Thermal Spectral Imaging for Air-to-Ground Target Detection

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Comments by the Symposium Chair on the Following Thermal Spectral charts

The following charts describe activities in the multi/hyperspectral sensing technical area. Spectral target detection adds another dimension to passive sensing. This may make it possible to relax spatial sampling requirements. The third chart shows conceptually how the detection pixel can grow compared to classic detection techniques, and it may also be possible to detect partially obscure targets. Later charts discuss the requirements for day / night target detection and our data collection activities designed to support day / night target detection. Our current challenge is to use the spectral dimension in the thermal regime, so we can detect targets both day and night. The technology for day only spectral based target detection using the .4 to 2.5 μm region is relatively mature. A trade must be performed between midwave and long wave IR bands when considering thermal spectral detection techniques. Currently it appears that the long wave IR is more suitable for spectral based target detection due to enhanced clutter rejection based upon a very uniform natural background. It would be easier to build a thermal spectral based sensor in the mid IR portion of the spectrum, so there is still interest in making that portion of the spectrum work for thermal spectral based target detection.

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THERMAL SPECTRAL IMAGING

- Passive spectral sensors have the potential for detecting and characterizing camouflaged and concealed targets in clutter
 - Clutter suppression $\Rightarrow$ detect low contrast targets
 - Low false alarm rate $\Rightarrow$ color discrimination
 - Relaxed spatial resolution $\Rightarrow$ broad area coverage
 - Material identification $\Rightarrow$ target characterization

Target size

FLIR pixel size

Spectral sensor pixel size

- Thermal infrared (3-12 μm) operation provides day/night capabilities

PROGRAM OVERVIEW

- **Proof of Concept Experiments**
 - Performed preliminary concept utility assessment based on FTIR data
- **Airborne Data Collection Instrument Assessment**
 - Supported development of Aerospace Spatially Enhanced Broadband Array Spectrograph (SEBASS)
 - Fielded SEBASS at WSMR and Redstone Arsenal (CARD SHARP)
 - Performed detection enhancement analysis
- **Airborne Data Collection Instrument Acquisition**
 - SEBASS High Altitude Reconnaissance Project (SHARP)
- **Airborne Data Collection**
- **Algorithm Optimization/Development**
- **Operational Sensor System Specification**

TRUCK DETECTION IN FOREST

Dual-Band Scatterplot

SCR (8.67 μm) = 0.23

SCR (9.23 μm) = 0.03

Color Ratio = 0.15

Clutter Correlation = 0.99988

Dual Band SCR = 12.93

Measurement Characteristics

- Woodland Painted Truck
- Conifer Forest Bkg ($\sigma_T = 0.83$ K)
- Redstone Arsenal (Exp: MHMTCM)
- Time/Date: 7:53 AM, 7-22-93
- Microflicks = $\mu\text{W}/\text{cm}^2\mu\text{msr}$

Spectral Radiance Contrast

ROBUSTNESS OF DETECTION PERFORMANCE

- Common band set optimized over variety of target/background combinations
 - Woodland and desert, open and camouflaged military vehicles in forest and desert
- Detection performance is robust to time-of-day and environmental conditions

MWIR VS. LWIR

- Robust spectral features found in the LWIR spectral region
- Performance generally reduced with MWIR-only restriction

SENSITIVITY REQUIREMENTS

- High sensitivity is required to achieve full multispectral potential

AEROSPACE SEBASS

NESR < 1 $\mu\text{W cm}^{-2} \mu\text{m}^{-1} \text{sr}^{-1}$ (at 122 Hz frame rate)

SEBASS OPTICAL LAYOUT

SEBASS DEWAR ASSEMBLY

AIRBORNE DATA COLLECTION INSTRUMENT

High fidelity measurement instrument

- Calibrated, low noise, well characterized

Addresses signature phenomenology

- Background false alarm statistics
- Atmospheric path effects (mean and variance)
- Broad *in situ* signature database development
- Sensor and algorithm performance limits

Spatially Enhanced Broadband Array Spectrograph System (SEBASS) High Altitude Research Project (SHARP)

Supports many operational scenarios

- U2, HAE-UAV ⇒ 60,000 ft, nadir to 70 deg.
- MAE-UAV ⇒ 10,000 ft, nadir to 30 deg.
- JSF, F-22, etc. ⇒ 30,000 ft, 70 deg.
- Space ⇒ 60,000 ft, nadir

NASA WB-57

FULLY ADAPTIVE CFAR ALGORITHM: ERIM

Decision Statistic Computed
in Moving Window Across Image

CFAR
Threshold

Spatial Filtering

$$r(\mathbf{X}) = (\mathbf{X}\bar{\mathbf{s}})^T \hat{\mathbf{M}}^{-1} (\mathbf{X}\bar{\mathbf{s}}) > \text{CFAR Threshold} \quad H_1$$

$$r(\mathbf{X}) = (\mathbf{X}\bar{\mathbf{s}})^T \hat{\mathbf{M}}^{-1} (\mathbf{X}\bar{\mathbf{s}}) < \text{CFAR Threshold} \quad H_0$$

where $\mathbf{X}$ = Pixel Observation Matrix
 $\bar{\mathbf{s}}$ = Target Spatial Shape Vector
 $\hat{\mathbf{M}}$ = Background Covariance

MULTIPLE LINEAR FEATURES ALGORITHM: ERIM

Normalization

Fixed Spectral
Thresholds

Spatial Filtering

SENSOR SYSTEM SPECIFICATION APPROACH

CONCLUSION

- **Spectral target detection and material identification has been demonstrated in MWIR/LWIR**
 - Initial results based on FTIR data, confirmed with SEBASS
 - Robust performance achieved with small (4-6) number of bands
 - Analysis indicates strong preference of LWIR over MWIR
 - Detection performance is contingent on excellent sensor performance, especially SNR
- **JMSP plans more thorough evaluation**
 - Airborne data collection instrument to address false alarm statistics and realistic collection scenarios
 - Thorough evaluation of detection/identification algorithms
 - Sensor system specification for target applications

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