B103 The Application of Wavelet Transform and Transfer Learning for Gasoline Classification Using a Hand-Held Raman Spectrometer

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Learning Overview: The goal of this presentation is to provide attendees with a practical solution for discriminating between gasoline and non-gasoline samples using a hand-held Raman spectrometer. The application of wavelet transform for Raman scattering signals will be discussed in this presentation. This study will also demonstrate how transfer learning can be applied to develop Artificial Intelligence (AI) to detect gasoline samples.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by introducing a new approach for effective detection of gasoline by adopting wavelet analysis and deep learning for Raman spectra processing. A machine learning model for distinguishing gasoline from seven common Ignitable Liquids (ILs) was developed based on deep learning algorithms. The model developed in this work could predict accurately for gasoline and non-gasoline liquids using a hand-held Raman spectrometer for signal collection.

Gasoline is one of the ILs that has been most widely used as an accelerant to speed up the escalation of fire in arson cases. A rapid and accurate approach to detect gasoline allows investigators to recognize and preserve the evidence in time correctly and get a head start tracing the prime suspect during the investigation. A hand-held Raman spectrometer combined with AI is an attractive analytical platform that offers a rapid and field-deployable capability for precise gasoline and non-gasoline ILs classification.

In this work, gasoline with three grades (regular, mid-grade, and premium) and seven different ILs (charcoal lighter, pure gum spirits of turpentine, kerosene, mineral spirit, hexane, xylene, and toluene) were chosen for AI development. A hand-held Raman spectrometer with a red 785nm laser wavelength was utilized to acquire 130 gasoline Raman spectra and 105 non-gasoline liquids Raman spectra. One mL sample was placed in a glass vial for Raman signal measurement. All Raman spectra of the samples were acquired under various conditions such as measuring under ambient light and without ambient light. Each spectrum was obtained with 20 seconds of integration time and has been baseline-subtracted to correct the background signal. The spectral range was recorded from 400 to 2,300cm^{-1} for analysis. The features of Raman spectra were processed by the Continuous Wavelet Transform (CWT) to create the scalograms, representing the absolute values of the CWT coefficients of the signals in the spectra. Followed by the data processing, a convolutional neural network for transfer learning was adopted to create a classifier to distinguish between gasoline and non-gasoline ILs based on the pre-trained neural network architecture. In the architecture, 144 layers acted as filters to identify common and specific features of the scalograms to be re-trained for recognizing scalograms from gasoline and non-gasoline. During transfer learning, 235 scalograms were randomly divided into two groups: 80% of the images (188 scalograms) for training and 20% of the images (47 scalograms) for model validation.

From the training progress, it was found that the constructed model successfully reached 100% accuracy in classifying gasoline and non-gasoline ILs within 2 epochs in a 20-epoch training cycle. The validation accuracy was reported as 100% accurate as well. This study demonstrated a new approach for gasoline classification based on Raman spectra using wavelet analysis and deep learning. No normalization of the spectra was required for AI development. Through this new approach, a trained AI model capable of rapidly and accurately detecting gasoline with different grades from seven other ILs was developed and successfully validated.

Hand-Held Raman Spectrometer, Wavelet Analysis, Deep Learning

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