# Multiresolution Thermal Imaging with a VIS+LWIR Camera

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## 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 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.

| | FLIR Boson 640 | FLIR Lepton 3 + R Pi |
|---|---|---|
| Cost | \$3000 | \$260 + \$190 |
| Resolution | 640 x 512 | 160 x 120 thermal<br>3200 x 2400 visible |
| Frame rate | 60 Hz | 9 Hz |
| Sensitivity | 50 mK | 50 mK |
| Horizontal FOV | Up to 95° | 57° |
| Spectral range | 7.5 – 13.5 µm | 8 – 14 µm |

Images: FLIR Systems

## 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 to must be changed to account for the emissive mechanism of thermal imaging [9].

### References

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2. J. W. Davis and V. Sharma, "Background-subtraction using contour-based fusion of thermal and visible imagery," *Computer Vision and Image Understanding*, vol. 106, no. 2, pp. 162–182, May 2007.
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4. L. Bienkowski, C. Homma, K. Eisler, and C. Boller, "Hybrid Camera and Real-View Thermography for Nondestructive Evaluation," in *Proceedings of the 2012 International Conference on Quantitative InfraRed Thermography*, 2012.
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8. E. Coiras, J. Santamaria, and C. Miravet, "Segment-based registration technique for visual-infrared images," *OE*, vol. 39, no. 1, pp. 282–290, Jan. 2000.
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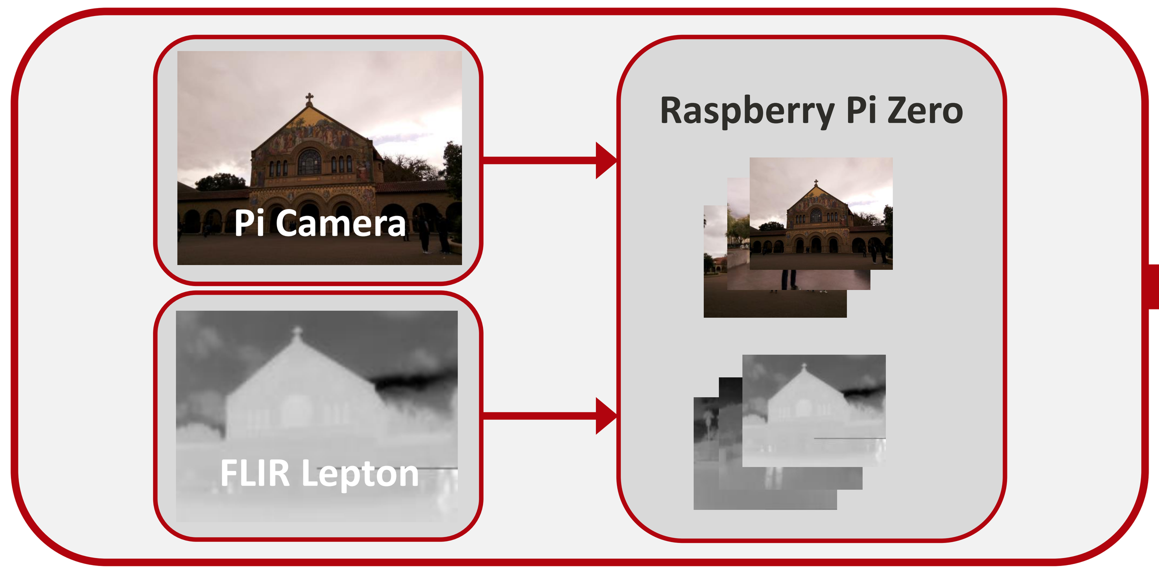
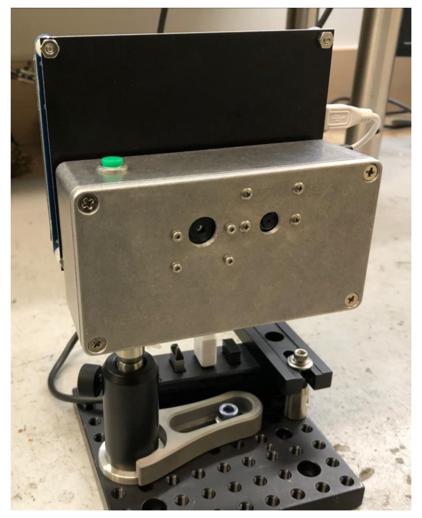
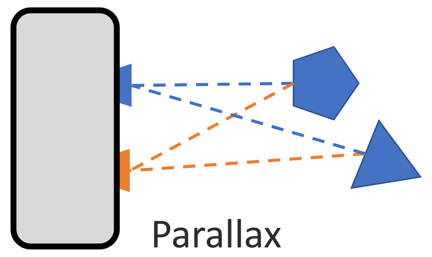
## Camera Hardware



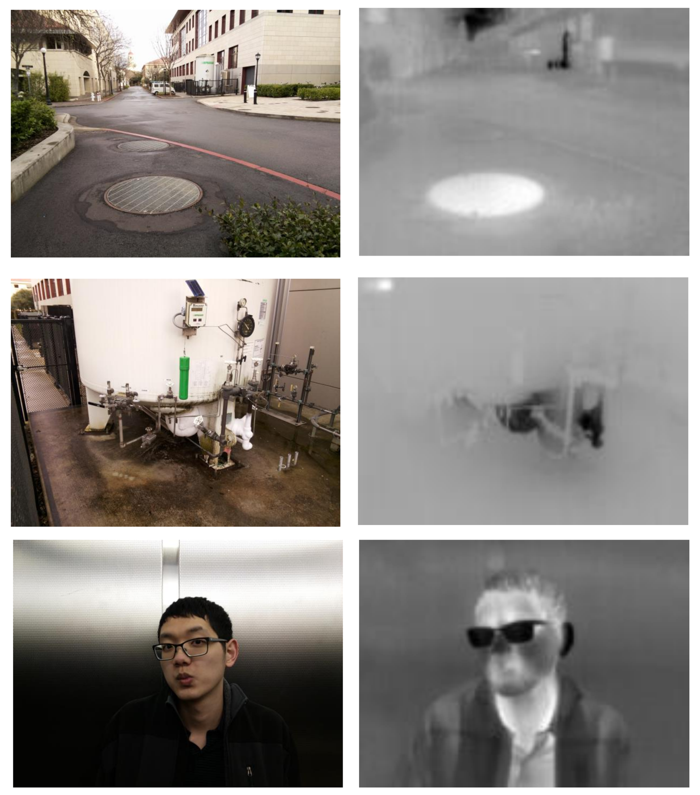

Camera Module





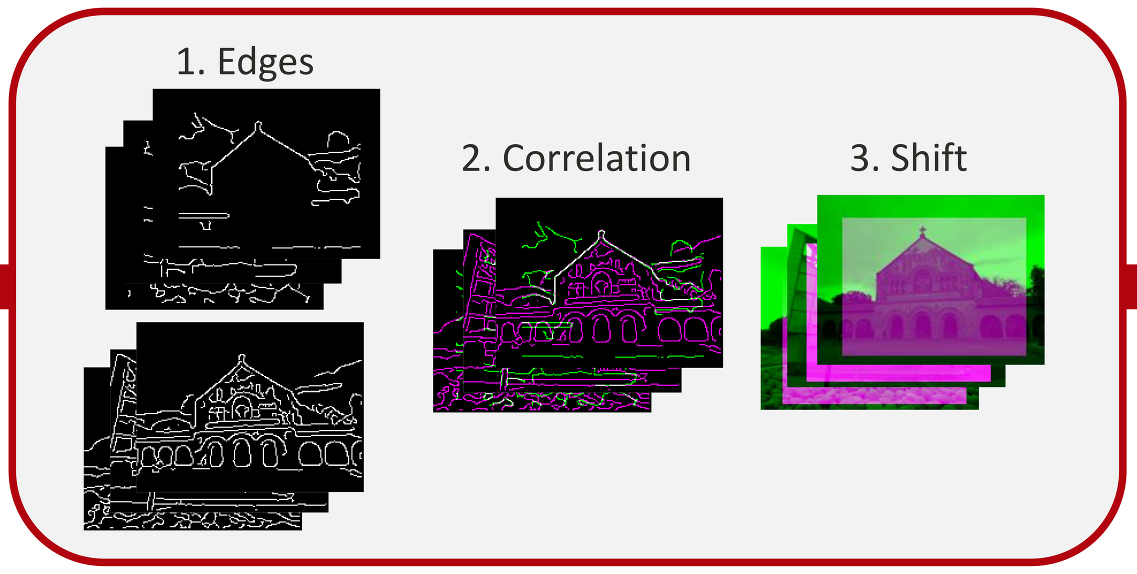
Parallax

Captured images stored on Raspberry Pi

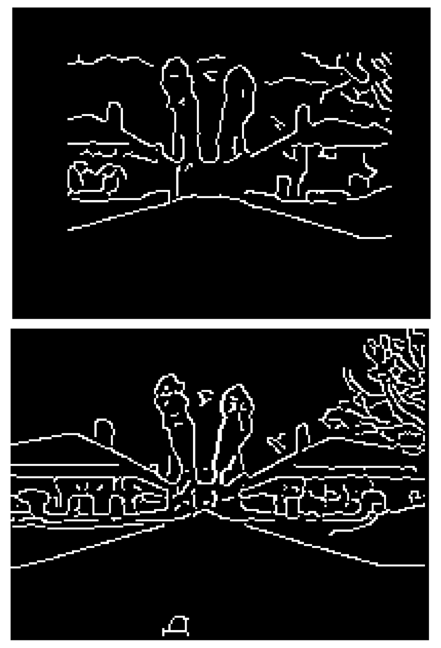


Example Usage

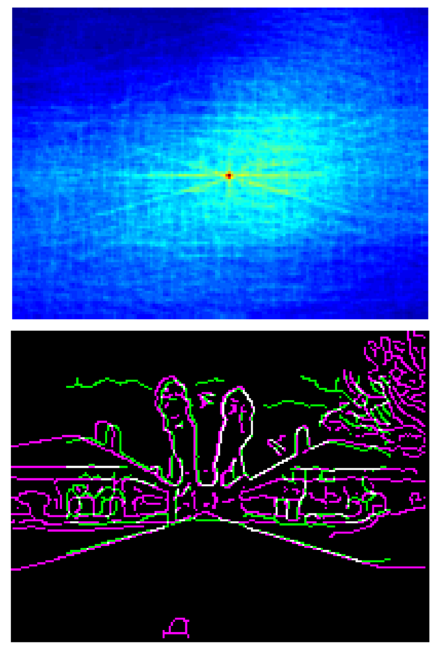
## Image Registration




1. Detect edges



2. Edge-edge correlation

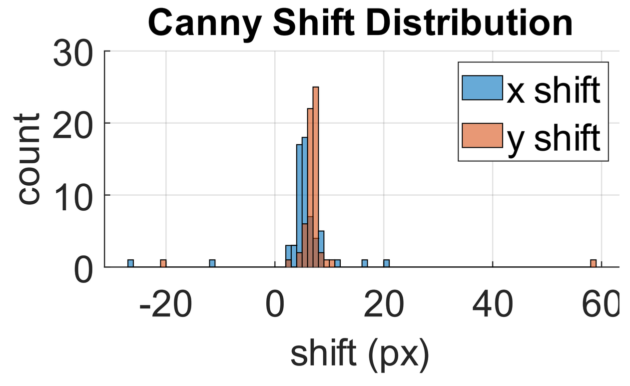


3. Shift to max correlation

Above: parallax

| Edge Method | Success* |
|---|---|
| **Canny** | **0.92** |
| Log | 0.82 |
| zerocross | 0.82 |
| Prewitt | 0.73 |
| Sobel | 0.73 |
| Roberts | 0.66 |

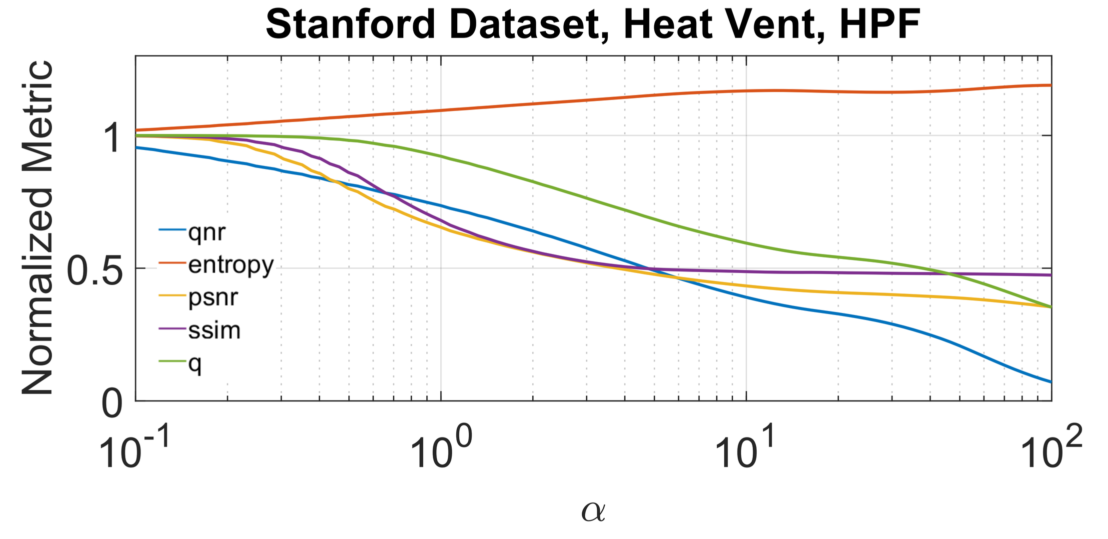
*N = 62




## Image Fusion

### Method 1: High Pass Filtering

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

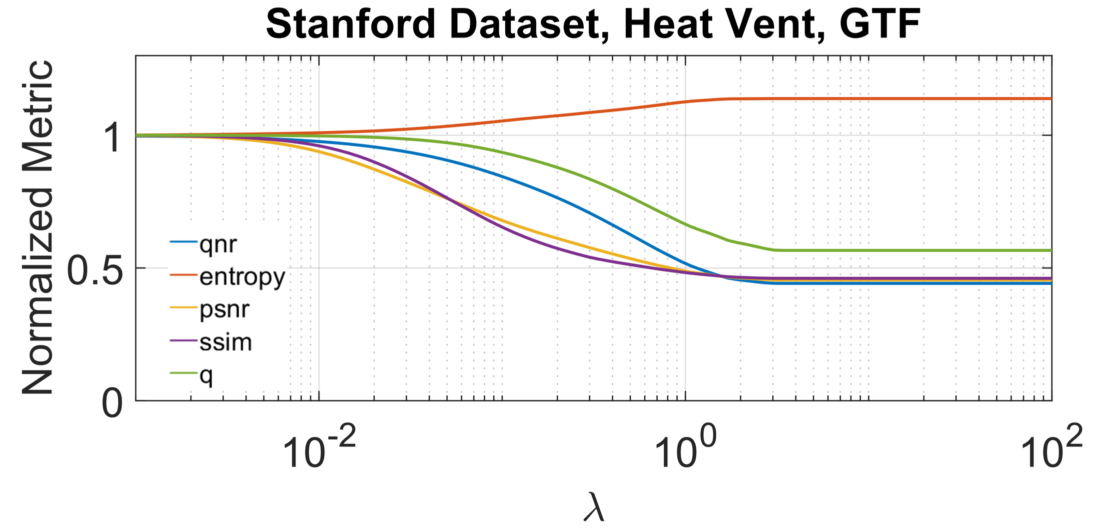



### Method 2: Gradient Transfer Function with ADMM+TV

Fused image $\boldsymbol{x}$ minimizes the objective function:

$$\varepsilon(\boldsymbol{x}) = \frac{1}{2}\|\boldsymbol{x}-\boldsymbol{t}\|_2^2 + \lambda\|\nabla\boldsymbol{x}-\nabla\boldsymbol{v}\|_1$$

First term: preserve intensity information from thermal image $\boldsymbol{t}$
Second term: transfer gradient information from visible image $\boldsymbol{v}$




High Pass Filtering

Gradient Transfer Function