Information-Theoretic Value of Evidence Analysis Using Probabilistic Expert Systems

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The evaluation and interpretation of evidence is often made under uncertainty where the task of reasoning involves estimating unknown quantities from some given observations. There is often a quest for data to reduce uncertainty. Forensic scientists are often called upon in courts to give expert testimony in a court of law or public enquiry, e.g. the source of a DNA sample. Their evaluation and interpretation of the evidence is often under scrutiny and they are often asked to justify their decision-making process. The task of decision-making, evaluating, and interpreting the evidence is further tested when there are multiple sources of evidence which may or may not relate to the same query. Information is seldom cost free and therefore there is a need to evaluate beforehand whether it is worthwhile to acquire and to decide which (sources of information) to consult that would optimise the desired goal (i.e. reduction in uncertainty about the inference).

Using information-theoretic concepts, Lauritzen and Mazumder (2008) defined a value of evidence (VOE) criterion I_q as a general measure of informativeness for any forensic query Q and collection of evidence $X_1,\ldots,X_K$ where the probability distribution of the query (given evidence) is of interest. When there are multiple sources of information, a decision-theoretic framework provides a systematic approach to considering which test(s) to perform that most contributes to reducing uncertainty regarding the query. A probabilistic network formulation provides an attractive platform for the graph-theoretic representation of the VOE problem and eases the laborious calculation of marginal and conditional probabilities of interest. When the configuration space for exact computations and exhaustive searching is infeasible, Monte Carlo sampling methods are employed.

The VOE criterion I_q, having a solid theoretical basis, has been directly applied to a variety of planning problems in forensic genetics to determine the quantity and choice of individuals and genetic markers to type to gain sufficient information for evaluation and interpretation (Mazumder, 2010). This approach is extended to consider other complex evidential reasoning cases involving multiple evidence types in which the graph modular structure and conditional independence properties are exploited to aid the decision-making and reasoning process. This research aims to contribute in three ways: (1) developing computational methods in VOE analysis using PESs, (2) developing a decision-theoretic framework for planning and inference in the evaluation of complex evidence structures, and advancing the evaluation and interpretation of forensic evidence methods.

References

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