B167 Application of Likelihood Ratios in Fire Debris Analysis

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The goal of this presentation is to discuss a statistical approach to classification of fire debris as positive or negative for the presence of ignitable liquid residue and the determination of a likelihood ratio for the two competing hypotheses. Conversion of the likelihood ratio to a verbal scale expressing support for one hypothesis relative to the other will also be discussed.

This presentation will impact the forensic science community by showing the benefit of exposure to concepts that are fundamental to the evaluation of forensic evidence.

Likelihood ratios can be understood in the framework of receiver operating characteristic curves, probability density distributions, and Bayesian decision theory. A likelihood ratio allows the forensic scientist to evaluate evidential value under two competing hypothesis in the absence of information regarding prior probabilities, which are often unavailable. The magnitude of the likelihood ratio can be converted to a verbal scale that expresses the strength of evidential support for the two competing hypotheses. Evett has proposed a verbal scale of support as defined by the following terms on the indicated likelihood ratio intervals: "none" (0, 1); "limited" (1, 10); "moderate" (10, 100); "moderately strong" (100, 1,000); "strong" (1,000, 10,000); and, "very strong" (>10,000).[1] In the event that prior probabilities are available, posterior odds can be determined.

One example that demonstrates these concepts is the classification of fire debris as positive or negative for the presence of ignitable liquid residue. The likelihood ratio under the hypothesis that a sample is positive (H+) or negative (H-) for ignitable residue, given some Evidence (E), is defined as the ratio of class-conditional probabilities — P(E|H+)/P(E|H-). The underlying statistical model is based on a set of extracted ions from total ion spectra of ignitable liquids.[2] The total ion spectra for ignitable liquids and substrate pyrolysis products were taken from the Ignitable Liquids Reference Collection and the Substrates Database and computationally mixed to produce a balanced set of 3,000 total ion spectra for samples that were defined to be positive or negative for ignitable liquid residue.[3] Principal component analysis was performed on the data set for feature extraction and a support vector machine with radial kernel function was trained on the resulting scores and tested by ten-fold cross validation with 20% hold-out.

As a hard classifier, the optimum model had a cross-validation accuracy of 90% (i.e., 275 of 300 ignitable liquid samples were correctly classified and 262 of 300 substrate samples were correctly classified). The probabilities of class membership were obtained from the support vector machine model using a flat prior probability and the strength of support for the competing hypotheses was determined from the likelihood ratio. Using Evett's verbal scale, of 300 ignitable liquid containing samples, the likelihood ratio for one sample showed strong support for the presence of ignitable liquid residue, 36 showed moderately strong support, 143 showed moderate support, 95 showed weak support, and 25 showed no support. Using the same verbal scale, of 300 substrate samples, the likelihood ratio for three samples showed moderate support for the presence of ignitable liquid residue, 35 showed weak support, and 262 showed no support. Results from further testing with other models will also be reported.

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Fire Debris, Likelihood Ratio, Statistics

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