B121 Using Kernel-Based Methods for Inferring the Source of Very Small Particles (VSPs) From Recovered Forensic Materials

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After attending this presentation, attendees will better understand a method that objectively models pairwise scores that are often obtained in the analysis of complex and high-dimensional forensic data. This method can be used to estimate the weight of evidence for a particular object of forensic interest.

This presentation will impact the forensic science community by: (1) providing a method to infer the source of forensic material by using the VSPs found on the surface of the material; and, (2) providing a method that models the dependency structure of pairwise scores and provides a numerical weight of evidence.

The objective comparison of complex signals in chemistry and, more particularly in forensic chemistry, with the view of inferring the source of a particular "trace" object is an ongoing issue. These issues show up either in how measurements are taken (dimensionality and/or compositional data) or the production/mass manufacturing of the trace material (e.g., paint, metals), leading to difficulty in the identification of identical materials.

Instead of looking at the trace material itself, the VSPs found in contact with the trace material are considered. VSPs are picked up in the environment(s) in which the trace material has been. These VSPs offer information regarding the geographic origins of the material despite non-uniqueness of the trace material due to manufacturing processes and allow a measure of relation between VSPs on trace material and known material, assisting in source identification of trace material.

Initial efforts classified sets of VSPs using a multinomial classifier. In order to reduce the complexity of the parameter space for this model, the types of the VSPs were categorized as determined by their dominant compounds.[1] Each source was characterized by a vector of relative proportions of these Target-Particle Types (TPTs), which could be used as parameter estimates in a multinomial model. The definition of TPTs involved the use of unsupervised clustering techniques with their inherent drawbacks (e.g., arbitrary choice of a limited number of TPTs to keep the dimension of the parameter space reasonable).

In this project, a method is proposed that circumvents these problems and enables the assignment of a probability distribution to control material from any given source based on its chemical signal. Instead of estimating parameters for TPTs, the raw data is directly worked with by leveraging the dimension reduction and discriminative powers of kernels, then extending the work of Gantz and Saunders for pairwise-score parametric models.[2] The subsequent model only requires the estimation of three parameters (once a kernel is chosen) and is subsequently used to infer the source of a trace object using a simple Bayes classifier.

The application of this method to the inference of the source of trace objects based on VSPs is illustrated. A dataset of VSPs recovered from carpet fibers throughout the United States is used and this method is applied method to: (1) reduce the complexity of compositional data obtained by SEM/EDS; and, (2) infer the source of the trace

material. Initial results of the method have a slightly improved classification rate of the trace fibers than that of the multinomial classifier, while significantly reducing the complexity of the parameter space.

This method can be extended to VSPs found on other types of recovered forensic materials such as weapons, drugs, or Improvised Explosive Devices (IEDs), and to other types of complex chemical signals.

Reference(s):

1. David A. Stoney, Cedric Neumann, Kim E. Mooney, J. Matney Wyatt, Paul L Stoney. Exploitation of very small particles to enhance the probative value of carpet fibers. *Forensic Science International.* 252:52-68, 2015.
2. Gantz D., Saunders C.P. (2014) Quantifying the Effects of Database Size and Sample Quality on Measures of Individualization Validity and Accuracy in Forensics. National Institute of Justice, Final Grant Report for Award 2009_DN_BX_K234

High-Dimensional, Weight of Evidence, Forensic Material