Multiresolution Thermal Imaging with a VIS+LWIR Camera

Jacob Hines¹, Evan Wang²
Departments of ¹Applied Physics and ²Electrical Engineering, Stanford University

Motivation

Thermal imaging, operating at long-wave infrared (LWIR) wavelengths, is important for a wide range of room temperature applications. However, cameras at this wavelength are expensive compared to typical visible cameras.

We built a multispectral camera that captures a high-resolution visible image to enhance a low-resolution thermal image at a fraction of the cost of higher-end thermal cameras.

<table>
<thead>
<tr>
<th>FLIR Boon 640</th>
<th>FLIR Lepton 3 + Pi</th>
<th>Pi Camera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$3000</td>
<td>$260 + $190</td>
</tr>
<tr>
<td>Resolution</td>
<td>640 x 512</td>
<td>160 x 120 thermal</td>
</tr>
<tr>
<td>Frame rate</td>
<td>60 Hz</td>
<td>9 Hz</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>50 mK</td>
<td>50 mK</td>
</tr>
<tr>
<td>Horizontal FOV</td>
<td>Up to 95°</td>
<td>57°</td>
</tr>
<tr>
<td>Spectral range</td>
<td>7.3 – 13.5 µm</td>
<td>8 – 14 µm</td>
</tr>
</tbody>
</table>

Related Work

Multispectral imaging over visible and IR wavelengths has been used to gain extra information for:

• Object identification [1, 2]
• Pedestrian detection [3]
• Product inspection [4]

Most multispectral fusion literature is concerned with combining VIS-NIR satellite images [5, 6]. Applying these results to VIS-LWIR presents challenges for image registration due to a mismatch in salient features of each image [7, 8].

Further, fusion methods and evaluation metrics must be changed to account for the emissive mechanism of thermal imaging [9].

References

2. R. V. Nelson, "Optical and thermal imaging for enhanced information extraction in remote sensing." In ESO 2007.

Method 1: High Pass Filtering

1. High-pass filter visible image with gaussian kernel, std \( \sigma (x) \)
2. Inject high-passed visible image into low resolution thermal image

Method 2: Gradient Transfer Function with ADMM+TV

Fused image \( x \) minimizes the objective function:

\[
x(x) = \frac{1}{2} \| x - t \|_2^2 + \lambda \| \nabla x - \nabla t \|_1^2
\]

First term: preserve intensity information from thermal image \( t \)
Second term: transfer gradient information from visible image \( v \)

High Pass Filtering

Gradient Transfer Function