B113 A Novel Machine Learning Approach Based on Quantitative Profile-Profile Relationship (QPPR) to Address Complex Source-Level Problems in the Forensic Analysis of Gunshot Residue (GSR)

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Learning Overview: The goal of this presentation is to describe a novel, machine learning approach to enhance the forensic profiling of organic GSR traces as well as to present its potential to address the most complex source-level problems in the reconstruction of gun crimes.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by showcasing a new, ground-breaking method for *in silico* profiling of chemical residues that could potentially also be extended to other forensic fields routinely encountering mutable traces.

GSR is a chemical trace that commonly assists law enforcement authorities in the investigation of gun crimes, for example, to recognize whether a suspect has recently been involved in a shooting activity or to estimate shooting distances during ballistic reconstructions. While its use at source level would be extremely useful too (e.g., for origin attribution and/or evidence association), nonetheless, this is still very challenging and limited to specific scenarios. The main problem here is the complexity of the mechanisms involved in GSR formation. In order to advance from this situation and promote a more systematic use of this evidence type, a novel *in silico* approach, QPPR has been developed and is presented herein.[1] This is based on the application of modern machine learning techniques to model the discharge process and predict the pre-discharge chemical profiles of selected ammunition components from those of the respective post-discharge GSR. The obtained profiles can then be compared with another and/or with other measured profiles in order to associate samples and make evidential links during crime investigation.

In particular, the approach was optimized and successfully tested for the prediction of Gas Chromatography/Mass Spectrometry (GC/MS) profiles of smokeless powders from those of the respective organic GSRs.[2,3] Results showed a high degree of similarity between predicted and experimentally measured profiles (media correlation = 0.982) after adequate combination of 14 machine learning techniques, including artificial neural networks and support vector machines. Evaluation of association performances by Receiver Operator Curve (ROC) analysis, for the comparisons between predicted-predicted and predicted-measured profiles, showed classification accuracies of 92.9% and 80.0%, respectively, in extrapolation mode and of 91.7% and 88.3%, respectively, in interpolation mode. These values were close to those obtained after direct comparison of the measured smokeless powder profiles with one another (accuracy = 98.6%), demonstrating excellent potential to correctly associate same-source samples in a number of different forensic scenarios and help to address source-level problems in complex situations. The novel modeling approach is therefore very promising and could unlock wholly new possibilities in the investigation of gun crimes, such as the ability to compare GSRs recovered from different crime scenes and link them in an "intelligence-led" perspective. The benefits are countless and may even extend to the analysis of other GSR fractions (e.g., primer GSR) or to other forensic fields that also routinely encounter mutable chemical traces such as, for example, the analysis of arson accelerants and environmental contaminants.

Reference(s):

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2. Matteo Davide Gallidabino, Francesco Saverio Romolo, Kelsey Bylenga, and Céline Weyermann. Development of a novel headspace sorptive extraction method to study the ageing of volatile compounds in spent handgun cartridge. *Analytical Chemistry* 86 (2014): 4471-4478, https://doi.org/10.1021/ac5004568.
3. Matteo Davide Gallidabino, Francesco Saverio Romolo, and Céline Weyermann. Characterization of volatile organic gunshot residues in fired handgun cartridges by headspace sorptive extraction. *Analytical and Bioanalytical Chemistry* 407 (2015): 7123-7134, https://doi.org/10.1007/s00216-015-8874-0.

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