FORENSIC INFERENCE AND AIDS TO DECISION-MAKING FOR SCIENTIFIC EVIDENCE

The reality of problems related to the (mis-)use of scientific evidence at trial cannot be ignored. Data published by US, EU and UK institutions show that a substantial proportion of identified miscarriages of justice have arisen from critical issues related to the evaluation and interpretation of scientific evidence. The United Nations, during its next March 55th session of the Human Rights Council in Geneva, will focus on this societal criticality. Action is needed urgently to reduce or eliminate such miscarriages.

Theoretical and practical work is needed to (a) concisely represent and process problems in inference and decision making for scientists and legal experts, (b) gather and extract knowledge from experience and data, and (c) develop and implement the best evaluations and interpretations of scientific evidence for the judicial system and procedures for ensuring decisions made are of the highest quality. Currently, these needs are not met. This failure is concerning for both scientists and others in the criminal justice system. It also may lead to undesirable consequences and costs. Scientists may be challenged on well-recognized, but unresolved, methodological difficulties. Also, there are increasing demands from society to demonstrate the transparency, foundations and principles of experts' procedures; media and the courts are less tolerant than before of the perceived failure to satisfy these demands. This project will develop relevant novel methodological approaches to these problems, with novel statistical and graphical inference and decision-making techniques. The aim is the development of a general framework to assist scientists in building more robust and more defensible grounds on which a meaningful, credible and trustworthy evaluation and interpretation of scientific evidence, with associated decision-making, and associated software, can be provided.

Forensic science theory and practice, and also many other tasks for inference and decision, require consideration of sets, and sometimes masses, of items of evidence with multiple forms, where uncertainty, arising from the absence, incompleteness, ambiguity, and random variation of information and knowledge, plays a key role. Inferential and decision-making problems, at several levels of complexity, need methods of formal analysis. These problems arise from the principle that evaluation and interpretation of forensic science data should be governed by the need to proceed rationally, understood as agreeing with the laws of probability theory. The applicant's previous work emphasises that probabilistic reasoning supports forensic scientists in acquiring a better understanding of the wide range of dependencies which may exist among different aspects of the evidence. The practical implementation of probabilistic analyses can be facilitated by methods associating probability and graph theory within a unified framework, known as Bayesian networks. These networks provide a valuable aid for representing relationships among characteristics in situations of uncertainty in the context of a case under investigation. Often, the interactions amongst masses of evidence are of interest, with a need for the logical analysis of these, yet they have received very limited research attention.

Consideration of uncertainty can provide additional help to the administration of criminal justice, beyond that of (probabilistic) inference, with investigation of decision-making under uncertainty. Decisions are at the heart of judicial proceedings. A court may have to decide if a defendant is the source of a given trace. A forensic scientist may have to decide whether or not to perform particular lab analyses or collect more data. The study of probabilistic reasoning under uncertainty in forensic science and law has received some, but limited, attention; systematic research on a coherent extension of probabilistic reasoning, with decision theory, to rational decision making under uncertainty within the criminal justice system is in its infancy. Research is needed to formalize the effective use of probabilistic models for masses of evidence, including where evidence may be thought to be missing, or additional evidence should be acquired. Research is also needed for coherent decision-making when there is little or no evidence and hence where traditional statistical or machine learning techniques cannot be used. Such research has the potential both to reduce much unnecessary evidence collection and to improve the results of the evaluation and interpretation of sets of evidence that have been collected. More rational and defensible strategies for policy making by decision makers in forensic science will be the outcome, especially a better understanding of the impact of the analyses of different types of scientific evidence.

The key objective is to secure the position of forensic science within legal proceedings. This will be achieved through the original development of a conceptual framework which will provide standards of reasoning useable to examine whether a given argument has the necessary credence to be considered sound and, thus, whether reasoners are logically entitled to their conclusions. For the development of such a framework, three interrelated interdisciplinary topics will be investigated.

The first concerns the masses of evidence that are available or may be available if future tests are conducted. Various properties of the data, including data from previous cases, will be studied. From this study, a reduced set of the masses will be provided for future consideration. The second concerns the evaluation and interpretation of the reduced set of the masses of evidence. The third concerns rational decision making. For example, attention can be paid to the gain in information achievable with the analysis of selected supplementary items of evidence.

It is a fundamental challenge in the justice system to make the best use of scientific evidence. To ensure the best use, research is needed in areas from probability and computational statistics to legal studies and forensic science. Synergies among these areas will be used to approach the tasks of reasoning, learning from data and making decisions to develop models with both conceptual significance and practical applications. The research will develop applications of formal modes of evidential reasoning under uncertainty where law and science interact. Solutions to current societal problems in a variety of scenarios will be provided. Examples include forensic toxicology for toxicity level decisions under the law, sex determination in forensic anthropology for body identification, AI and human authorships for texts and malicious messages, and decisions for age estimations of living persons. Robust and defensible probabilistic methodologies will be developed, replacing current heuristic approaches to provide scientifically coherent answers to help legal decisions based on forensic science. In addition, the models will play a role in the re-assessment of evidence in cases where a (possibly wrongful) conviction has been supported by the erroneous interpretation of scientific evidence. There will be three outputs: (1) an open access portfolio of reference models and a suite of relevant teaching activities, including at least one MOOC and specific e-learning modules (2) open access statistical packages for the analysis of different types of data and different types of problems in a legal context, and (3) a statistical package to deal with associated decisions.

The ideas will be difficult for mathematically challenged jurists; concern for this is outweighed by increasing support for ideas that overcome the biases and fallacious conclusions for which unaided intuitive reasoning is known. The administration of criminal justice will be enhanced by this research programme for forensic inference and decision aids for scientific evidence.