Enhancing Thermal Imaging via Multi-Frame Fusion

Real-Time Super-Resolution with Webcam-Based Motion Estimation

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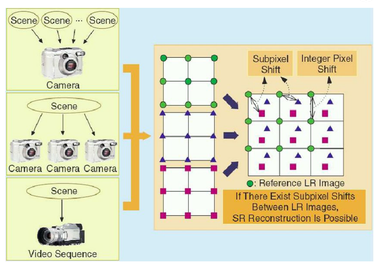
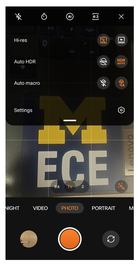
Motivation

High-resolution thermal cameras are valuable tools in applications like equipment diagnostics, human temperature monitoring, and autonomous navigation.
Despite wide application of thermal cameras, their cost is creating a barrier for end-users.

Model	Resolution	Price
FLIR E6 PRO	240 × 180	$1,739.13
FLIR T530-24	320 × 240	$12,119.00
FLIR T530-24-14	320 × 240	$13,729.00
FLIR T530-24-42	320 × 240	$13,729.00
FLIR T530-42	320 × 240	$12,119.00

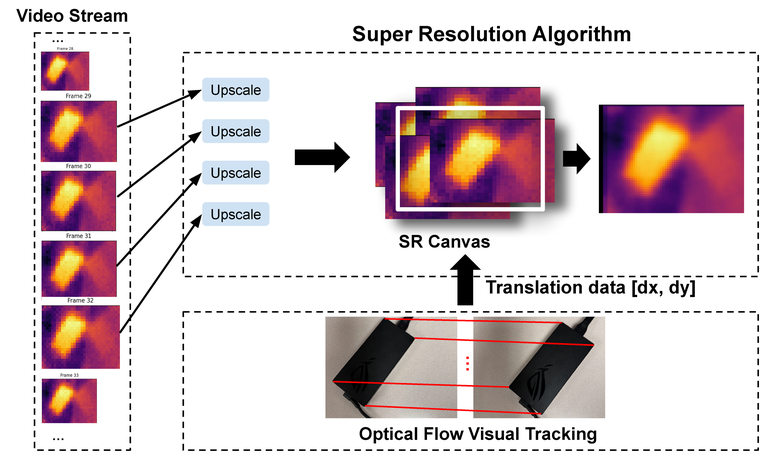
Regular cameras have benefited greatly from software-driven image enhancement. HDR imaging — now standard in smartphones — captures multiple frames and combines them to create more detailed images.





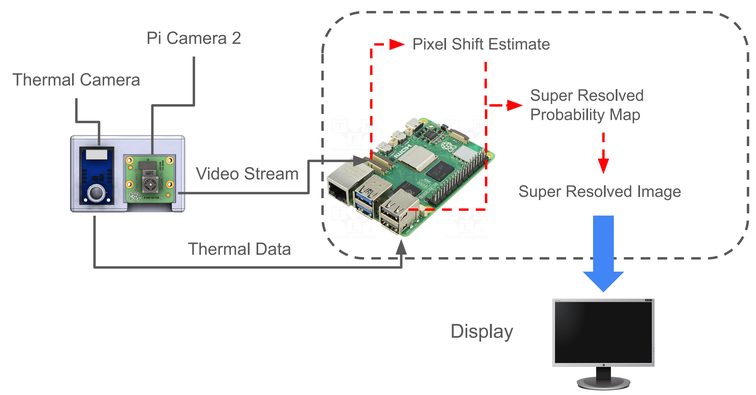
Inspired by this idea, we explore using multi-frame super-resolution on thermal images. Instead of exposure differences, we capture small shifts between frames using natural hand motion. A webcam tracks this motion using a visual tracking algorithm, allowing us to align and combine multiple low-resolution thermal frames from an MLX90640 sensor into a sharper composite image offering a low-cost path to higher-resolution thermal imaging.

Method

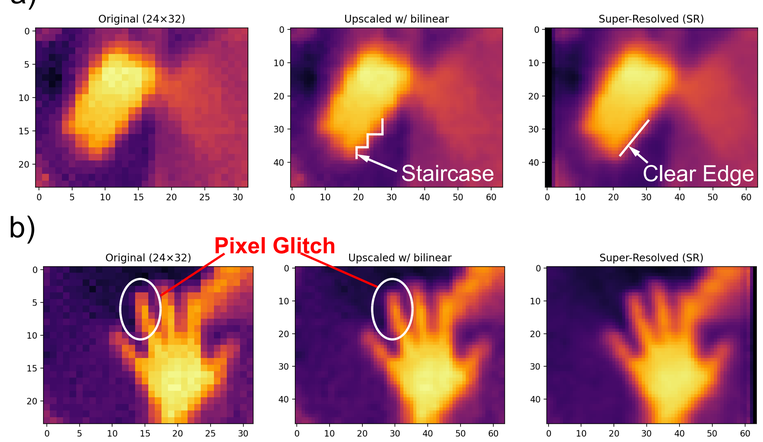


Multi-frame Super Resolution (SR) is used to reconstruct a high-resolution thermal image by fusing several low-resolution frames with sub-pixel shifts. To estimate these shifts, a webcam is mounted alongside the thermal camera; as the setup moves, the webcam captures its motion, which could be correlated to the thermal camera's translation.

Our prototype uses a Pi Camera 2 as the WebCam and MLX90640 as the thermal camera. A Raspberry Pi 4 is used to process data and display results.



Results



We compared our super resolution algorithm with image upscaling with bilinear interpolation.

Figure a) shows the super resolution of a laptop power supply (rectangular shape). Direct bilinear interpolation inherits sampling artifacts in the low resolution images, creating staircase artifacts in the result, while our SR algorithm shows a clear, straight edge.

Figure b) compares the response of bilinear and our SR algorithm to sudden signal glitches in original thermal image. As our algorithm considers multi-frame information, the effects are minimized.

Overall, our SR algorithm:
i) exhibits less staircase artifacts
ii) shows high temporal robustness
iii) is real-time applicable

[1] A. A. Rad, L. Meylan, P. Vandewalle, and S. Süsstrunk, "Multidimensional image enhancement from a set of unregistered differently exposed images," in Proc. SPIE 6498, Computational Imaging V, 2007, pp. 649808.
[2] FLIR Systems, "Commercial & Residential Building Inspection with FLIR," [Online].
[3] Transcat, "FLIR E PRO Series Thermal Cameras," [Online]. Available: