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Towards source level evaluation of the evidential value of fibre examinations

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ABSTRACT

This paper aims to provide the first steps towards a numerical source level evaluation of fibre evidence. For that purpose, likelihood ratio equations are derived for four generic scenarios, in which the source frequency, the number of references and trace types investigated, and the number of matches vary. Previous experimental studies into the evaluation of fibre evidence are reviewed and we demonstrate how the results of these studies, as well as other data, can be used to evaluate the derived equations for the four scenarios. Evaluation is not straightforward and requires a number of assumptions. This is mainly because the relevant population under consideration in a specific case cannot be sufficiently evaluated. In addition, the subjective match-criterion in current forensic fibre examinations makes it impossible to implement a good evaluation of the within-variation of samples. As a result, the discrimination power, currently calculated for discrimination studies, is only valid for samples with negligible heterogeneity. We conclude that reporting a numerical evidential value for forensic fibre examinations is not yet feasible as the data are available for only a few types of fibres and cannot be used without several assumptions. We propose a number of developments that are required to improve the accuracy and numerical analysis.

1. Introduction

The forensic examination of fibres and textiles is important in the investigation of many crimes due to the widespread presence of textiles and their tendency to shed fibre traces. Even a mild contact with a textile may cause fibre transfer. If transferred fibre traces can be attributed to a particular donor, they may establish a relation between that donor and a crime scene or a victim [1]. To establish such a relation, fibres from a *reference textile* (i.e. an item of known origin such as the garment of a suspect) may be compared to *fibre traces* (i.e. questioned material) by a forensic fibre examiner. Such an investigation typically comprises of fibre comparisons via microscopy and microspectrometry (MSP) [1].

If there are no meaningful differences between the reference fibres and fibre traces, the fibre examiner will often state that they 'match'. A match does not imply that the investigated reference material is the source of the recovered fibre traces: textiles are generally mass-produced and there will most likely be other textiles that also could have transferred matching fibre traces.

Instead, a match should be considered a laboratory result, on which conclusions regarding the origin or the transfer of the fibre traces can be based. A possible conclusion is that the 'reference textile may not be excluded as the source of the investigated fibre traces'. Though correct, this conclusion is in itself not very informative: some types of fibres, e.g. white or blue denim cotton, are notorious for their occurrence in many textile items. Therefore, there may be many textiles (other than the reference textile under investigation) that 'may also not be excluded as the source of the investigated fibre traces' and thus the evidential value of the match is negligible. Other types of fibres are less common and have a higher evidential value: the chance that an arbitrary textile sheds matching fibres is low. The evidential value of a match is thus determined by the frequency of the fibre type investigated or, more general, by the extent to which fibres from different sources can be discriminated by the techniques used. Accordingly, fibre examiners will not only compare fibres, but also classify them, e.g. as 'white wool' or 'pink polyamide'. Classification facilitates the estimation of the frequency (see information and references in Section 3).

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The evidential value of a comparative fibre study is of paramount importance to the courts, as it enables judges to evaluate the significance of the forensic results. Neglecting important evidence or emphasising results of low evidential value may lead to miscarriages of justice. The most transparent way of evaluating the forensic results is through the use of numerical evidential values. In recent decades, several studies have been carried out in order to provide numeric background information on the frequency of fibres (see the summary in Section 3). Nevertheless, the authors are not aware of any forensic laboratory that routinely reports numerically the source level evidential value of fibre cases to the courts. Instead, the evidential value at source level of a fibre examination is provided using a verbal statement.

Only a few case reports have appeared in the literature on the numerical analysis of evidence, e.g. the work by Woltman [2] and Zadora [3]. Such analyses are mainly based on studies of the background population of fibre traces, such as those by Cook and Wilson [4] and Jackson and Cook [5]. While this approach is in itself valid, it requires several assumptions and estimations. Assigned values may be conservative due to the prudence of the forensic expert. This may render the evidential value obtained so small as to be useless.

The main difficulty in the evaluation of forensic fibre examinations is that many aspects should be considered and combined to form a consistent picture [6,7]. Some of these aspects rely heavily on case information, such as information about the nature of the contact between the perpetrator and the victim, or the time between a crime and the recovery of the questioned traces, and the possibility of an innocent contact between suspect and victim.

In this paper, steps towards a structured approach to combine such different aspects are taken. We will focus on the *numerical evaluation* of evidence at *source level*. We agree with Houck [8] that obtaining objective and numerical information is in many cases very complex and that the popular notion that numbers make the evidence stronger is not necessarily correct. We also agree with Dror [9] that even domains that are far from objective can be extremely valuable. Nevertheless, an objective and numerical evaluation is the most accurate, transparent, and scientific approach and also prevents ambiguities in the wording of conclusions [10,11].

A number of statistical studies on the transfer of fibres have appeared in the literature, see e.g. [12,13]. These studies propose activity level models, where not only the source of the transferred fibres is considered, but also the mechanisms through which these traces were transferred. Activity level conclusions are very relevant as they are close to the considerations of the court. However, a thorough evaluation of the evidential value at source level is required before an evaluation at the activity level can be routinely carried out in a justified manner. In our opinion, source level evaluation has only received minimal consideration. In the current contribution, we will examine the relevant factors for source level evaluation but make no assumptions on the mechanism through which fibre traces were transferred. Shedding and persistence will thus be neglected. We agree that these factors may be relevant for identifying the source of a fibre. For example, an item that cannot shed fibres is certainly not the source of recovered fibre traces. Nevertheless, shedding and persistence are better considered in an activity level evaluation, as proposed by Cook et al. [14] in their original work on the hierarchy of propositions. This reduces the complexity of the evaluation, but we will show that, even when transfer mechanisms are neglected, the evaluation requires various simplifications and assumption.

The remaining part of this study will be divided into five sections. Section 2 will focus on a theoretical derivation, and will propose equations for a number of generic scenarios. Section 3 will review the most relevant literature on the source level evaluation of fibre evidence. Section 4 aims to relate the experimental data of Section 3 to the theory described in Section 2 and illustrate the possibilities and limitations encountered. Section 5 will provide numerical evidential values of the proposed scenarios after which the conclusion and outlook will follow in Section 6.

2. Theoretical evaluation of scenarios

In this section, we will provide four case scenarios. For every scenario, two hypotheses are proposed and the evidence is evaluated by calculating a likelihood ratio (LR). In the first scenario, a single trace and a single reference material are considered; later scenarios consider the involvement of a different number of reference materials, traces and matches. We propose to consider the evidential value of the reference materials and traces as a group rather than to evaluate them individually. An overview of this and alternative approaches may be found in Meester and Sjerps [15] in the context of the analysis of DNA traces. The advantage of the selected approach is that different garments are treated as a group and can more easily be linked to the person that owns them.

The general hypotheses considered in the current paper are:

H_p: q types of fibre traces originate from a set of m reference materials.
H_d: The obtained reference items are not the source of the investigated n types of fibre traces.

where H_d implies that the traces originate from one or more other sources in a relevant population. Definitions of the variables used and derivation of the evidential value at source level, expressed as an LR, are provided in Appendix A. The hypotheses used in the four scenarios below are basically specific and simplified versions of these general hypotheses. Also, the equations for the LR derived in this appendix can be transformed into the equation for any of the other scenarios by inserting the proper values for those scenarios. Nevertheless, we will also provide derivations for the different scenarios in the main text to illustrate our approach.

Scenario 1. *During a robbery, the victim is restrained with tape. Later, a suspect is identified based on tactical information and taken into custody. The blue polyester gloves found in the suspect's pocket and the tape recovered from the victim are sent to the lab for examination. During the laboratory analysis, a clear glove-print is observed on the tape. Fibres from this print are isolated and match the fibres from the suspect's gloves.*

In this case a single reference material is related to a single type of fibre traces. The proposed source level hypotheses are:

H_p: The gloves are the source of the fibres isolated from the tape.
H_d: Another textile is the source of the fibres isolated from the tape.

The following symbols are proposed to facilitate the derivation:

r: the gloves (i.e. the obtained reference material) contain fibres of type r;
k: the trace fibres (i.e. material recovered from the tape) are of type k; We explicitly assume that all fibre traces of the same type originate from the same source.
E: the evidence, comprising both the classifications of r and k and a match between these fibres, or $r = k$;