Conceptual, formal and practical aspects of forensic and judicial applications of probabilistic tools

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Many formal models of human reasoning have beed developed so far, but investigations of the applications of these tools in practice are rather underdeveloped. The project focuses on the use of probabilistic tools in the context of judicial and forensic justifications of factual claims (henceforth, JAF contexts). The goal is to develop conceptual, formal (theoretical) and practical aspects of such applications, filling the existing gaps. Subjects involved in establishing facts in court clearly usually do not have full information about the case at hand, and so they have to reason about the probabilities of various events. Yet, despite the gravity of the matter (see e.g. the case of Lucia de Berk, who due do various probabilistic mistakes was sentenced for murder), the notion of probability used by such subjects, is not supported by a well developed mathematical theory.

Examples of research problems that will be studied are the following challenges - in each case the goal is to establish how the issue is handled in real life cases, and to find a principled and correct way of handling the phenomenon mathematically:

(a) balancing probability and the conjunctive property. Often, especially in civil cases, the plaintiff is supposed to prove each element of her case on the balance of probability - that all of her claims are more probable than their negations. Consider a fairly simple situation, where the case is composed of three probabilistically independent claims: C1, C2 and C3; the plaintiff's case is the conjunction of these claims: C=C1&C2&C3. Suppose the plaintiff succeeded at proving each element of her case on the balance of probability, by establishing that, say, P(C1)=P(C2)=P(C3)=0.6. Since the claims are assumed to be independent, if standard probability theory applies we should have: P(C)=P(C1)xP(C2)xP(C3)=0.216. So the plaintiff succeeded at proving each element of her case on the balance of probability, but failed to establish her case on the balance of probability. Should she, or should she not win the case?

(b) lack of understanding of the conditions under which the probabilities of various events can be multiplied to obtain the probability of their conjunction. This mistake led to the wrongful conviction of Sally Clark, in whose case low probabilities of individual SIDS (Sudden Death Syndrome) have been multiplied to calculate the probability of the death of both siblings.

(c) conflating various conditional probabilities. This turns out highly relevant, for instance, for how DNA matching results are interpreted. For instance, in the case of the murder of Diana Sylvester, where the suspect was identified by partial DNA match (5 out of 13 of loci, due to the degeneration of the genetic material). The defense argued that DNA matches are more often than official FBI statistics indicate, arguing in fact about the probability of a couple of people in a group being a (partial) match, instead of arguing about the probability of a random person being a match given a prior sample of genetic material.

(d) ignoring probabilistic properties of fallible tests. A test (such as lie detector, DNA matching, testing for a type of bacteria etc.) have their performance graded in probabilistic terms (the key factors being their sensitivity and specificity). Practitioners who rely on those tests have little understanding of how these probabilistic considerations impact the reliability of various potential conclusions. For instance in the case of the murder of Meredith Kercher Judge Hellman decided, against what mathematical calculations should tell him, that a second DNA test is excluded from the case, saying: *The sum of the two results, both unreliable… cannot give a reliable result.*