

Emergent explosive threats for use with threat anomaly detection (ThreAD)

Languirand, Eric R.,¹ Collins, Matthew D.,¹ Buchman, Jacob A.²

¹U.S. Army Combat Capabilities Development Command Chemical Biological Center, Aberdeen Proving Ground, MD, ²Army Educational Outreach Program Fellow

Abstract

Rapid analysis of an area to identify where to sample with a high-fidelity instrument is imperative when attempting to understand where potential chemical threats are on surfaces. In an area with an unknown threat, it is important to maintain a protective posture. Being able to identify the specific areas to sample will aid in reducing the time it takes to adequately sample a large area and help point the user to smaller areas of interest. There may be one or more areas on a surface that require sampling to fully understand the potential threats that may be present. We have shown that using a threat anomaly detection (ThreAD) algorithm developed by DEVCOM CBC provides a methodology to find areas of interest via anomaly detection.

This work outlines the method behind the algorithm and discusses potential use-cases. One such use-case is with hyperspectral reflectance data in which we show explosives are shown as anomalous in real-time on surfaces. Additionally, this work delves into the clustering and separability of potential threats from surfaces but also separates reagents from products of emerging explosive threats. This method of anomaly detection may prove useful as a GO/NO-GO identifier for potential threats, as a pointer for high fidelity instruments to sample, or as a data filter to quickly identify which spectra require further analysis.

Background

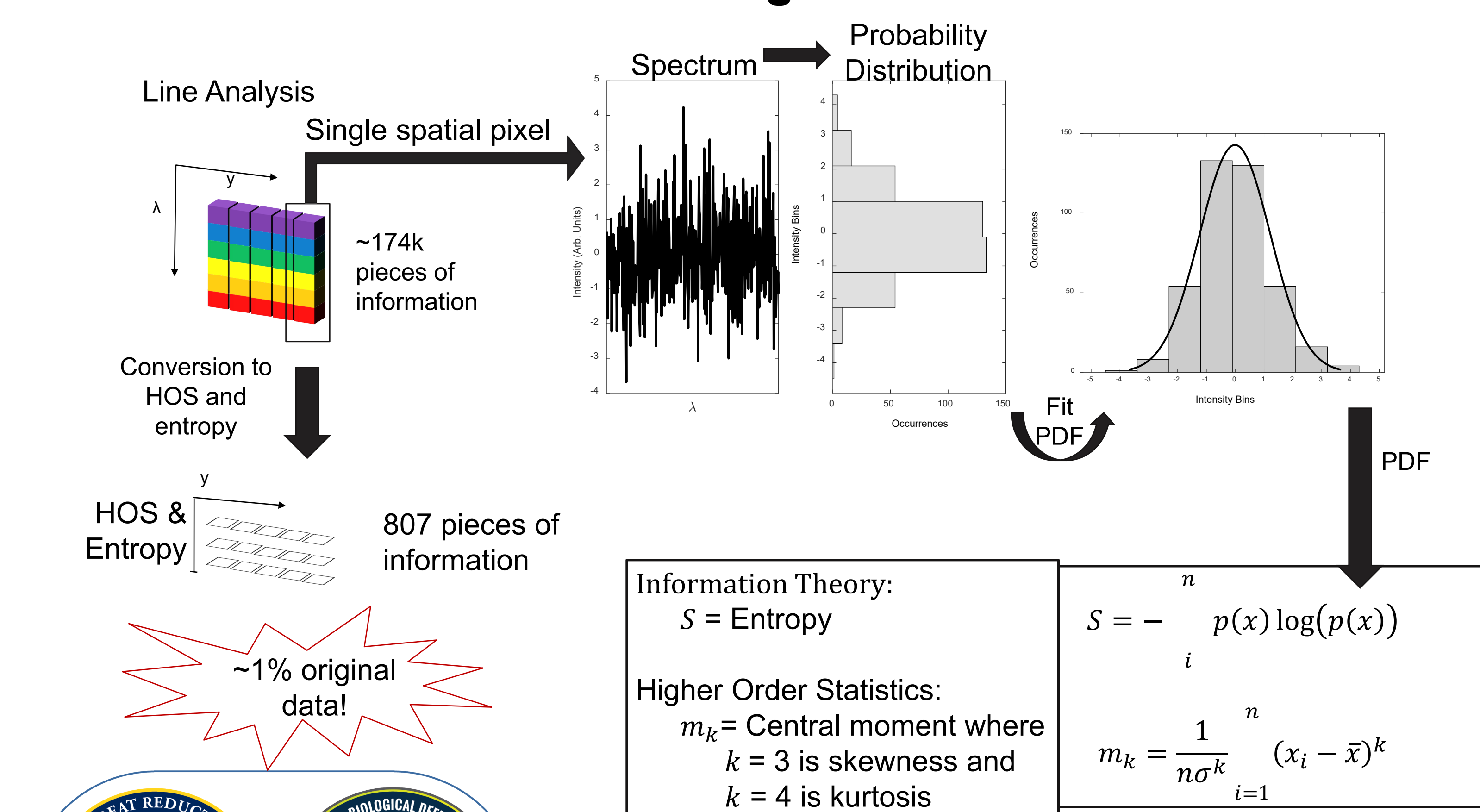


Figure 1: Each frame is read in via camera-link and the spectra are converted to the probability distribution pixel wise in real-time to determine the higher order statistics and entropy, compressing the data by approximately 99%.



DEVCOM CBC @ DTRA CBD S&T Conference

Scan the QR Code to view all of CBC's
2024 DTRA CBD S&T Conference materials
<https://cbc.devcom.army.mil/cbdst-conference/>

This method utilizes a semi-supervised machine learning technique to label potential threats as anomalies. The data is read in real-time and, using DBSCAN, the background is learned. The learned background is then compared to the remaining pixels in the data set in real time *without referencing* which reduces the computational burden and fielding requirements.

Results and Discussion

Exemplifying the utility of this algorithm, Figure 2 shows the real-time detection of pharmaceutical surrogates and explosives on concrete. A hyperspectral spectrometer was translated from right to left (with respect to the figure) while illuminated with solar-similar lights. Generally, the surface concentration of each analyte (Figure 2; yellow = less, green = more) scales with the amount of analyte that is present. Additionally, a positive control was added in the form of asphalt (upper right of test area). Additionally, further algorithm optimization has improved our real-time performance by over 2-fold without any differences in anomaly detections on test data.

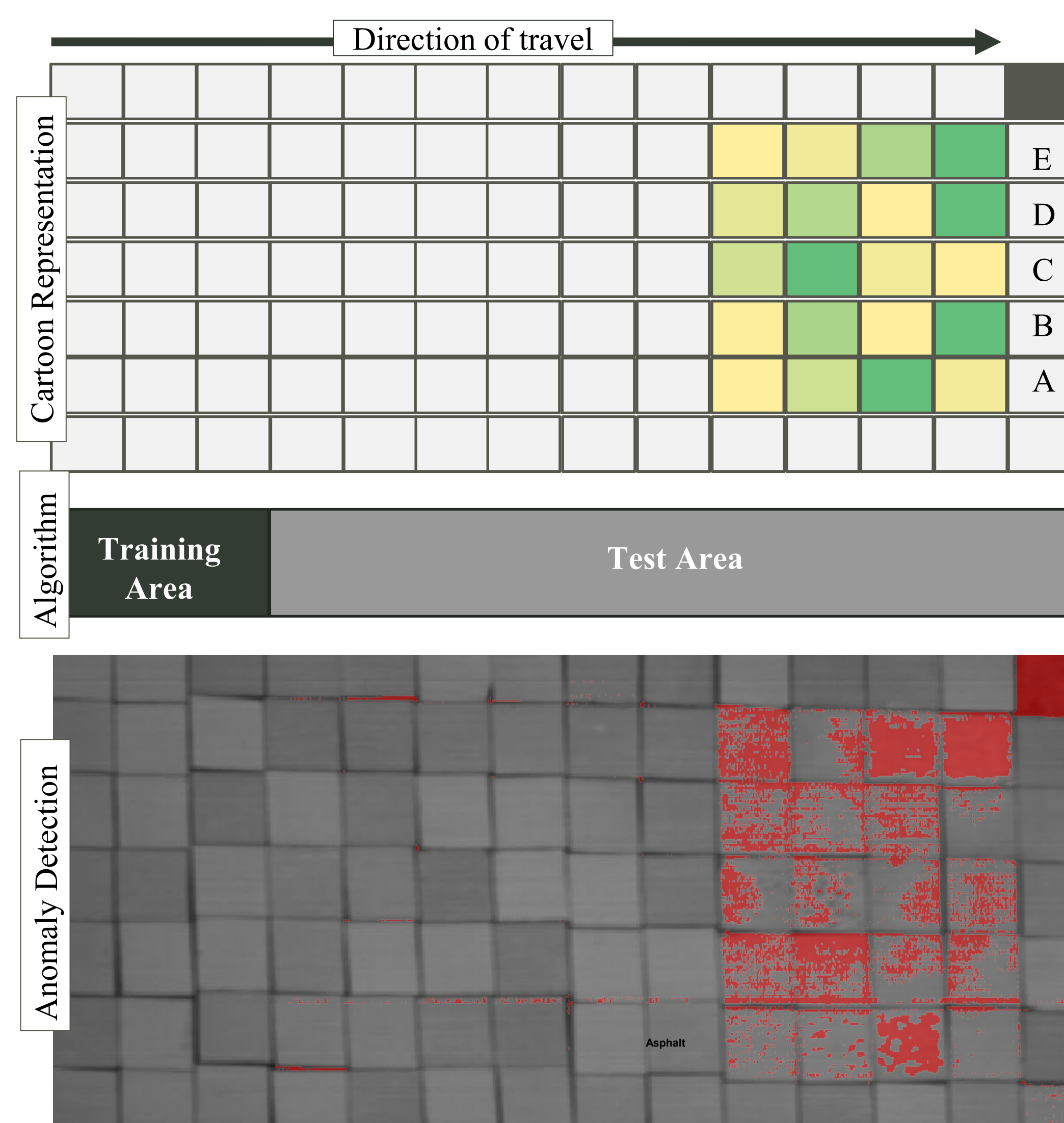


Figure 2: Cartoon representation of a data set showing concrete substrates in an array with pharmaceutical surrogates (A), and explosives threats (nitrates, B; chlorates, C; nitrosamines, D and E) and color coded for relative surface concentrations (Top). A cartoon representation of the stages of the algorithms is also shown with training of the background at the beginning followed by testing by comparing each pixel to the learned background via DBSCAN clustering (middle). The areas with explosives and pharmaceutical surrogates show anomalies (red pixels) compared to the background and generally scale with the relative concentration of the analyte on the surfaces (bottom).

In addition to anomaly detection, there is a potential for class identification of compound using the parameterization strategy employed here. As the spectral content changes, the PDF changes, and therefore the parameters employed change as well. Similar compounds that possess similar moieties often have similar spectra and therefore may also parameterize to similar areas in 3D coordinate space. Figure 3 exemplifies this via general grouping of emerging compounds of interest (green open circles), nitrates (light blue and burgundy open circles), and nitroamines (yellow and orange open circles). Additionally, a buffer to learn new background variations as they arise can be implemented, as shown in Figure 4.

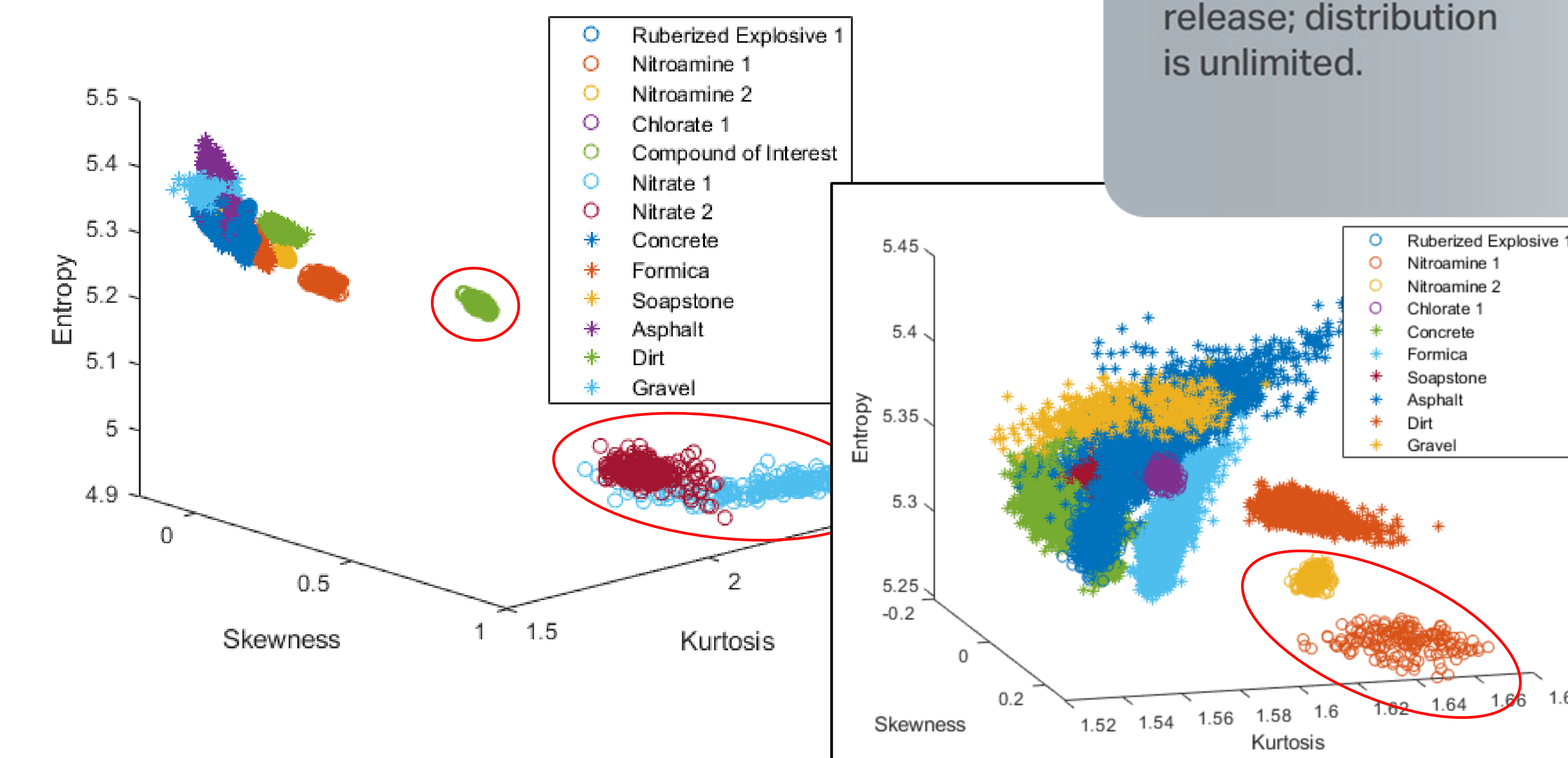


Figure 3: Grouping surfaces and analytes with general grouping of similar analytes highlighted by the red ovals indicate a potential for class-based identification using the ThreAD algorithm.

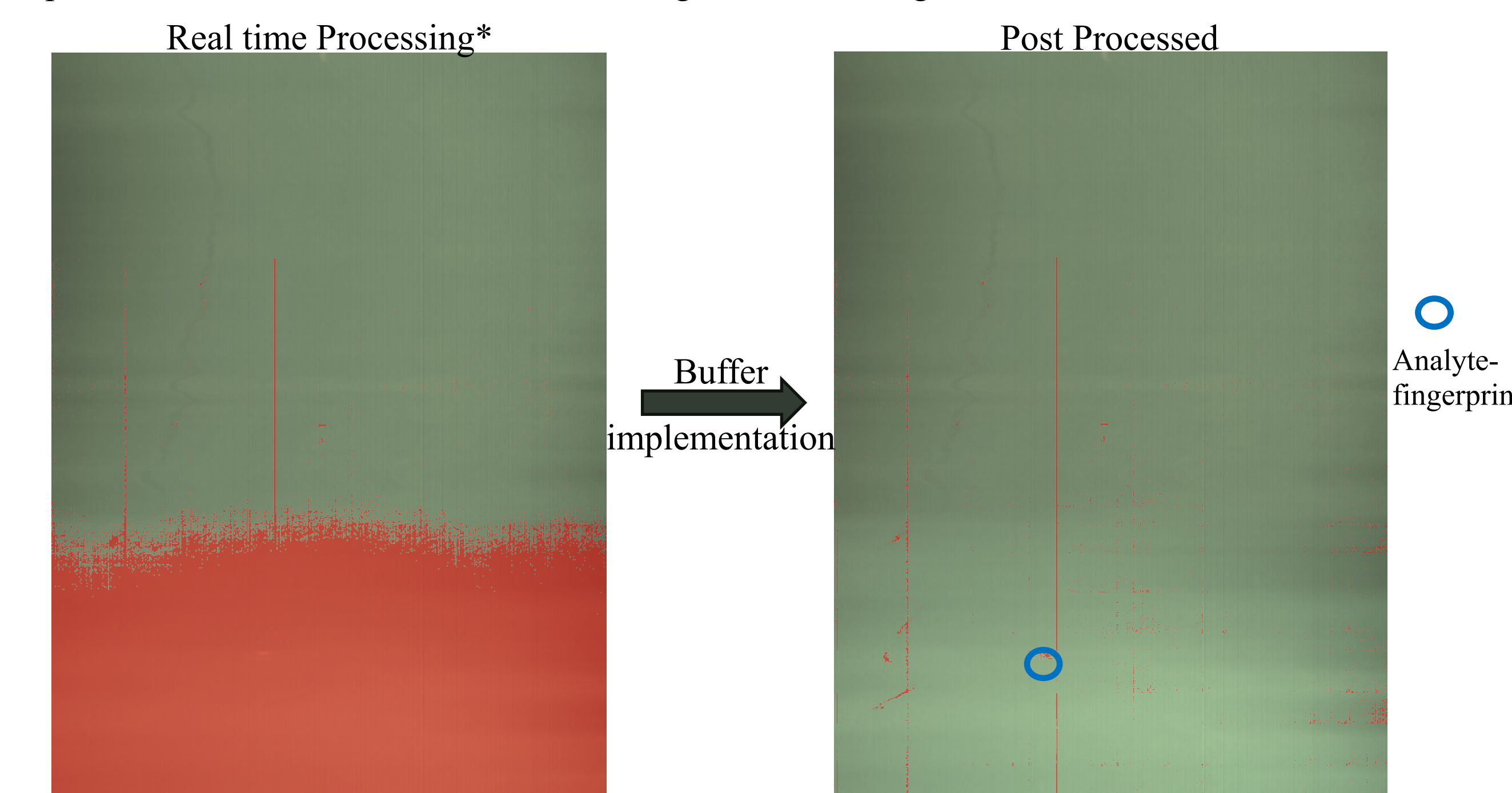


Figure 4: Learning the background one time and with no referencing can cause false anomalies (left) when processed with our current real-time algorithm. Implementing a buffer to continually learn the background when it changes provides an opportunity to have a higher fidelity system (right). A fingerprint that was not originally seen was able to be located once the buffering was implemented.

Conclusions

Threat anomaly detection (ThreAD) can provide real-time semi-supervised machine learning of anomalies of potential threats. Parameterization provides the rapid analysis along with a potential for class identification. No referencing presents potentials for changing backgrounds to cause anomalies, but that can be mitigated by employing a buffer and continuously learning the background with minimal computational burden.

Acknowledgements: R&D funding for this work was authorized under the Army DEVCOM-CBC Explosive Forensic program element number 0602144A and project number BL2. The authors would also like to acknowledge the Army Educational Outreach Program (AEOP) for financial support for JAB. The views expressed in this document are those of the authors and do not necessarily reflect the official policy or position of the Department of Defense or the U.S. Government.

CBDS⁺

Approved for public release; distribution is unlimited.