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Potential Payoff of Fusion Between HSI and Other Sensors

S. M. Hsu and H. K. Burke

MIT Lincoln Laboratory

19th Space Control Conference

MIT Lincoln Laboratory

4 April 2001

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### Title and Subtitle
Potential Payoff of Fusion Between HSI and Other Sensors

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### Distribution/Availability Statement
APUBLIC RELEASE

### Supplementary Notes
See Also ADM001334, Proceedings of the 2001 Space Control Conference (19th Annual) held in Lincoln Laboratory, Hanscom AFB, MA on 3-5 April 2001.

### Abstract
HSI: Hyperspectral Imaging
SAR: Synthetic Aperture Radar
HPI: High-resolution Panchromatic Imaging

### Subject Terms
Unclassified
Hyperspectral Imaging (HSI)

- High dimensionality data
  - High spatial resolution EO imagery
  - Hundreds of co-registered, contiguous, narrow spectral channels ($\lambda/\Delta\lambda \sim 100$)
  - 0.4 to 2.5 $\mu$m systems exist, 3 to 12 $\mu$m emerging

- Diverse applications
  - Atmospheric characterization
  - Terrain delimitation
  - Target detection
  - Material identification
  - Spatially unresolved object detection
Motivation

• Combined sensing of HSI with others offers potential for greater payoff

• Examples:
  – HSI and SAR
    Complementary roles result in surface penetration, false alarm reduction and target identification enhancement
  – HSI and Panchromatic Imagery
    Enhanced spatial and spectral information for improved background delimitation and better target characterization/identification
Outline

• Overview
  – Objectives
  – Fusion applications

• Fusion examples
  – SAR/HSI
    Explore different phenomenologies
  – HSI/HPI
    Utilize superior respective spectral and spatial resolutions

• Summary

HSI: Hyperspectral Imaging
SAR: Synthetic Aperture Radar
HPI: High-resolution Panchromatic Imaging
HSI/SAR Fusion Example: Dixie-97 Data Collection, 28 May 1997

- Forest, roads, open area backgrounds
- Fabric nets, exposed and concealed vehicles
- Overlapping coverage for HSI and SAR fusion

<table>
<thead>
<tr>
<th>HYDICE</th>
<th>P-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4 &lt; λ &lt; 2.5 μm</td>
<td>200 – 700 MHz</td>
</tr>
<tr>
<td>Viewing geometry</td>
<td>Nadir viewing</td>
</tr>
<tr>
<td>Depression angle</td>
<td>~ 30°</td>
</tr>
<tr>
<td>GSD</td>
<td>0.76m x 1.1m</td>
</tr>
<tr>
<td></td>
<td>0.23m x 0.4m (resampled)</td>
</tr>
</tbody>
</table>
SAR/HSI Detection Comparison and Sample ID Fusion Approach

<table>
<thead>
<tr>
<th></th>
<th>Trees</th>
<th>Grass</th>
<th>Roads</th>
<th>Camo Nets</th>
<th>Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHF SAR</td>
<td>FA</td>
<td>Low</td>
<td>Low</td>
<td>No Det</td>
<td>Det</td>
</tr>
<tr>
<td>HSI</td>
<td>ID</td>
<td>ID</td>
<td>ID</td>
<td>Det in open</td>
<td>Det in open</td>
</tr>
</tbody>
</table>

FA = False Alarm
ID = Identification
Det = Detection

SAR Detection → Vehicles, Trees, etc.

HSI Feature Analysis → Terrain Charact. (Roads, trees, open areas) Camo Nets

Co-registration → Map Terrain Features → Reduce SAR FA

→ Superimpose Camo Nets on SAR detection → Det vehicles under nets

→ Other SAR Detections → Material ID
HSI Analysis Results

Sample Spectra

- Camou. net
- Road
- Grass
- Tree

Relative Intensity

Wavelength (μm)

Net detection

Background characterization

- Nets
- Roads
- Grass
- Trees
- Shadow
Fusion of SAR/HSI Detections

P-3 UHF SAR 6 dBsm Thresholded

HYDICE HSI Open area/Fabric net Detection

Combined SAR/HSI Data Vehicle under Net Identified

SAR detection confirmed and material identified using HSI

Vehicle under net

Vehicle partially exposed

Gray Tan Paint

SAR Chip

HSI Chip

Open area

Fabric nets
SAR/HSI Fusion Summary

• Common data set identified
  – Dixie-97 with forest background
  – Fabric nets, vehicles, vehicle under fabric net

• HSI data detected fabric nets not seen by SAR
  – Terrain characterization also established

• SAR/HSI image co-registration accomplished

• Fusion of SAR/HSI data results in:
  – Detection of vehicle under net
  – Reduction of SAR false alarms
  – Confirmation of SAR detection and material identification

→ Complementary roles between HSI and SAR illustrated
Outline

• Overview
  – Objectives
  – Fusion applications

• Fusion examples
  – SAR/HSI
  – HSI/HPI
    Enhanced spatial-spectral analysis

• Summary

HSI: Hyperspectral Imaging
SAR: Synthetic Aperture Radar
HPI: High-resolution Panchromatic Imaging
Motivation for Fusion of HSI and Panchromatic Imagery

- HSI and high resolution EO sensors often co-exist in measurement platforms (Space, A/C, and UAV)
- Spatial resolution for Pan typically 3-8 times better than HSI

Example Space Platforms

<table>
<thead>
<tr>
<th>Satellite</th>
<th>EO-1 (NASA)</th>
<th>Warfighter-1 (Air Force)</th>
<th>NEMO (Navy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSI Spectral</td>
<td>0.4 - 2.5 µm 220 bands</td>
<td>0.4 - 2.5 µm 200 bands</td>
<td>0.4 - 2.5 µm 210 bands</td>
</tr>
<tr>
<td>Scene Size</td>
<td>7.5 km x 100 km</td>
<td>5 km x 20 km</td>
<td>30 km x 200 km</td>
</tr>
<tr>
<td>HSI IFOV</td>
<td>30 m</td>
<td>8 m</td>
<td>30 m</td>
</tr>
<tr>
<td>Co-incident Pan (Visible band)</td>
<td>10 m</td>
<td>1 m</td>
<td>5 m</td>
</tr>
</tbody>
</table>
Fusion of Hyperspectral and High Resolution Panchromatic Images

- Combined spatial and spectral information from high resolution data for enhanced background characterization and target detection / identification
Spatial and Spectral Analysis Approach

HSI

Background classification & Anomaly detection

Sharpened HSI

Bkgrd. sta. & Material spectra

(Enhanced) Background classification & Target detection

Co-registration

Target template

Edge detection

HPI

Target detection & ID
Background Classification and Anomaly Detection on HSI

- Background map from unsupervised classification
- Anomaly detection also accomplished
Spatial Processing on HPI

- Edge detection obtained with application of Sobel operator
- No apparent separation in HPI intensity between sample material classes

Panchromatic image with edges

Sobel operator:

\[
S_{x,y} = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} + \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}
\]

Sample Target Intensity in HPI

- Paint 1
- Paint 2
Target Identification:
Fusion of HSI and Panchromatic Imagery
Target Identification:
Fusion of HSI and Panchromatic Imagery

RGB Image

HSI: Material ID

Pan: Spatial Edges

Combined Result

- Paint 1
- Paint 2
- Edges
- Large (4x8 m²)
- Small (3x6 m²)
Target Identification: Fusion of HSI and Panchromatic Imagery

- RGB Image
- HSI: Material ID
- Pan: Spatial Edges
- Combined Result
  - Paint 1
  - Paint 2
  - Edges
  - Large (4x8 m²)
  - Small (3x6 m²)

- Target material identified
  - Spectral matched filtering
Target Identification: Fusion of HSI and Panchromatic Imagery

- Target material identified
  - Spectral matched filtering
- Target size, shape and orientation determined
  - Spatial filtering of edges from Pan

**HSI:**
- Material ID

**Pan:**
- Spatial Edges

**Combined Result**
- Paint 1
- Paint 2
- Edges
- Large (4x8 m²)
- Small (3x6 m²)

**RGB Image**
HSI/HPI Fusion Summary

• Simulated data generated
  – Measured data from high resolution HSI as “truth”
  – HPI data by band integration
  – HSI data by spatial degradation

• Methodology developed for combined spatial/spectral analysis

• Fusion of HSI/HPI data results in:
  – Enhanced background classification
  – Better target characterization and identification

Product enhancement illustrated by HSI/HPI fusion