APPLICATION NOTE

Real-time Characterization of Smoke Candles Using Infrared Hyperspectral Imaging

Abstract

The development of efficient countermeasure devices like flares and smoke candles requires detailed characterization in order to suit their proper application. However, the gas clouds produced by these devices may turn out to be difficult to characterize. Infrared hyperspectral remote sensing now brings crucial information to this task which could not be obtained before. The Telops Hyper-Cam, a standoff infrared hyperspectral sensor, was used to characterize smoke candles developed by the Military University of Technology in Poland. The results are presented through the Reveal D&I interface, a real-time gas detection and identification software which provides visualization of gas clouds for multiple gases simultaneously, along with their evolution in time. The powerful detection algorithms developed by Telops illustrate their full potential as they were used for the field characterization of smoke candles.

Introduction

The development of efficient countermeasure devices is a challenging task for intelligence agencies. Flares and smoke candles are versatile devices which can be used for different purposes including protection of soldiers, positioning, rescue, communication, decoys, and screening agents. Their optimal design resides in an accurate mixture of the different chemicals involved in its combustion. Some of these chemicals are infrared-active species which can be observed using thermal imaging. Infrared hyperspectral imaging brings this approach to another level as it adds a spectral dimension to the infrared images. The Telops Hyper-Cam (Figure 1) is a standoff infrared hyperspectral sensor which can be used to selectively identify numerous compounds based on their unique spectral signature. However, processing of hyperspectral data may turn out to be a demanding task as it requires advanced knowledge about signal processing and detection algorithms. Reveal D&I, a real-time gas detection and identification software developed by Telops, takes full advantage of the rich information provided by hyperspectral imaging. It provides rapid feedback during field experiments as it allows real-time visualization of multiple gases simultaneously. In order to illustrate the usefulness of this tool, it was used to characterize gaseous emissions of smoke candles in field trials carried out by the Military University of Technology in Poland.

Figure 1: The Telops Hyper-Cam LW in its weatherproof enclosure.

Experimental Information

The Telops Hyper-Cam is a compact hyperspectral imaging instrument using Fourier Transform Infrared (FTIR) spectroscopy. It provides a unique combination of spatial, spectral and temporal resolution for a complete characterization of the substances being monitored. Its high performance and efficiency as a standoff chemical agent detector has been proven through numerous field campaigns. The Hyper-Cam Long-Wave features a Focal Plane Array (FPA) detector containing 320×256 pixels over a basic $6.4° \times 5.1°$ field of view. The spectral resolution is user-selectable between 0.25 and 150 cm^{-1} over the 7.7 to 12.0 µm spectral range. The Hyper-Cam offers a high sensitivity for each pixel of the scene under observation. The sensor is capable of generating calibrated hyperspectral images (Fourier transformed and radiometrically calibrated) in real-time at the highest data rate available.

This real-time feature was brought to another level with Reveal D&I; a real-time gas detection and identification software. A snapshot of its user-friendly interface is presented in Figure 2. Along with the large collection of infrared signatures from the commercial spectral libraries, the user can benefit from the powerful detection algorithm built into Reveal D&I by using its own infrared signature as an input. This specific feature was used in the present work to illustrate the versatility of Reveal D&I in for the characterization of military smoke candles.

Figure 2: Reveal D&I Software

Results & Discussion

Different types of smoke candles were characterized using infrared hyperspectral imaging. A typical image recorded during an ongoing experiment is illustrated in Figure 3. Comparison between both images clearly illustrates the different screening efficiency in both visible and infrared spectral range.

Figure 3: Visible (top) and broadband infrared (bottom) image of an ignited smoke candle used for screening.

A hyperspectral image recorded during another experiment is shown in Figure 4. The gaseous emissions produced by the smoke candle appear white as they are much warmer than all other objects in the background. The spectral information provided by infrared hyperspectral imaging is also illustrated in Figure 5 where different pixels reveal different spectral features depending on their location in the scene. As an example, the spectrum of a pixel located near the ignition point (blue spectrum), representative of chemical products from the flare combustion, presents a distinct emission spectral feature at 1275 cm^{-1} as opposed to a pixel located on a tree (red spectrum).

The infrared signature of some chemicals, which will be referred to as Chemical 1 and Chemical 2, involved in the prepared mixtures were added to the existing spectral library of Reveal D&I. This way, one can benefit from the real-time platform without worrying about signal processing and the development of detection algorithms. The exact nature of these compounds will not be divulgated for confidentiality purposes.

The complete experiment sequence as seen from the Reveal D&I interface is illustrated in Figure 5. The simultaneous presence of different gases at separate time frames clearly illustrates the combined spatial, spectral and temporal resolution provided by the Telops Hyper-Cam. The chemical imaging performed in real-time allows tracking of the different targets quite easily at different stages during the experiment. The presence of Chemical 1 can still be detected once the flare appears extinct on the visible image since the gaseous emissions are relatively hot. In addition to the spectral inputs provided by the user for this experiment, the presence of ammonia in the combustion gases could be detected (red). Its presence may be explained by the decomposition of ammonium compounds, chemicals commonly encountered in energetic materials.

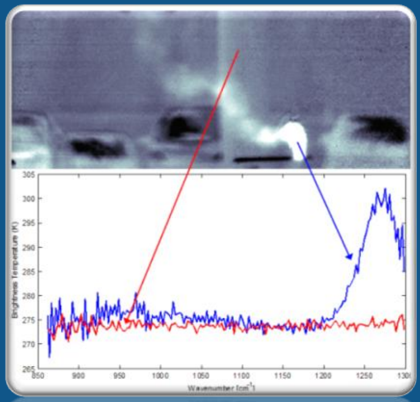

Figure 4: Infrared image of an ignited flare (top) showing the spectrum of different pixels in the scene (bottom).

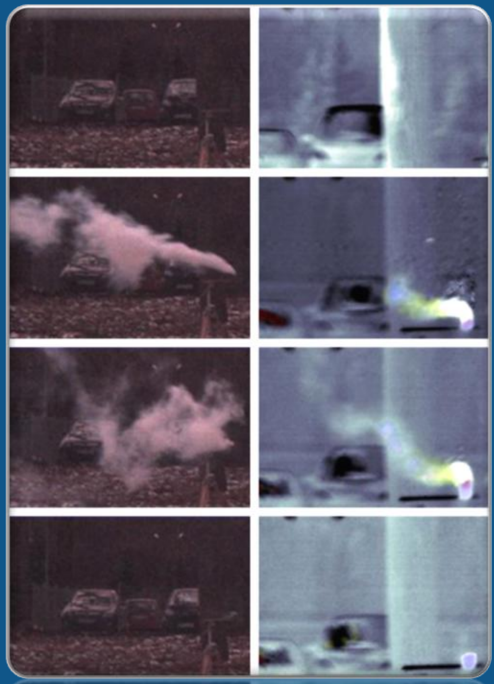

Figure 5: Successive detection images and their associated visible image before (top two images) and during (bottom six images) flare combustion. The different targets are labeled as follows: Chemical 1 (blue), Chemical 2 (yellow) and ammonia (red).

Conclusion

The rich information provided by infrared hyperspectral imaging is brought to a real-time stage through the interface of Reveal D&I. It was shown that users can easily benefit from its built-in signal processing and detection algorithms in order to get a rapid feedback and improve efficiency of field trials.

www.telops.com

100-2600 St-Jean-Baptiste avenue Quebec, QC, G2E 6J5 | Tel: 418.864.7808 | Fax: 418.864.7843 | sales@telops.com