B102 The Development and Validation of Machine Learning Models for Fire Debris Analysis

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Learning Overview: After attending this presentation, attendees will understand about machine learning methods and how these methods can be validated and applied in fire debris analysis.

Impact on the Forensic Science Community: The presentation will impact the forensic science community by demonstrating that data analysis methods based on machine learning can objectively evaluate fire debris data and render a probabilistic estimate of the evidentiary value, which is not possible utilizing current methods based on ASTM E1618-14.

Machine learning is an artificial intelligence method that relies on statistical techniques to learn complex data patterns and make predictions on new data. Real-world applications of machine learning include voice recognition systems on cell phones, internet search engines, facial recognition, and traffic pattern predictions, among many others. Complex problems in forensic science are also amenable to machine learning applications. One example application of a challenging data analysis problem in forensic science is the detection of ignitable liquid residue in fire debris data. Several processes contribute to the complexity of recognizing the presence of an ignitable liquid residue in fire debris. Partial combustion and pyrolysis of substrate materials in a fire produce many chemical compounds that are also found in commercial ignitable liquids. Fire often leads to partial evaporation of the ignitable liquid, resulting in a modified chromatographic profile. Highly varied background signals and biological degradation effects combine to further-enhance the data analysis challenge.

Unlike currently used methods of data analysis that rely on the analyst for visual pattern recognition, machine learning methods are not subjective and can produce either categorical decisions or validated estimates of evidential value in the form of likelihood ratios. Machine learning methods, such as support vector machines, quadratic and linear discriminant analysis, k-nearest neighbors, and others have been used in research to estimate the evidentiary value of fire debris samples, even in the presence of highly varied background signals.[1-5] Research results from the use of machine learning in the analysis of fire debris data will be presented. Validation of machine learning results will be evaluated based on performance metrics, including receiver operating characteristic analysis, detection error tradeoff plots, Tippett plots and empirical cross entropy plots.[4,5]

Similar validation metrics are not available for currently used fire debris data analysis methods based on ASTM E1618-14. Calculation and reporting of likelihood ratios based on the machine learning methods will be discussed.

Reference(s):

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4. Sigman, M.E.; Williams, M.R. Assessing evidentiary value in fire debris analysis by chemometric and likelihood ratio approaches. *Forensic Sci Int* 2016, *264*, 113-121.
5. Coulson, R.; Williams, M.R.; Allen, A.; Akmeemana, A.; Ni, L.; Sigman, M.E. Model-effects on likelihood ratios for fire debris analysis. *Forensic Chemistry* 2018, *7*, 38-46.

Fire Debris, Machine Learning, Method Validation