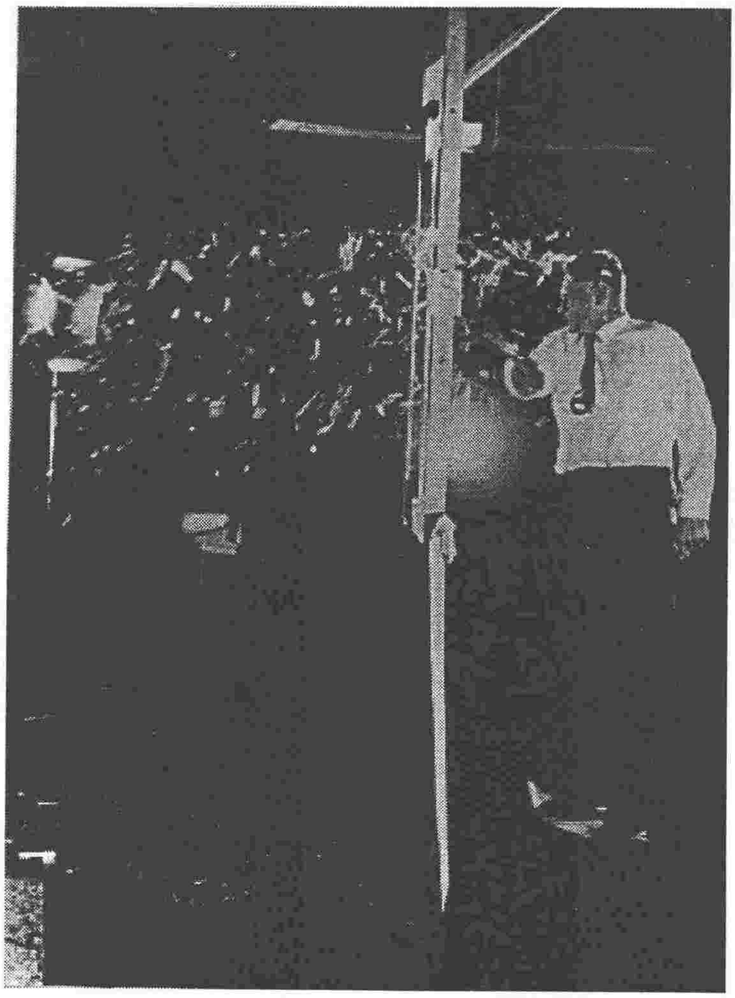
# Forensic Applications of Bayesian Inference To Glass Evidence


## James Michael Curran

Nelson, D.F. and Revell, B.C. Backward fragmentation from breaking glass. Journal of the Forensic Science Society 1967; 7:58-61. Reprinted with the kind permission of the Forensic Science Society.

A Thesis
submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy,
The University of Auckland

December 1996

# Abstract

The role of the scientist in the courtroom has come under more scrutiny this century than ever before. As a consequence, scientists must constantly look for ways to improve the validity of the evidence they deliver. It is here that the professional statistician can provide assistance. The use of statistics in the courtroom and in forensic science is not new, but until recently has not been common either. Statistics can provide objectivity to subjective assessments and strengthen a case for the prosecution or the defence, but only if is used correctly.

The aim of this thesis is to enhance and replace the existing technology used in statistical analysis and presentation of trace evidence, i.e. all non-genetic evidence (hairs, fibres, glass, paint, etc.) and transfer problems.

## Preface

The role of the scientist in the courtroom has come under more scrutiny this century than ever before. As a consequence, scientists must constantly look for ways to improve the validity of the evidence they deliver. It is here that the professional statistician can provide assistance. The use of statistics in the courtroom and in forensic science is not new, but until recently has not been common either. Statistics can provide objectivity to subjective assessments and strengthen a case for the prosecution or the defence, but only if it is used correctly. The field of forensic science contains vast untapped and exciting opportunities for the professional statistician. Some fields have been studied extensively, such as DNA and glass, but there exist many more areas that have yet to be explored.

The aim of this thesis is to enhance and replace the existing technology used in statistical analysis and presentation of trace evidence, i.e. all non-genetic evidence (hairs, fibres, glass, paint, etc.) and transfer problems. Although the material in this thesis concentrates solely on problems related to glass, the technology and ideas are easily transferred to any type of evidence in forensic science.

The thesis is arranged into nine chapters, the first seven dealing with a particular problem area in the statistical analysis of glass evidence. The first chapter provides an up-to-date summary of the physical techniques used in forensic laboratories for the analysis of glass samples.

Chapter 2 reviews the literature of previous and current statistical treatments of forensic glass evidence, concentrating mostly on the work of Dr. Ian Evett of the Forensic Science Service, a major pioneer in this field. Dr. Evett's past work laid the foundations for the use of statistics in the analysis of trace evidence, and his current work is a valuable contribution to the field. The material in Chapter 2 has been published previously in the Proceedings of the A.C. Aitken Centenary Conference [1].

Chapter 3 deals with the properties of significance tests. Computer simulation is used extensively to examine the behaviour of these significance tests under specific forensic conditions. Based on the simulated and theoretical results obtained, recommendations are made for anyone who proposes to use these tests in their analyses.

Chapter 4 deals with the problem of grouping. This problem arises from the possibility that a sample of glass recovered from a suspect may have come from one or more sources. The method developed by Triggs and Curran in Chapter 4 has appeared in Forensic Science International [2], and an extended report has been published in the University of Auckland Department of Statistics Technical Report Series [3]

The first half of chapter 5 introduces the idea of significance testing into the interpretation of elemental concentration data from forensic glass data. The techniques used in this chapter can be used for any trace evidence that has discriminating chemical properties. The second half of chapter 5 extends the continuous Bayesian approach to the analysis of forensic glass data to the multivariate elemental concentration problem. The research in chapter 5 has been provisionally accepted for publication in the official publication of the Forensic Science Society, Science and Justice, due to appear in 1997.

Chapter 6 applies the methodology of graphical modelling to the subject of assessing transfer probabilities. This approach, first used for assessing fibre evidence by Dr. Evett, has provided some of the most realistic distributions of transfer probabilities ever seen (Pers. Comm. J. Buckleton, 1996). This chapter has also been written up for publication and has been submitted to Science and Justice.

Chapter 7 extends the evaluation of the grouping method of Triggs and Curran [2,3] to a Bayesian context. The continuous Bayesian approach to the interpretation of glass evidence is extended for situations where more than one group of glass is present. The behaviour of the analysis is then examined with respect to three grouping situations. Based on the results of this chapter, recommendations for the inclusion of grouping information in a Bayesian analysis are made.

A major part of this Ph.D. project has been to provide easy to use software for the analysis of glass evidence. The chapter eight of this thesis is a brief introduction to the software written for this purpose: STAG. The style in chapter 8 is markedly different than that used in previous chapters, mainly because it is intended for a different audience. Chapter 8 has appeared previously in conjunction with Technical Appendix 1, the formal programme description for STAG, as an ESR technical report.

Chapter 9 summarises the advances that have been made in this research and outlines the directions for some future research.

The list of people I wish to thank is constrained by physical page space and so I must be brief. Thanks firstly to my supervisors, Dr. Chris Triggs and Dr. John Buckleton for their continued enthusiasm and support; to ESR for the scholarship, and to all those in the ESR Physical Evidence Unit for their friendship and willingness to help; to Dr. Ross Ihaka who saved me countless hours of programming various distribution functions by letting me borrow his code; to Werner Schmidt; Andrew Balemi, Alain Vandal, and John Pearson for their nefarious friendships; and last but not least my wife Karin for putting up with me.

James Curran, 16 December 1996.