Generalized Assorted Camera Arrays: Robust Cross-channel Registration and Applications

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Introduction

Generalized Assorted Cameras (GAC) surpass limitations of traditional cameras by using an array of cameras, each capturing a specific color channel. The flexibility gained by using GAC arrays allows for targeted deployment tailored to the requirements of specific application systems. In this work we show how GAC arrays can be employed for RGB color imaging, incorporating side-band near-infrared information and capturing hyperspectral video with high spatial, temporal, and spectral resolution. Critically, our method does not require repetitive camera elements in the array.

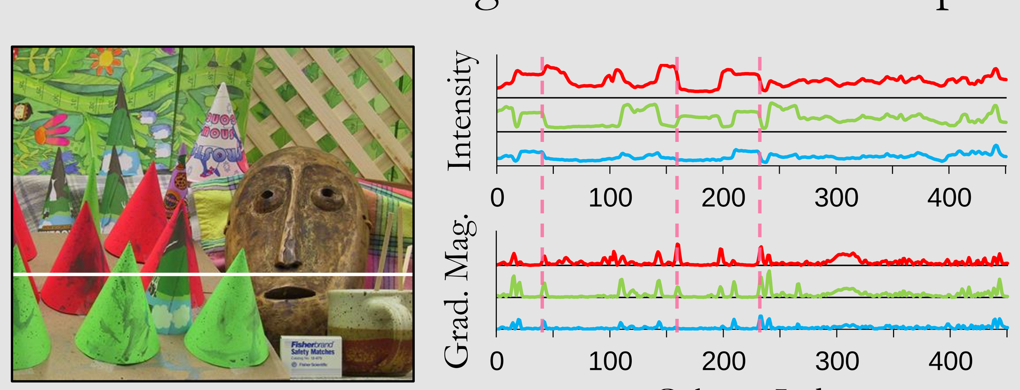
Motivation

RGB imaging: The Bayer pattern used on color cameras leads to, lower spatial frequency, pixel cross-talk, demosaicing artifacts, thick optics on smartphone cameras, and 2 dimensional images with no depth information. GAC can surmount all of these limitations in a 2×2 array of cameras.

RGB+NIR: Adding one NIR camera to the array allows for "natural" image retouching and enhanced vein visibility for medical professionals.

Hyperspectral (HS) video: Current HS cameras are expensive, have low SNR, and need static scenes. We use cheap commodity broadband filters on our GAC to capture HS video with high SNR.

Image registration: Since the sensors in the GAC are not co-located there is a need for sub-pixel cross-modal registration. While pixel intensities are differ in each channel edge locations **do** correspond

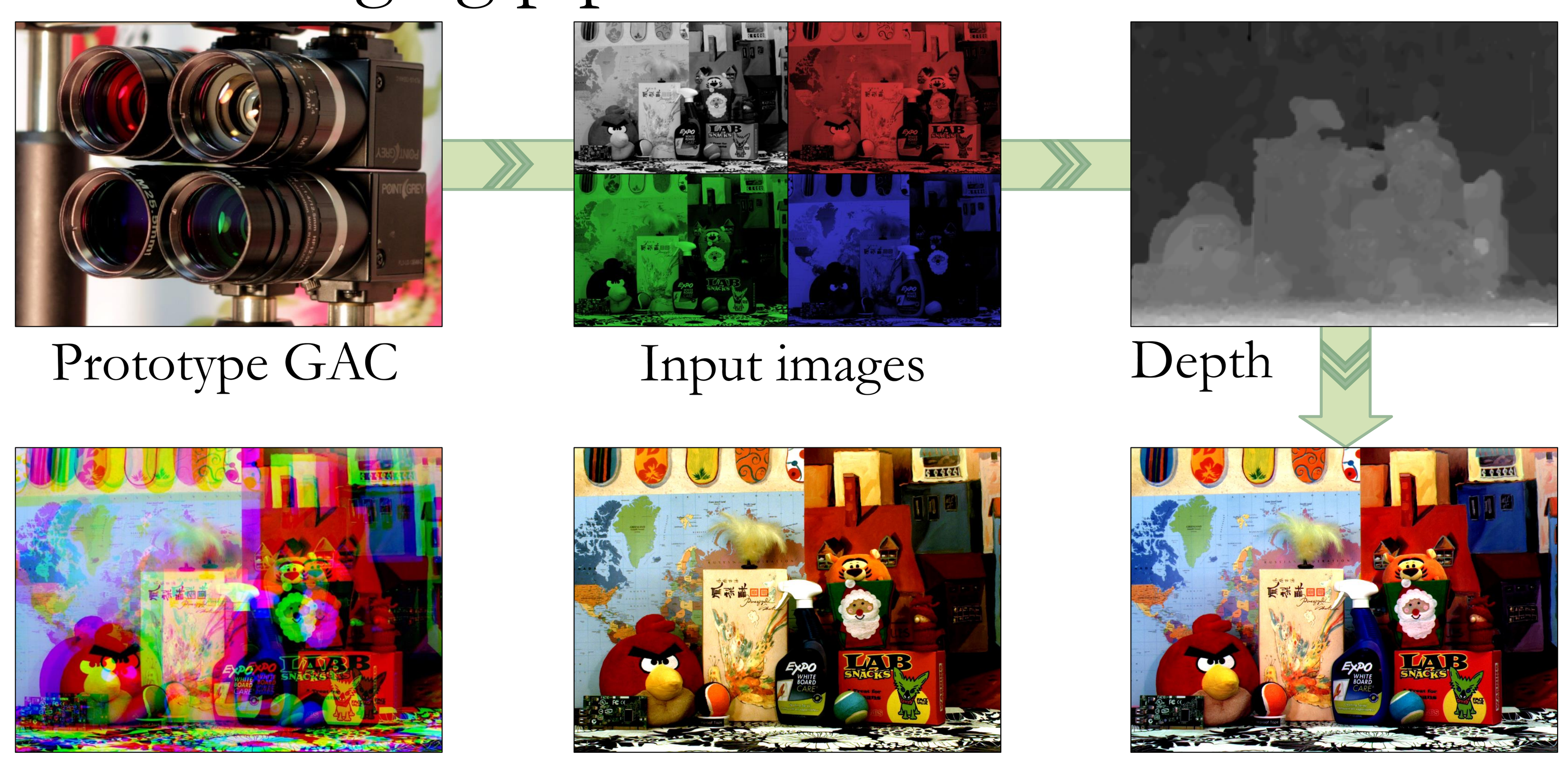


We compute multi-view correspondence across color channels by matching normalized gradients in a local window around pixel p for each depth d:

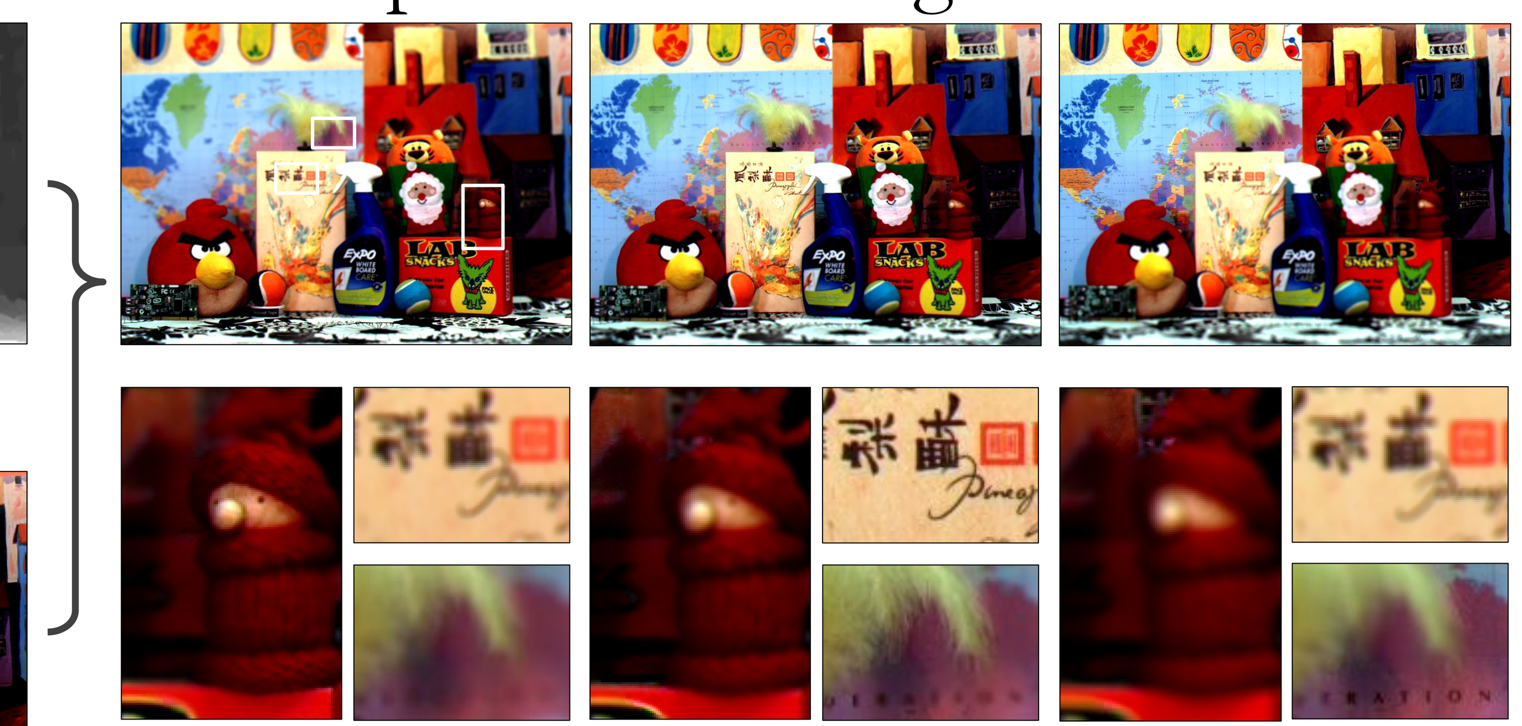
$$C(p,d) = -\sqrt[M]{\sum_{u,v} \prod_{\Lambda=1}^{M} \hat{G}_{\{p,d\}}(u,v,\Lambda)} \quad (1)$$

Generalized Assorted Cameras for RGB imaging

Color imaging pipeline



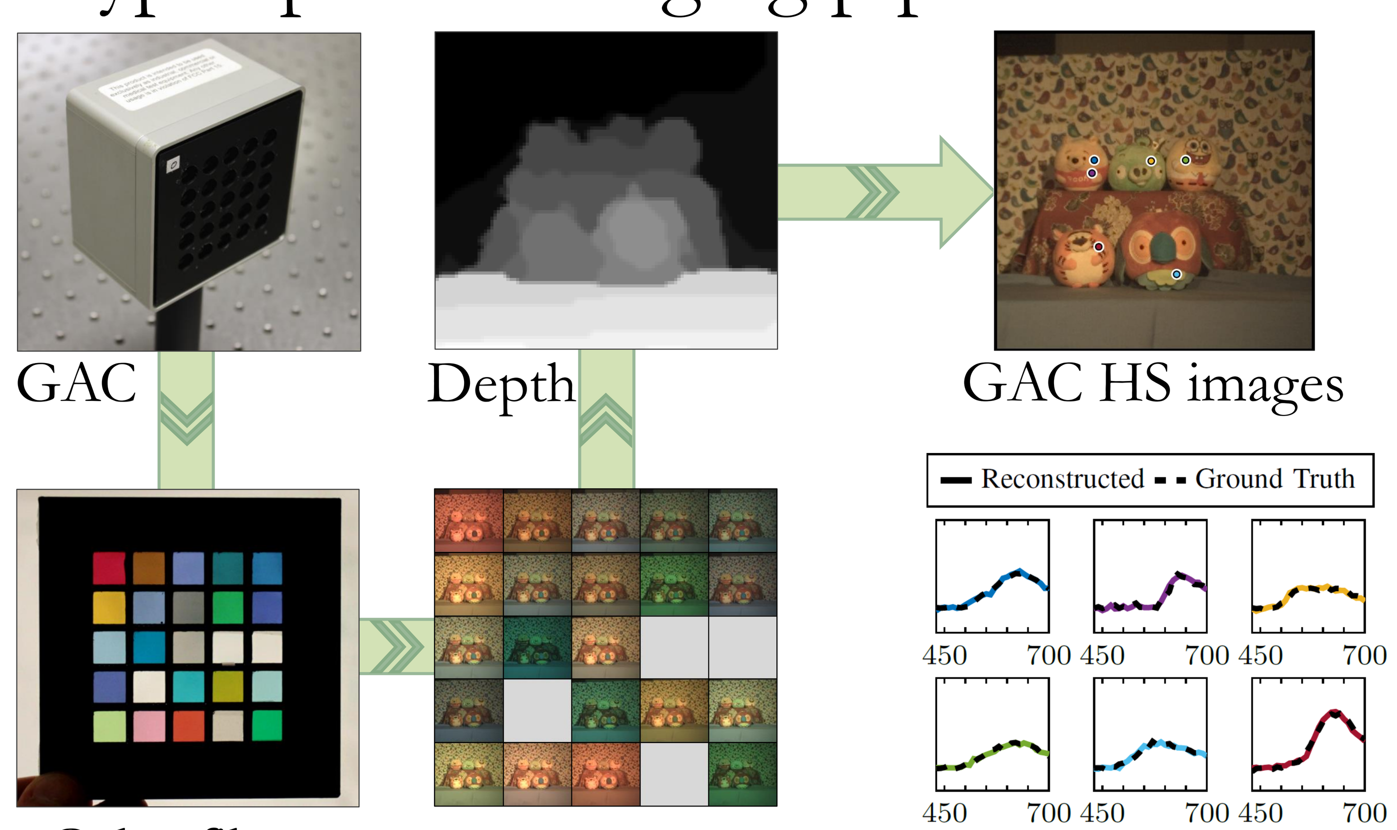
Post-capture refocusing



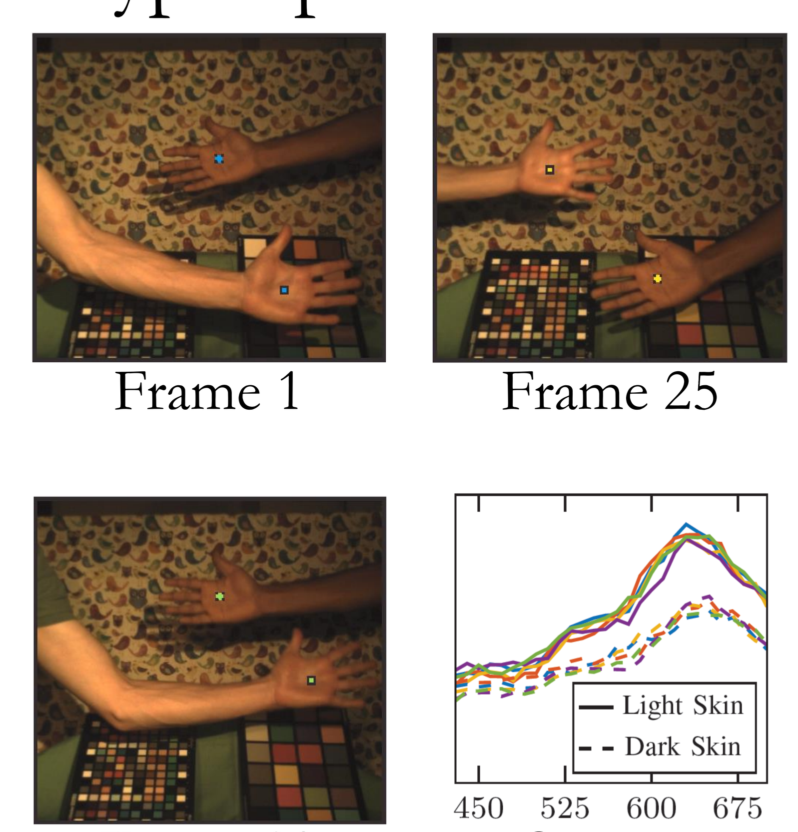
Low Light

GAC for Multiplexed Hyperspectral (HS) Imaging

Hyperspectral imaging pipeline



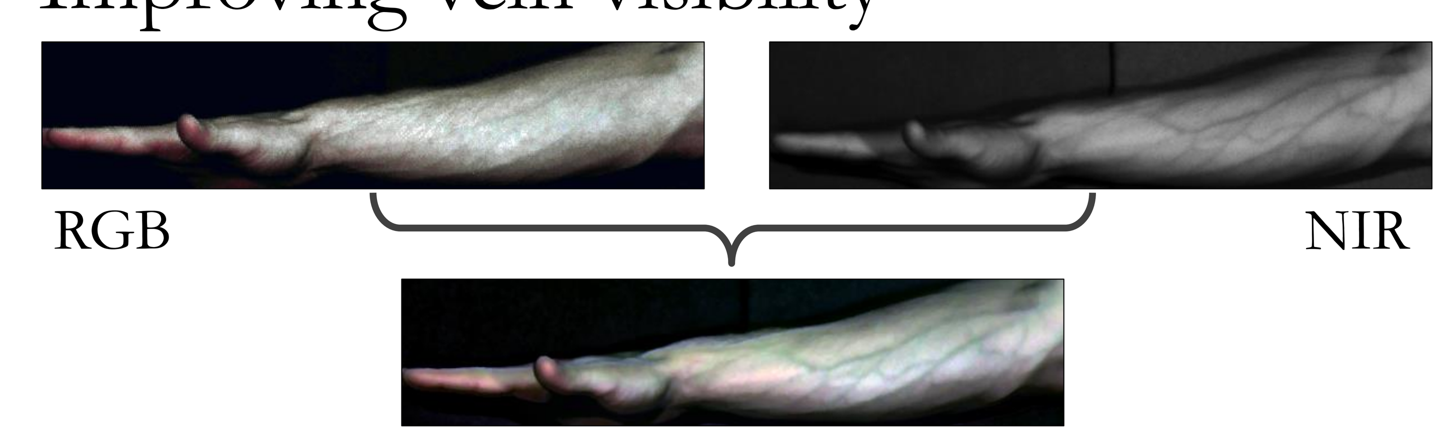
Hyperspectral video



GAC for RGB+Near-Infrared

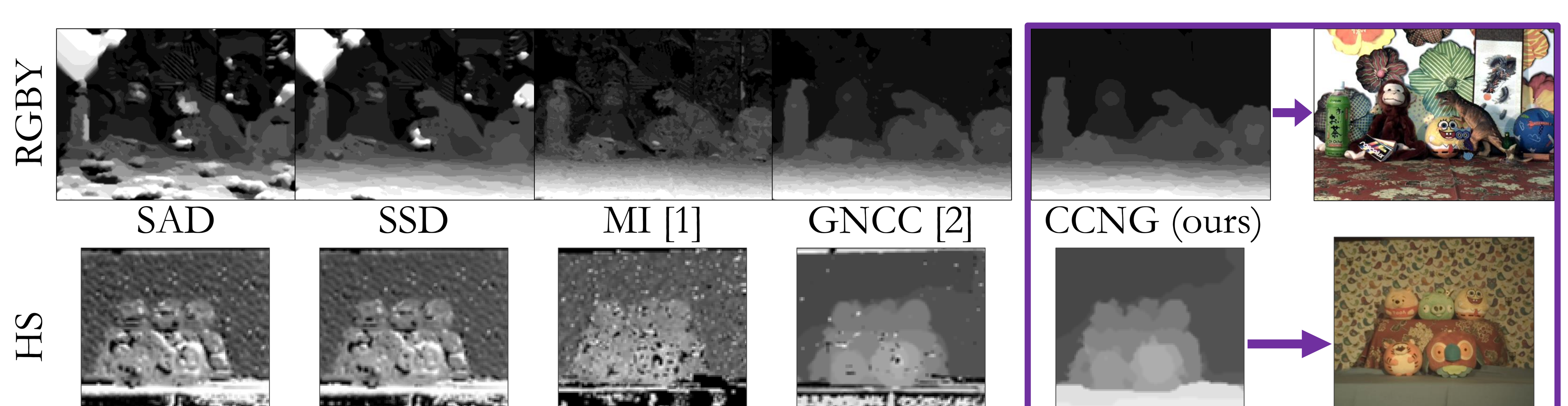
Natural image retouching

Improving vein visibility



Cross-channel Normalized Gradients (CCNG)

Using the cost term in (1) and a bilateral smoothing term $S(p,d)$, a depth map D is found by minimizing: $D(p) = \arg\min_{d} C(p,d) + \mu S(p,d)$, which is used to align images in the GAC.



Conclusions and Future Work

Our cross-modal registration and flexible GAC framework provides

- Accurate depth maps recovery for complex scene geometry
- Improved RGB imaging with refocusing
- Easy implementation of application-specific camera arrays
- Hyperspectral video acquisition with high light throughput

Our future work will be to investigate GAC with heterogeneous elements

References

[1] Hill, Derek L., Colin Studholme, and David J. Hawkes. "Voxel similarity measures for automated image registration." Visualization in Biomedical Computing 1994. International Society for Optics and Photonics, 1994.

[2] Bando, Yosuke, Bing-Yu Chen, and Tomoyuki Nishita. "Extracting depth and matte using a color-filtered aperture." ACM Transactions on Graphics (TOG). Vol. 27. No. 5. ACM, 2008.