Handling Anonymous Witness Evidence using Bayesian Network idioms

Norman Fenton, 6 July 2015

This working paper is inspired by a problem told to me by Henry Prakken

Hypothetical case *initial* evidence:

- A crime has been committed.
- A person W calls the police to say that he has reason to believe that person D committed the crime
- D is known to the police with previous convictions
- W remains anonymous and provides no details about his evidence against D (so we do not know if W witnessed something relevant, or heard a confession etc)
- D is charged with the murder

Using the idioms based approach (Fenton et al 2013) we can model this scenario as shown in Figure 1.

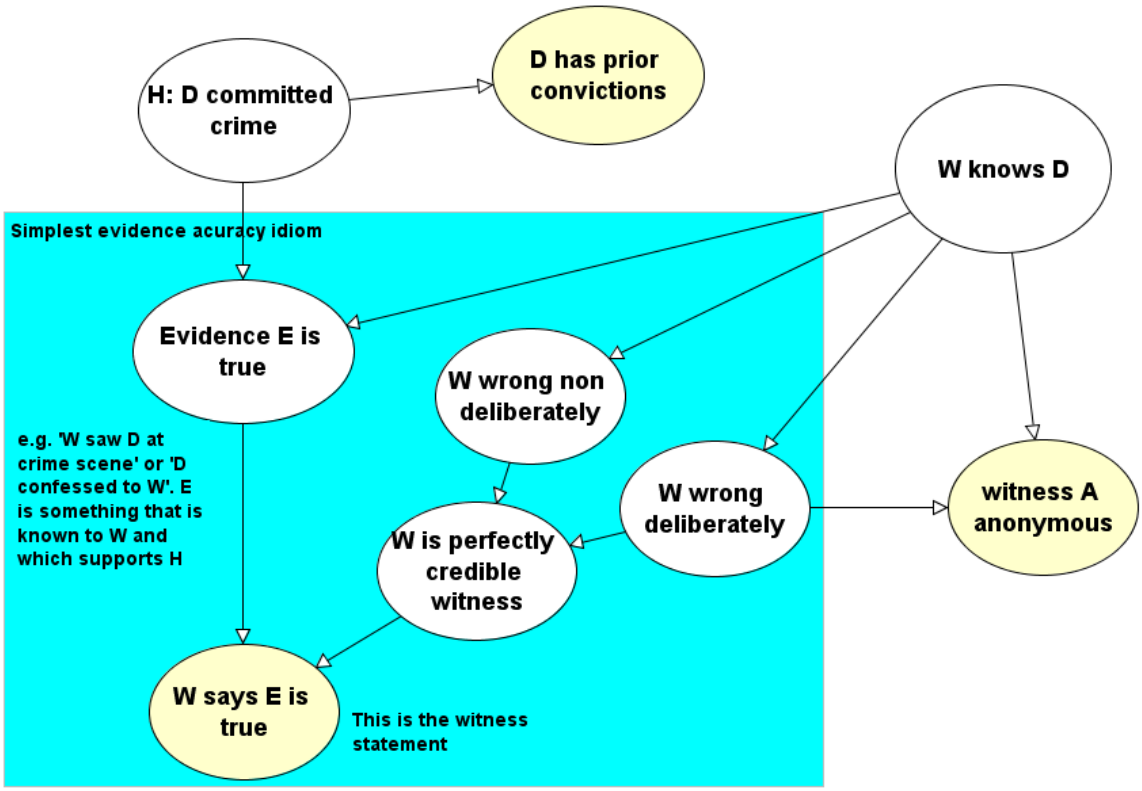

Figure 1 Initial model of case

Note the core 'evidence accuracy' idiom in the model. This simply recognises the difference between an unknown hypothesis H (such as "E is true") and a witness statement claiming H. If the witness is perfectly credible then the witness statement suggests that H is true. But W may be wrong either deliberately (such as if he has a motive to frame D) or non-deliberately (such as if D resembles somebody else). You can think of these as alternative narratives to arrive at an inaccurate witness statement.

In this case we have to extend the simple idiom to incorporate the anonymity of the evidence and the witness's possible relationship with the defendant.

Let us suppose that the prior probabilities are as shown in Figure 2 (i.e. we assume prior probability that D committed the crime is 1 in a 1000 and a prior probability of 1 in 10 that W knows D).

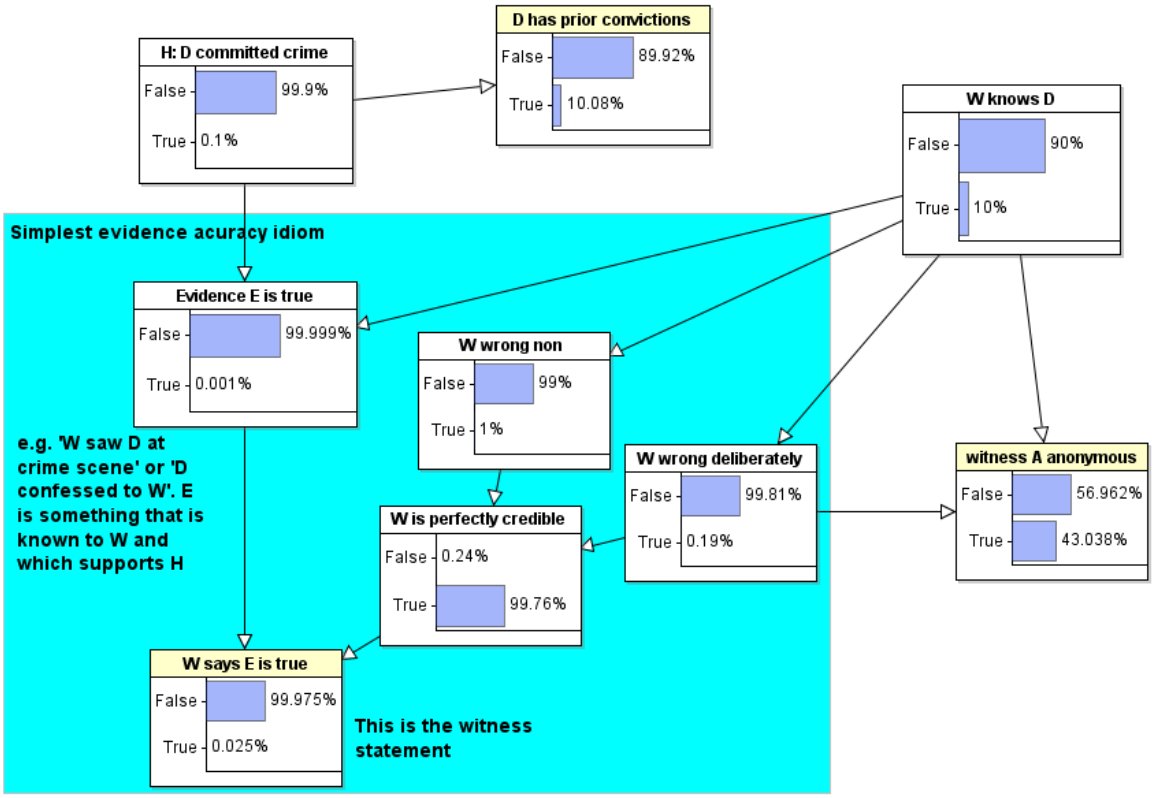

Figure 2 Simple model with prior marginals

Entering the prior conviction evidence has an impact – the probability of guilt increases from 0.1% to 0.89% but clearly provides no reason to charge D. However, entering the witness statement results in the changes shown in Figure 3.

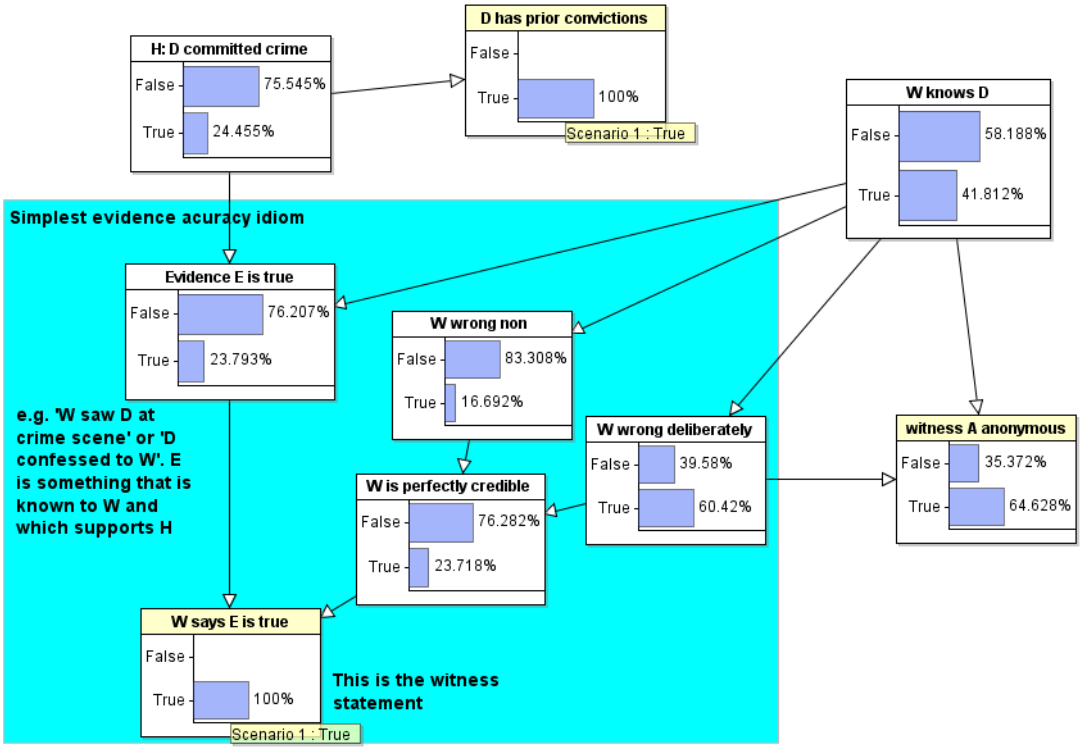

Figure 3 Witness statement added

There is now a 24% probability that D committed the crime. However, when we enter the fact that A is anonymous this drops to less than 19% – as shown in Figure 4.

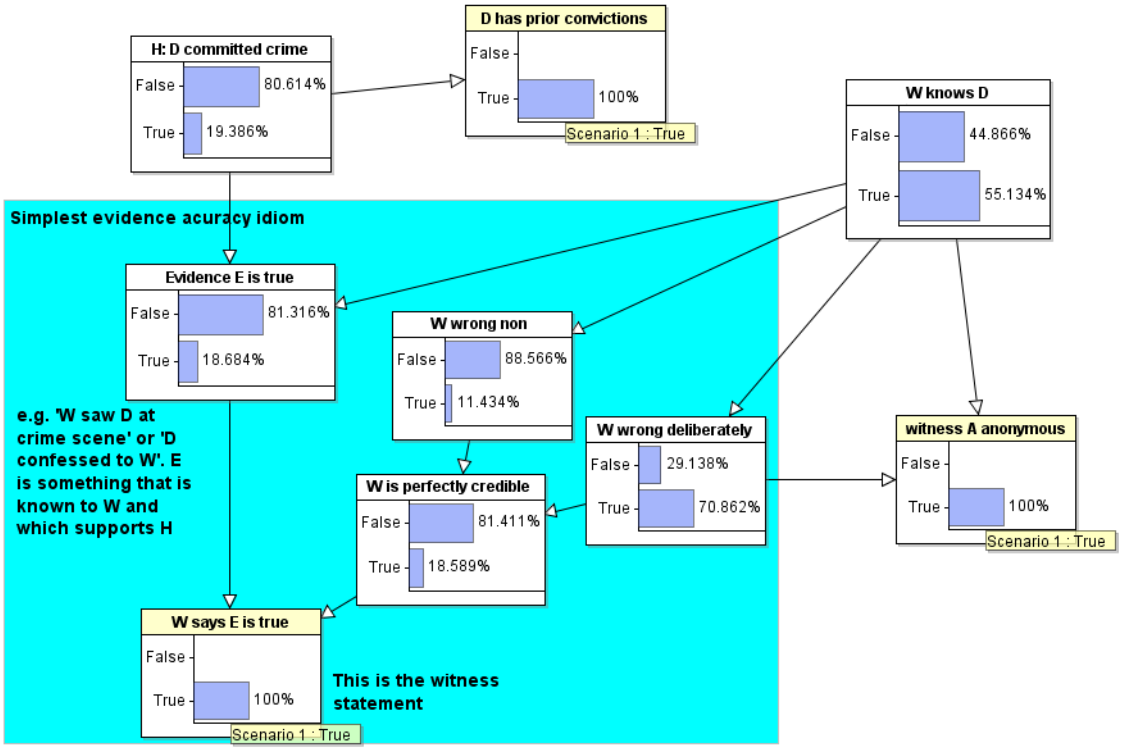

Figure 4 Witness is anonymous

The model explains why – there is now a better than evens chance that W knows D and a very good chance that W is wrong deliberately.

Hypothetical case *additional* evidence:

Having charged D with the crime the police discover that D worked next door to the scene of the crime. This is considered extremely powerful evidence against D and is sufficient to get a conviction. Indeed, any evidence that 'puts the defendant potentially at or near the crime scene' is considered to be evidence of 'opportunity' and should increase the probability of guilt for the simple reason that only people at the scene could have carried out the crime. If, for example, there were originally 1000 potential suspects but we determine that only 100 of these could have been at the scene then the probability of guilt for any person ***known*** to be at the scene increases tenfold from 0.1% to 1%.

However, in this case, this 'opportunity' evidence adds significant complications to the model because it has multiple dependencies to existing nodes. Specifically, in addition to its need to be a parent of H (as per the *opportunity idiom*) we have to recognise the following:

If W knows D then it is almost certain that W also knows that D worked next door to the crime scene. If W wishes, for example, to frame D then knowing that D worked next door to the crime scene provides additional incentive to make a deliberately wrong anonymous statement to the police. Even if W does not know D the fact that D worked next door is also more likely to mean that W will wrongly point the figure at D.

It follows that the impact of the new evidence works both ways. On the one hand it increases our belief that D was at the crime scene and therefore that D committed the crime, while on the other it also increases our belief that the witness would wrongly identify D as being guilty.

The revised model that incorporates the new piece of evidence is shown in Figure 5.

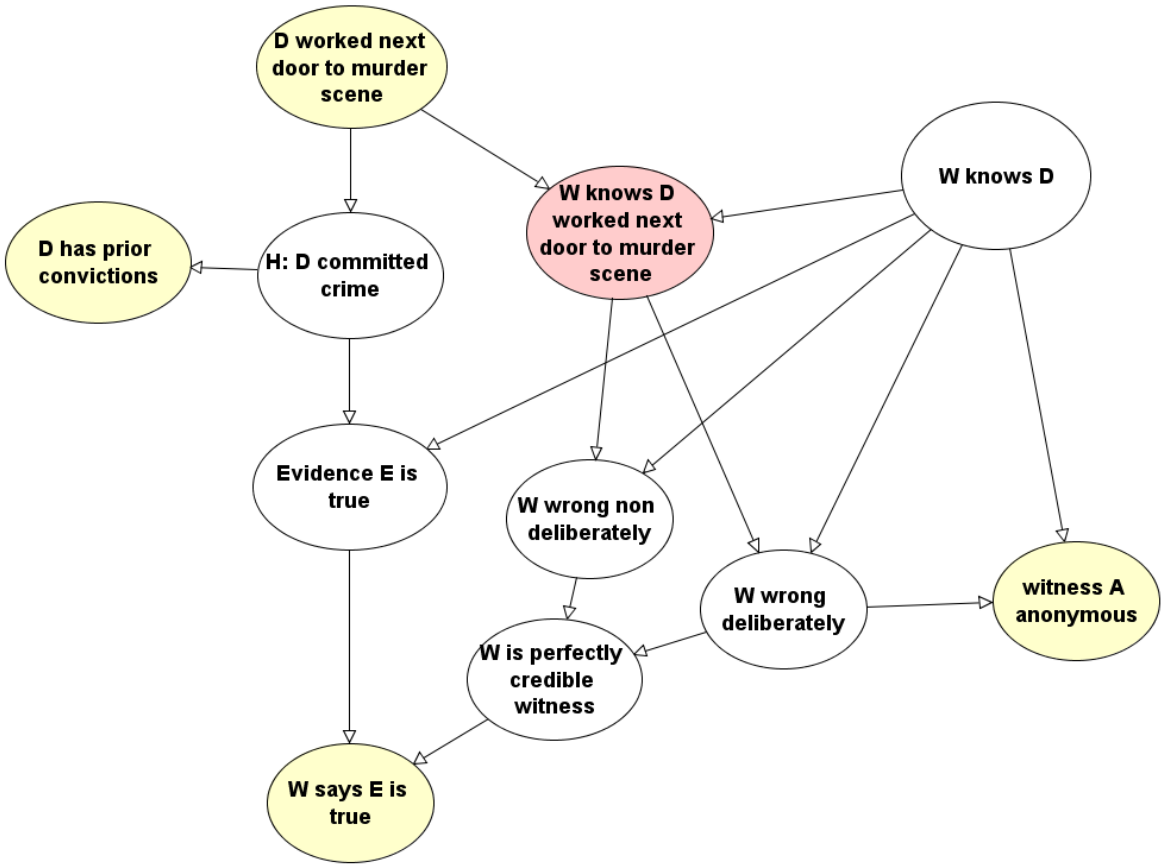

Figure 5 Revised model with new evidence

Note that, in addition to the new evidence node itself ("D worked next door"), we must add another node ("W knows that D worked next door") and that this latter node influences the two nodes associated with the credibility of W's witness statement.

In this version of the model we assume that it is 10 times more likely D committed the crime if he worked next door than if he did not. However, running the model with the previous evidence and the new evidence results only in a small increase in probability of guilt as shown in Figure 6.

TBD: lots more sensitivity analysis considering different ranges for the priors.

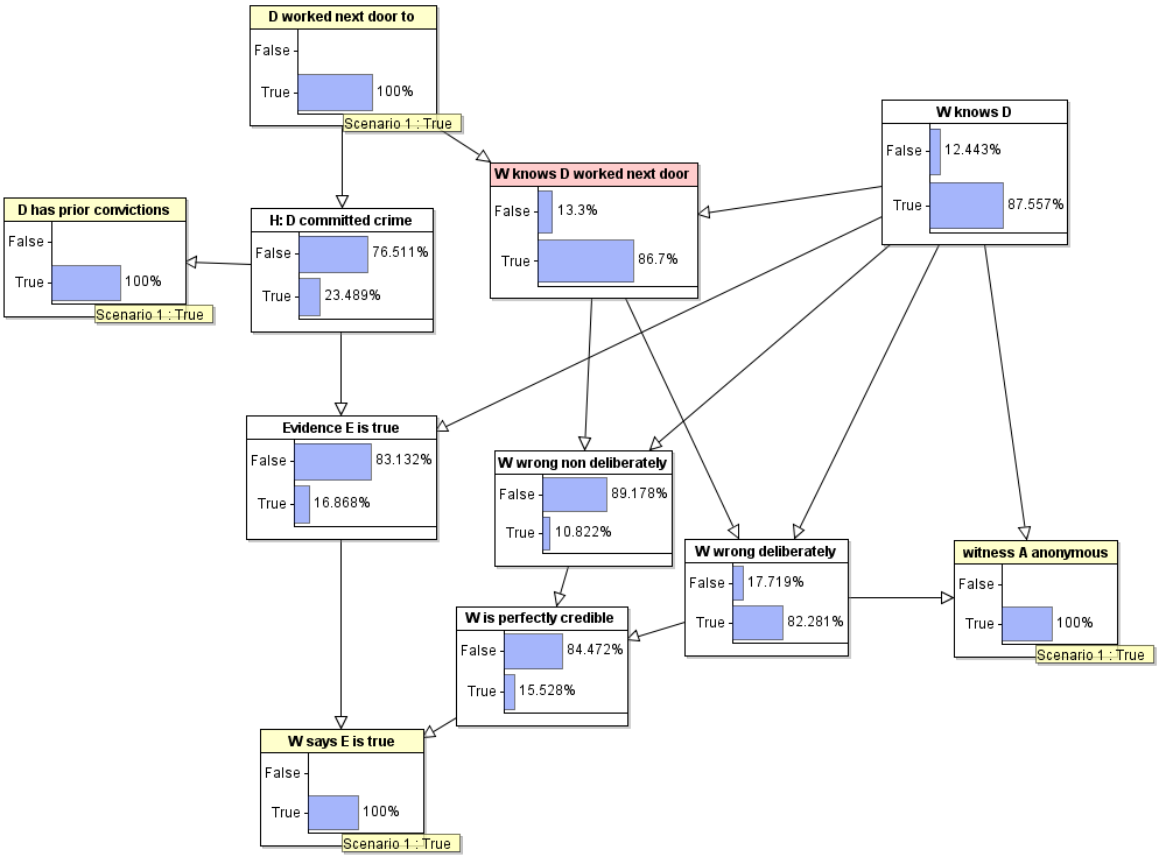

Figure 6 New evidence added to previous

Whereas it was 19% before it is now 23%. This is explained by the fact that it is more likely than before that W is deliberately wrong.

Figure 7 shows the much more dramatic effect of anonymity in this. If W was not anonymous the same assumptions and evidence results in a 60% probability that D committed the crime.

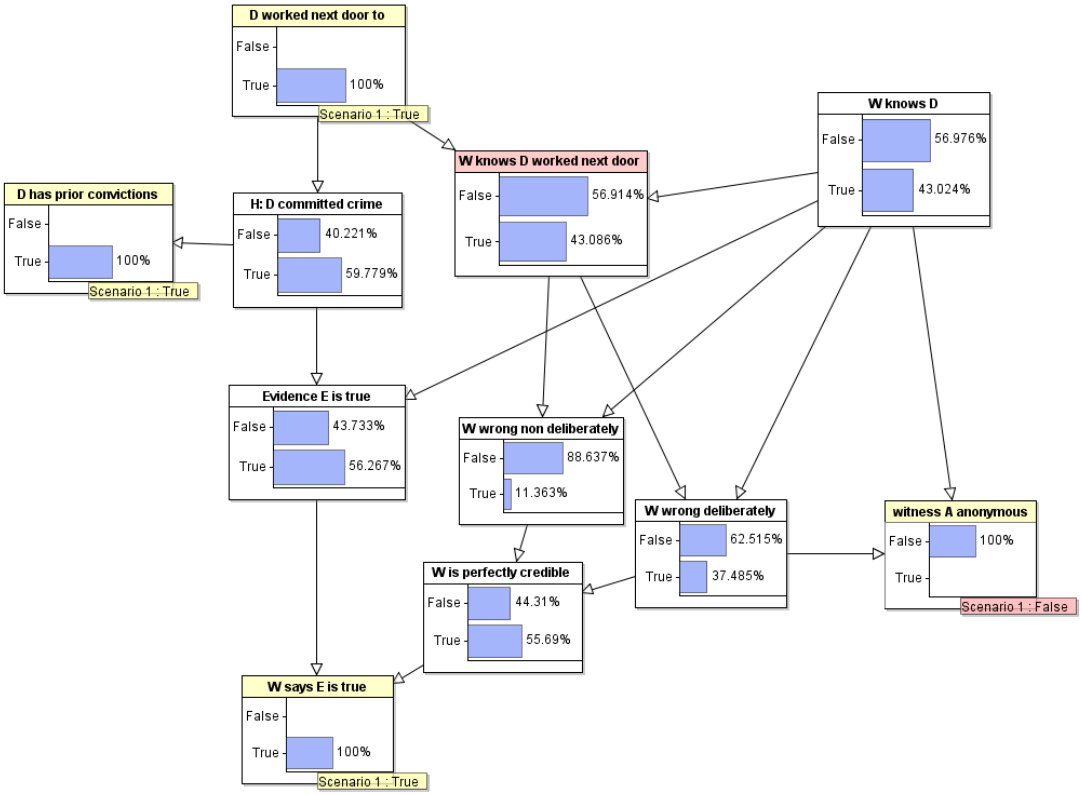

Figure 7 Effect of anonymity

The above suggests a general idiom for handling anonymous witness evidence as shown in Figure 8.

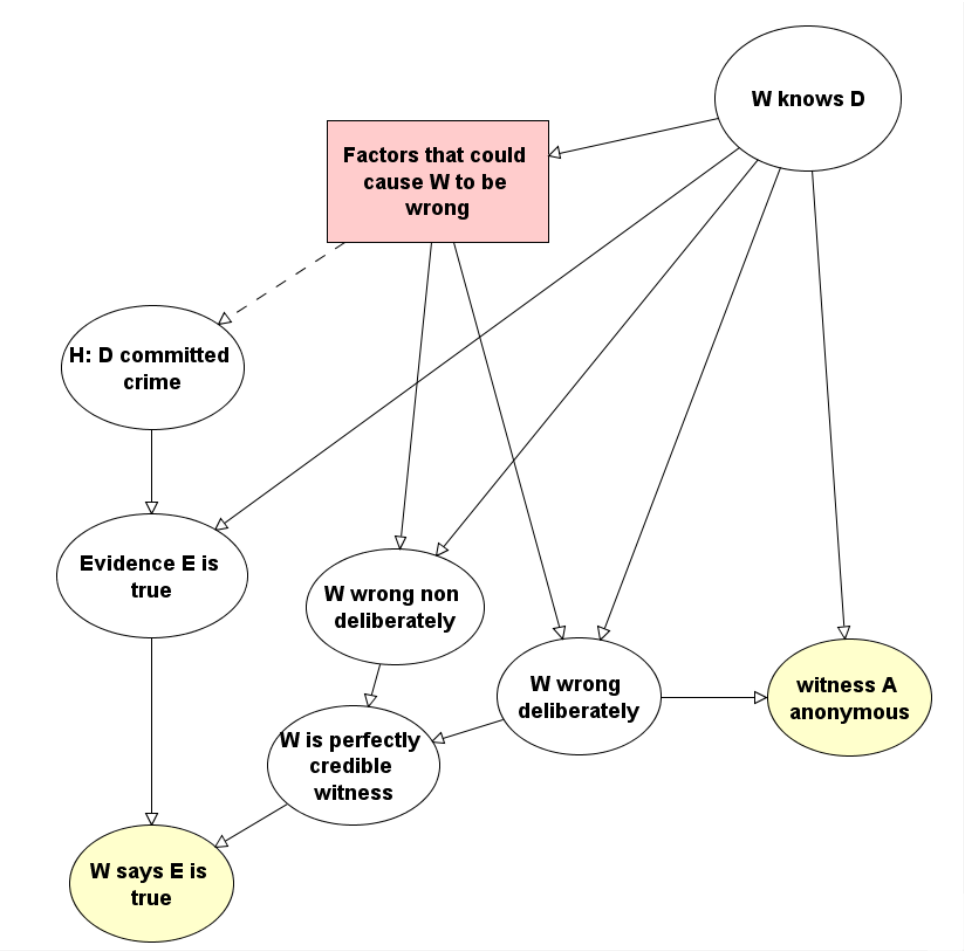

Figure 8 Generic idiom for handling anonymous evidence

Comments

Obviously the model can be extended to deal with more complex relationships than simply the Boolean "W knows D". I have created such a model where this node is replaced with one called "W relationship to D" which has states:

- No relationship to D or crime
- Friend of D uninvolved in the crime
- Friend of D involved in the crime
- Enemy of D uninvolved in the crime
- Enemy of D involved in the crime

However, the NPTs become rather complex.

References

Fenton, N. E., D. Lagnado and M. Neil (2013). "A General Structure for Legal Arguments Using Bayesian Networks." Cognitive Science 37, 61-102 http://dx.doi.org/10.1111/cogs.12004.