed. The transfer path from UNKNOWN PERSON U STABBED PERSON Y (4) follows a similar structure, but includes a node for unknown background DNA on the knife. The BN is concluded with a DNA FINDINGS ON KNIFE (11) with states "DNA of X only", "DNA of U only", "DNA of X and U" or "no DNA".

We have not assigned the probabilities in the CPTs. However, if this is done, the LR can be derived by instantiating H_1 and H_2 consecutively and read the probabilities of the case findings given the propositions from DNA FINDINGS ON KNIFE.

Final remarks on Part II

Part II advocates the idiom-based approach to modeling evaluations given activity level propositions in forensic science. In Chapter 2, we reviewed existing idioms within and outside of the forensic discipline and organized them into five categories: *cause-consequence idioms*, *narrative idioms*, *synthesis idioms*, *hypothesis-conditioning idioms*, and *evidence-conditioning idioms*. We elaborated on generic idioms and emphasized forensic instantiations that are useful for modeling activity level evaluations using Bayesian networks. The collection is by no means exhaustive; for example, we omitted the induction idiom and the reconciliation idiom from Neil *et al.* (2000). Nevertheless, we think that these idioms are a good starting point for constructing "basic" case models. In fact, in Chapter 3, we illustrated the idiom-based approach by combining some of the idioms in category A, B and C to develop a larger template model. The template model is a generalization of Taylor's template model in Taylor *et al.* (2018) and includes the ideas of Kokshoorn *et al.* (2017) concerning the dispute over the actor or activity.

Although idioms are based on generic reasoning and can be applied to multiple modeling problems, case models still reflect the expert's perspective of a case. Therefore, an idiom-based approach alone is not sufficient to ensure consistency among Bayesian networks created by different experts. Moreover, we focused on the qualitative design of a Bayesian network as the idiom-based approach largely focuses on identifying the structure of a Bayesian network. Practical methods for forensic experts to identify the relevant variables or to elicit the conditional probabilities from experts are underdeveloped in the forensic literature, and so, much work remains to be done.