Automated Cueing to Man-Made Objects
Via Multi-Spectral Image Exploitation

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MASTER
Technical Progress

The efforts during this period of the program focused on image-based multi-spectral calibration and continuous investigation of multi-spectral prescreening algorithms.

Imaged Calibration In order to generate a spectral signature of an object for either single snapshot detection or multi-snapshot change detection, the object's reflectance in each band must be determined. The reflectance is the ratio of the radiance received and the radiance reflected by the object on the ground. The radiance received at the remote sensor, due to effects caused by the atmosphere, is a scaled and offset version of the radiance reflected by the object on the ground. The atmospheric effects must be reversed, or corrected, in order to determine the actual radiance of the object from which the reflectance will then be determined. Most existing algorithms require knowledge of the atmospheric conditions at the time the image data was collected to determine reflectance from the imagery. One method termed blackbody subtraction does not require a priori knowledge, but performs an image-based simple atmospheric correction. The Daedalus 3600 imagery obtained in previous months was used to test the reliability of the calibration process.

Black Body Subtraction: Many of the atmospheric correction approaches begin by removing the atmospheric path radiance received at the sensor. The atmospheric path radiance is the energy scattered within the atmosphere adding to the radiance leaving the ground surface. The atmospheric path radiance is commonly removed using the histogram minimum method also known as black body subtraction. A histogram of each band is generated. Each band is assumed to contain very dark objects expecting to have values close to zero. The lowest pixel values in the histograms are subtracted from the entire band to remove the atmospheric path radiance. The atmospheric path radiance is band independent.

Application to Daedalus 3600 Multi-Spectral Sensor Data: The quantized Daedalus 3600 sensor data is not sufficient for generating spectral signatures thus requiring the data to be calibrated. A gain and offset on the Daedalus 3600 sensor are adjusted digitally by the operator to avoid signal saturation. The quantized data, not taking into account gain and offset, does not provide the proper information to generate spectral signatures. The gain and offset setting of the sensor will determine the sensor output for a given radiance at the input. As the operator adjusts the gain and offset the output for the same radiance input will change. Therefore it is
necessary to calibrate the quantized sensor data for the production of consistent spectral signatures.

The method for calibrating the Daedalus 3600 sensor data for the visible through near IR bands was provided by the Remote Sensing Lab (RSL) at EG&G. A gain setting is included in the raw sensor data for each scan line. The gain is stored as an eight bit value with the actual setting ranging from 0 to 10 (000 represents a gain of zero and 111 represents a gain of 10). The quantized sensor data is adjusted for the gain by dividing the sensor data by the actual gain.

The offset is provided with the raw sensor data for each scan line. The offset is stored in an eight bit value which must be converted to a voltage bias. The voltage bias for the Daedalus 3600 ranges from -2.5v to 2.5v. The voltage bias is then converted to a radiometric response relative to 0 volts. This value is found on a channel by channel basis using an experimentally obtained relationship between the bias voltage and the radiometric response relative to 0 volts. The gain adjusted value is then normalized by the resulting radiometric response relative to zero. A final constant, integrated radiance/DN, based on the scan speed and channel number, converts the adjusted digital value to radiance.

A set of AMPS image data of the DC Mall area was used to examine the spectral signatures of both man made and natural structures using calibrated data. The AMPS data consisted of four channels within the visible to near IR portion of the electromagnetic spectrum (Channels 1-4). Table 1 lists the channel numbers and the spectral bands they encompass.

<table>
<thead>
<tr>
<th>Channel</th>
<th>Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 0.45</td>
<td>0.52 μm</td>
</tr>
<tr>
<td>3 0.52</td>
<td>0.60 μm</td>
</tr>
<tr>
<td>4 0.63</td>
<td>0.69 μm</td>
</tr>
<tr>
<td>8 0.91</td>
<td>1.05 μm</td>
</tr>
<tr>
<td>9 3.00</td>
<td>5.50 μm</td>
</tr>
<tr>
<td>10 5.50</td>
<td>14.0 μm</td>
</tr>
</tbody>
</table>

Spectral signatures of several structures were generated from two sets of image data taken over the same area approximately 10 minutes apart. The spectral signatures for each of the man made and natural structures from the first image were compared to their spectral signatures from the second
image. Ideally, the spectral signatures of an individual structure will not change from image to image. Figure 1 compares the spectral signatures of two man made objects, first with no atmospheric correction and secondly with atmospheric correction using the black body subtraction method. The dotted line represents the spectral signature of RFK stadium from both image sets and the solid line represents the spectral signature of a bridge from both image sets. Other than being slightly offset, the spectral signatures of the two man made objects remain consistent over the two image sets. Another interesting feature is the two objects practically have identical signature for channels 1-3. They become different in the near IR band. Therefore, the near IR band would be useful in distinguishing these two man made structures. Figure 2 contains the spectral signatures of two other man made structures. The spectral signatures shown in Figure 2 support the claim derived from Figure 1.

![DC Mall Signatures for Man Made Structures](image)

**Figure 1. Spectral Signatures of Man Made Structures**
Figure 2. Spectral Signatures of Man Made Structures

The spectral signatures of the man made structures were not affected by the atmospheric correction other than a slight offset of the signatures. The black body subtraction implements a channel by channel bias removal. The implementation of the black body subtraction on the DC Mall image sets resulted in an offset of the spectral signature. The shapes of the spectral signatures were very barely affected. Thus, the atmosphere had no significant affect on the generation of the spectral signatures.

Spectral signatures of three natural scenes were generated from two locations in both of the two image sets. Figure 3 and Figure 4 contain the spectral signatures of a river, trees and a grassy
area. The natural scenes demonstrate the same results as those shown by the man made structures. The spectral signatures are consistent through time and the atmospheric correction has little to no effect on the spectral signatures. The spectral signatures of the natural scenes also show consistency when the same type of scene in a different location was used to generate the spectral signature. This definitely holds true for the trees and river. They have the same spectral signature for both locations in both image sets. The grassy area, however, does differ slightly in the near IR band for the two different locations. This effect may be due to different types of grass in the two locations.

Several man made objects appearing to be constructed of the same material were used to generate spectral signatures for one of the image sets. Figure 5 contains the spectral signatures. four of the five signatures are almost identical in the visible bands then begin to differ in the near IR bands. The fifth signature is very similar in shape to the other four, however, it is offset. The materials of the man made objects are most likely very similar, since they exist in different locations, the near IR bands differ slightly as illustrated in the previous four Figures.

Figure 3. Spectral Signatures of Natural Scenes
Figure 4. Spectral Signatures of Natural Scenes
Figure 5. Spectral Signatures of Multiple Man Made Structure of the same Material

Multi-Spectral Prescreening

In parallel, we applied our prescreening process documented in our previous progress report to multi-spectral imagery with camouflaged objects. These experiments indicate that our prescreening process is able to capture the subtle spectral differences between the camouflaged objects and the natural background.

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