Correlation-Based Deblurring Leveraging Multispectral Chromatic Aberration in Color and Near-Infrared Joint Acquisition

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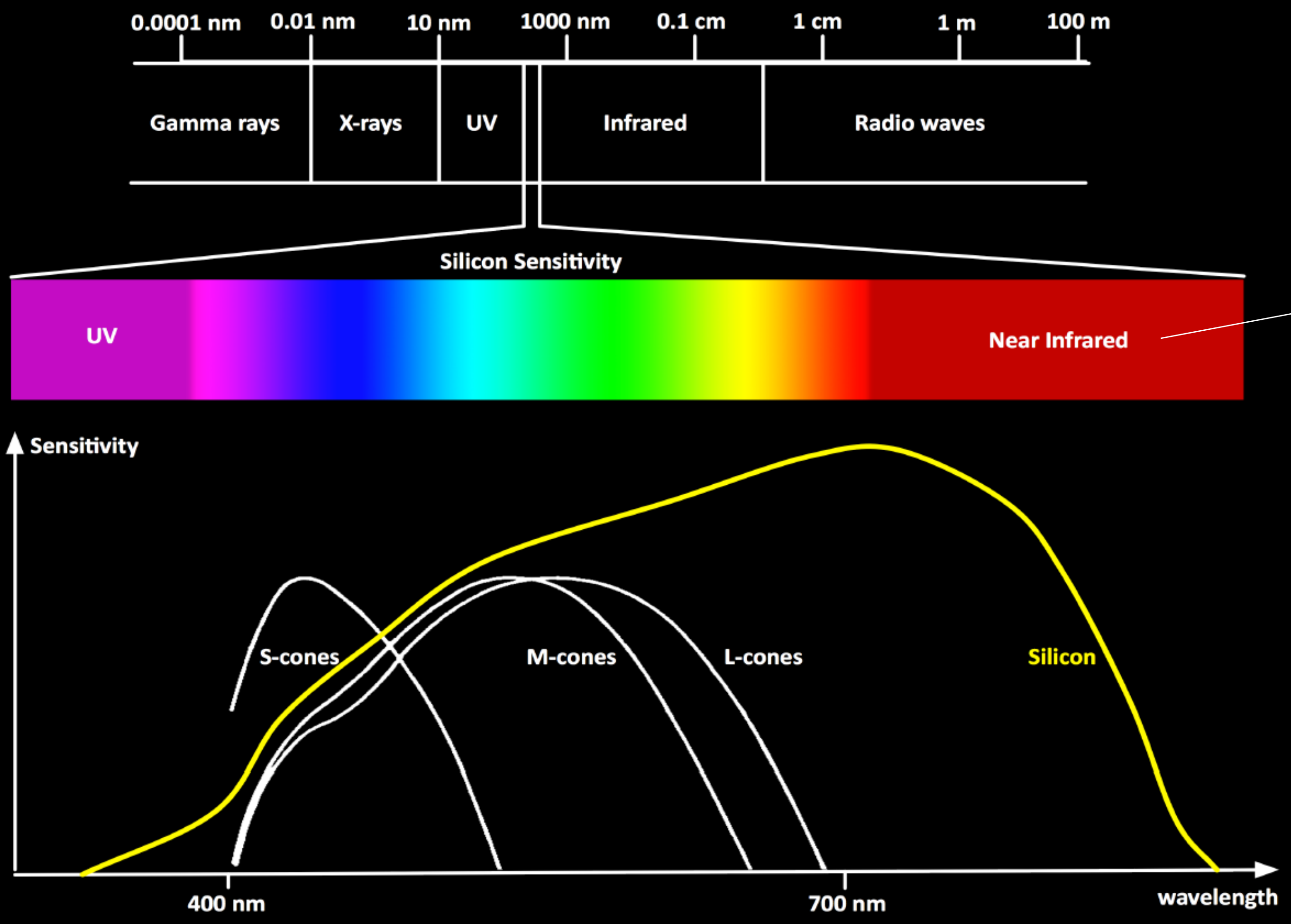
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

NIR and its acquisition

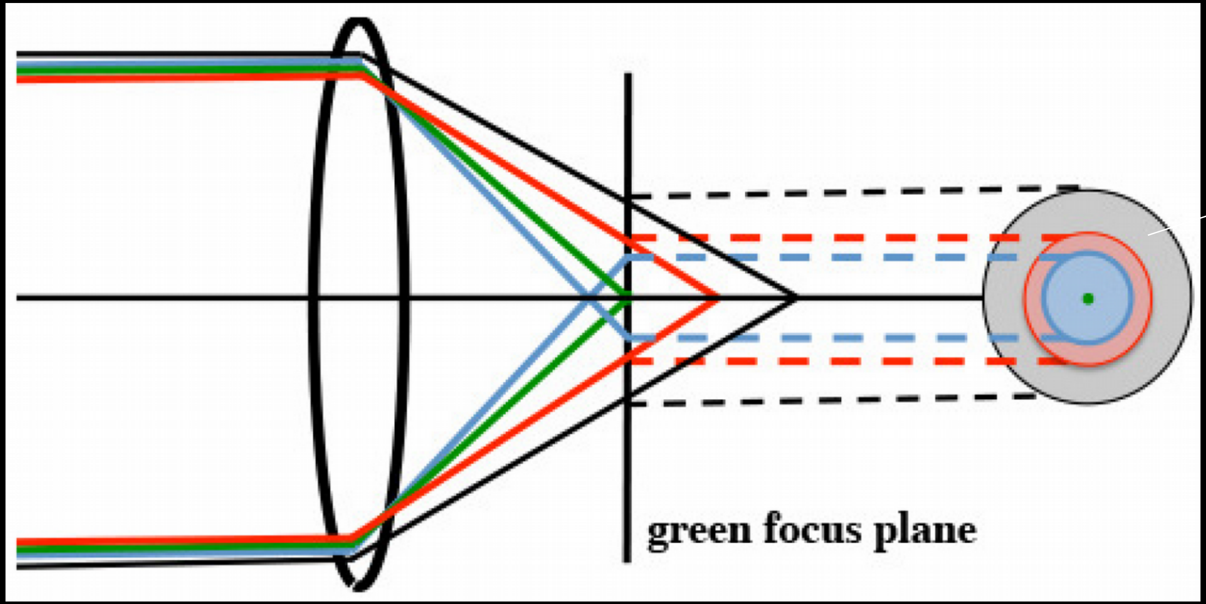


≈ 700 - 1000nm

Some applications

- Haze detection and removal
- Shadow detection
- Skin smoothing
- Material-based segmentation
- Vegetation detection
- Face authentication
- …

Chromatic aberration (longitudinal)



circle of
confusion

Different wave bands converge at different focal points!

➡ Only one is captured in focus*

*Unless the camera resolution is even lower than the blur radius

Chromatic aberration in color and NIR [1]

Color NIR

[1] Z. Sadeghipoor, Y. M Lu, E. Mendez, and S. Süsstrunk, “Multiscale guided deblurring: Chromatic aberration correction in color and near-infrared imaging,” in 23rd European Signal Processing Conference (EUSIPCO), 2015, pp. 2336–2340.

Borrowing from spectral neighbors

Main idea:

$$\nabla N \approx \nabla Color$$

Solution:

$$k = argmin_k ||\nabla N_{blur} - k * \nabla Y||_2^2$$

uniform blur model assumption

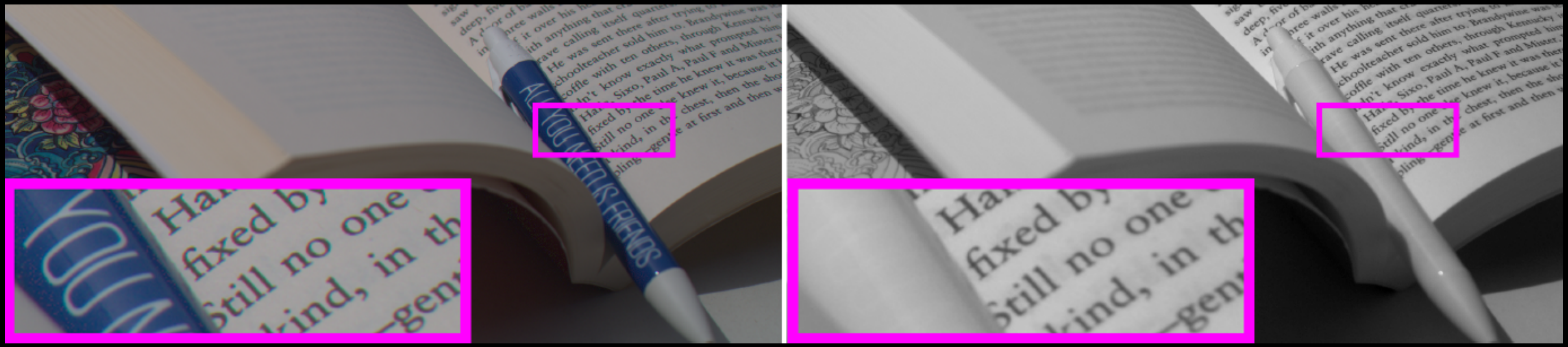
where is a Gaussian kernel

$$N_{deblur} = argmin_N ||N_{blur} - k * N||_2^2 + ||\nabla N - \nabla Y||_2^2$$

where Y is the pixel-wise color average

N_{blur} original NIR
N_{deblur} deblurred NIR

Shortcoming and solution



Color NIR

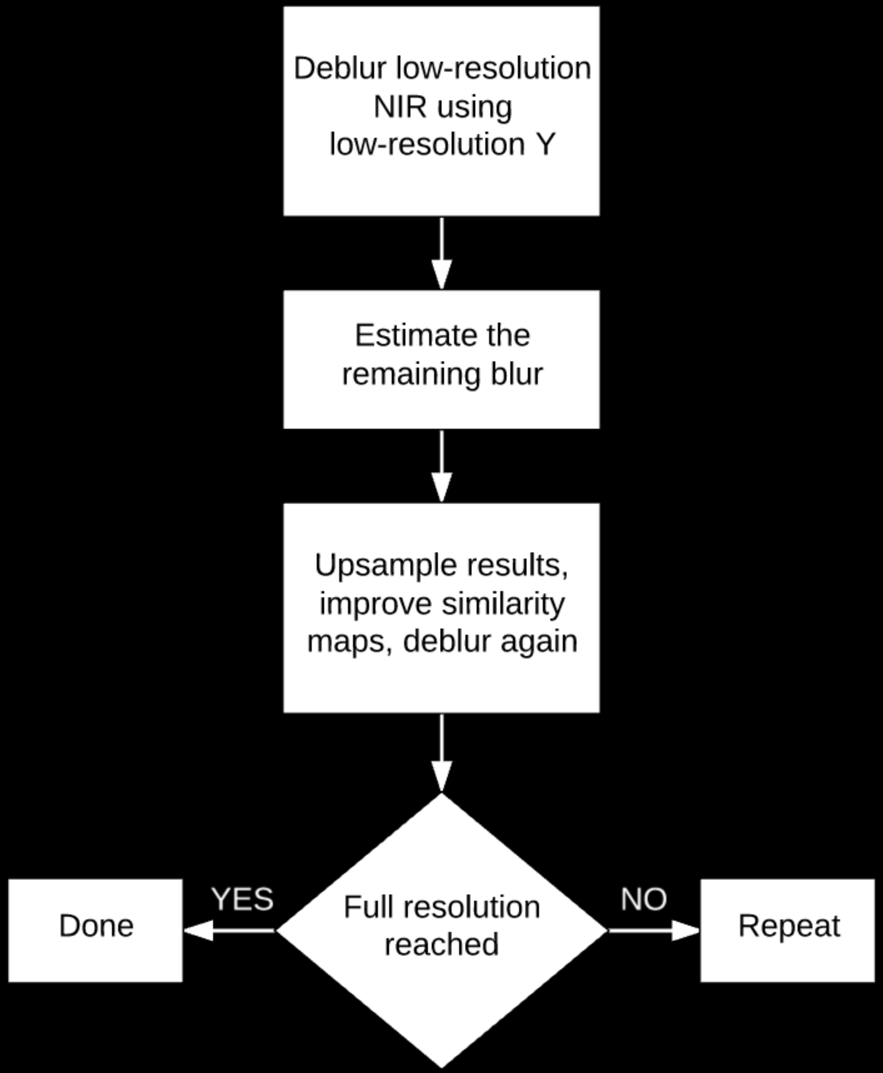
Color and NIR similarity:

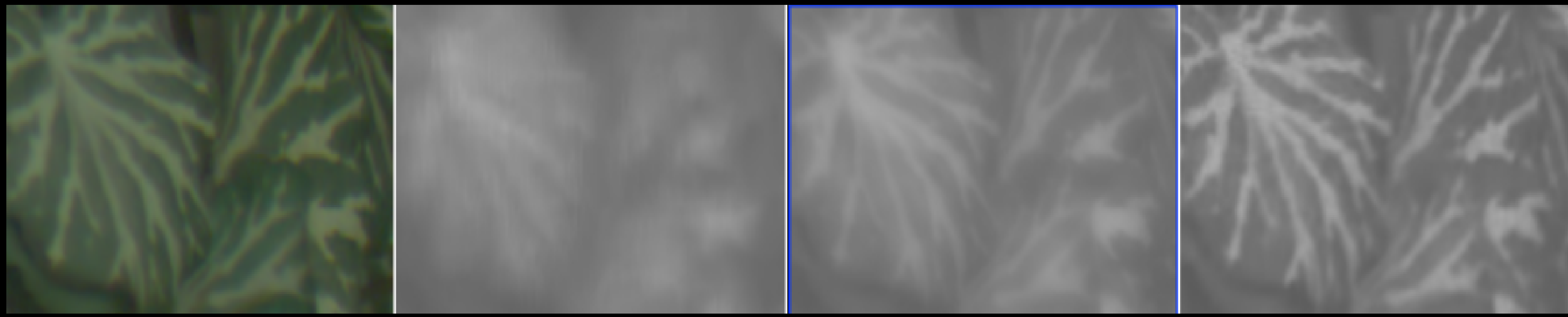
$$M = 1 - \frac{|\nabla N - \nabla(k * Y)|}{|\nabla N + \nabla(k * Y)|}$$

Similarity maps incorporated:

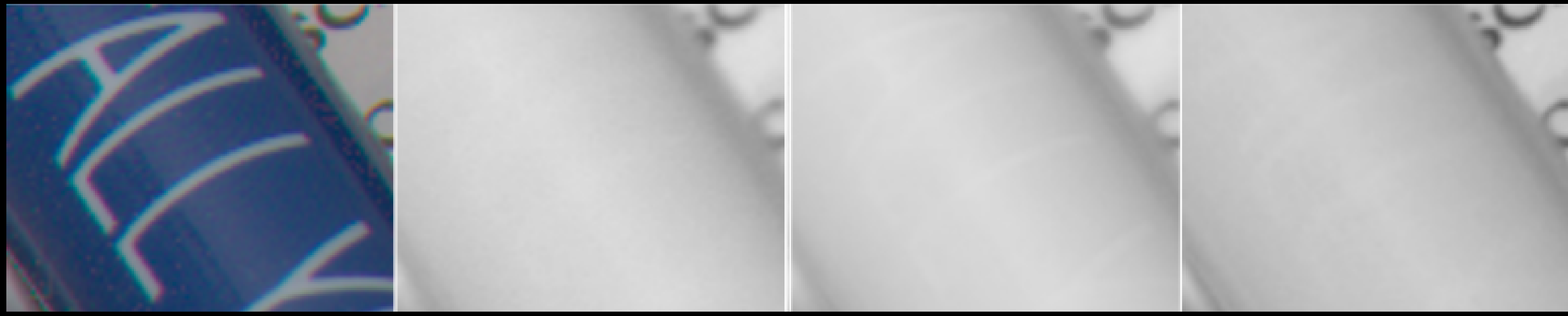
$$N_{deblur} = argmin_N \lambda ||N_{blur} - k * N||_2^2 + ||\nabla N - \mathbf{M} \odot \nabla Y||_2^2$$

Full deblurring algorithm





original RGB image | original blurred NIR | deblurring result | ground-truth NIR



original RGB image | original blurred NIR | deblurring result | ground-truth NIR

Limitations: uniform blur assumption

Deblurring

Original NIR image

NIR image after deblurring

Limitations: color average as guide

Average sharpness values of different channels.

	R	G	B	Y
sharp.	0.6235	0.5942	0.6196	**0.5114**

→ Loss in hyperspectral information

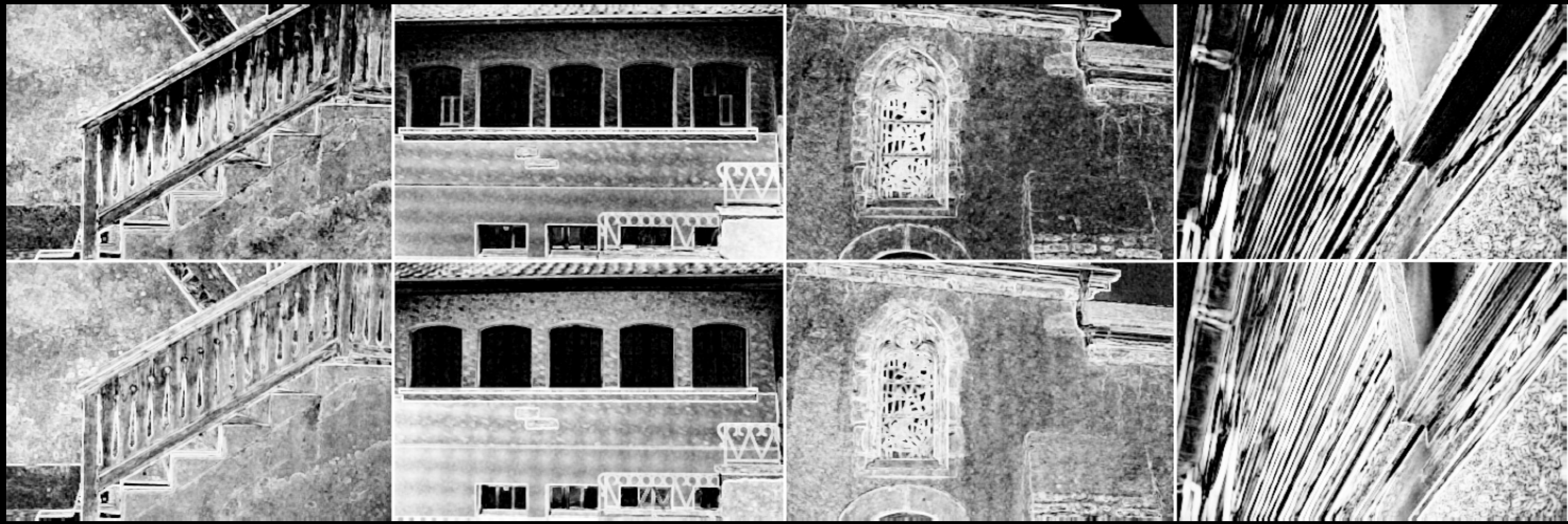
Searching for all information

Spectral correlation

	NIR	R	G	B
NIR	1	0.8436	0.7938	0.6975
R	-	1	0.9215	0.8510
G	-	-	1	0.9310
B	-	-	-	1

Spectrally closer
→ higher average NCC

Spectral correlation seen spatially



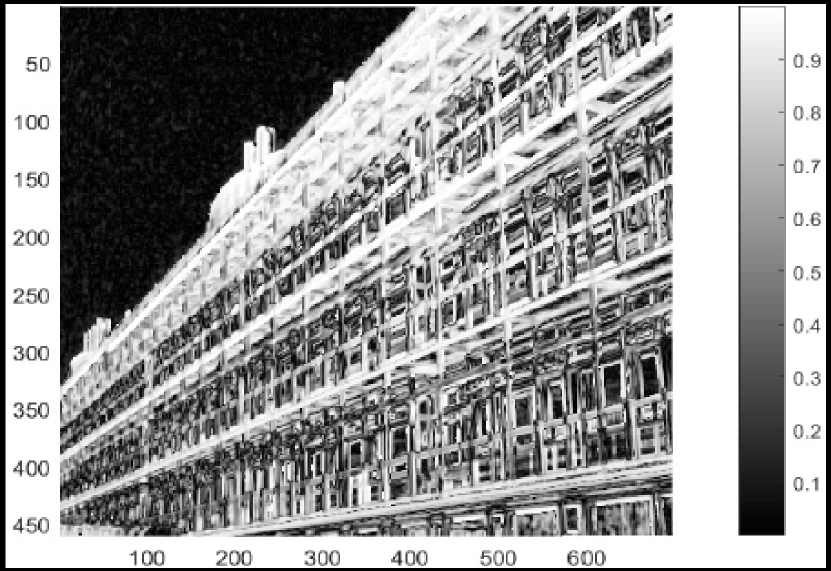
Top row: NCC between NIR and Blue
Bottom row: NCC between NIR and Red

Searching for all information

Spatial correlation

Luminance

NIR



NCC

High-frequency correlation

Searching for all information

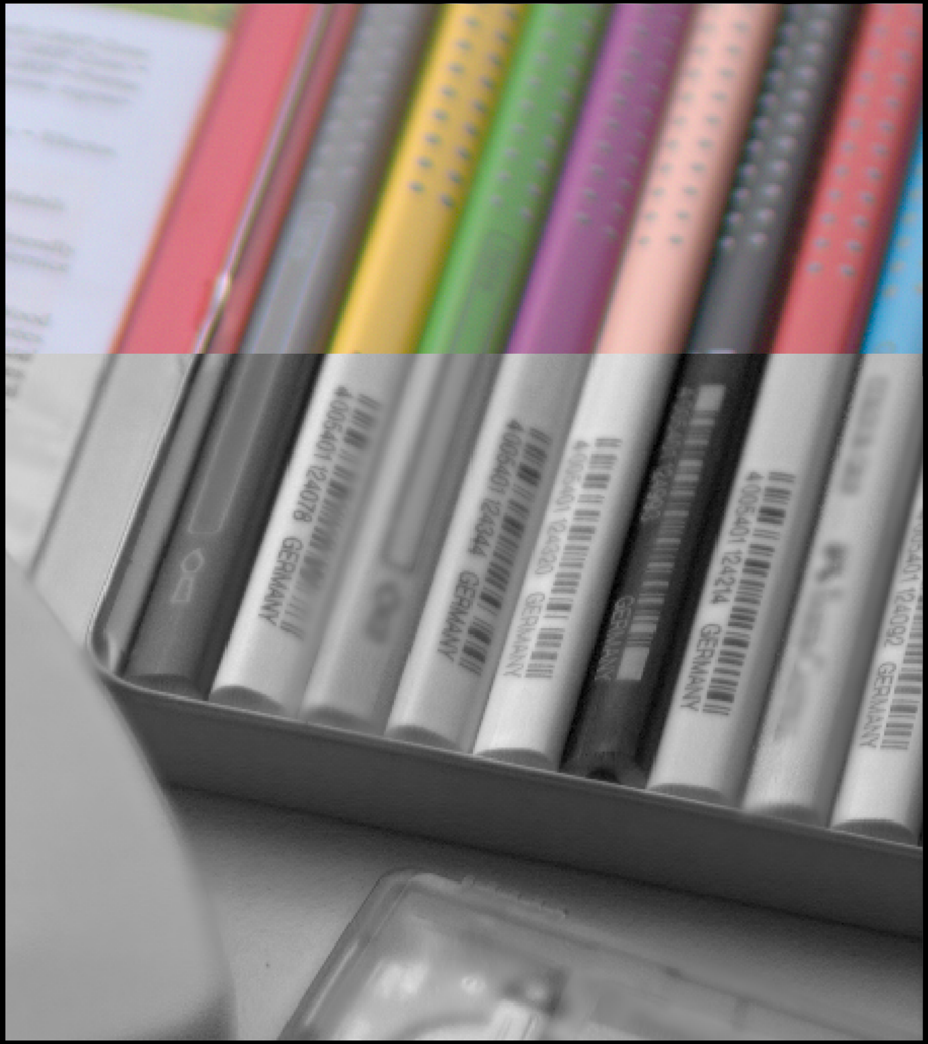
…but spatial distribution of high-frequency is
affected by object reflectance & chromatic aberration

Red

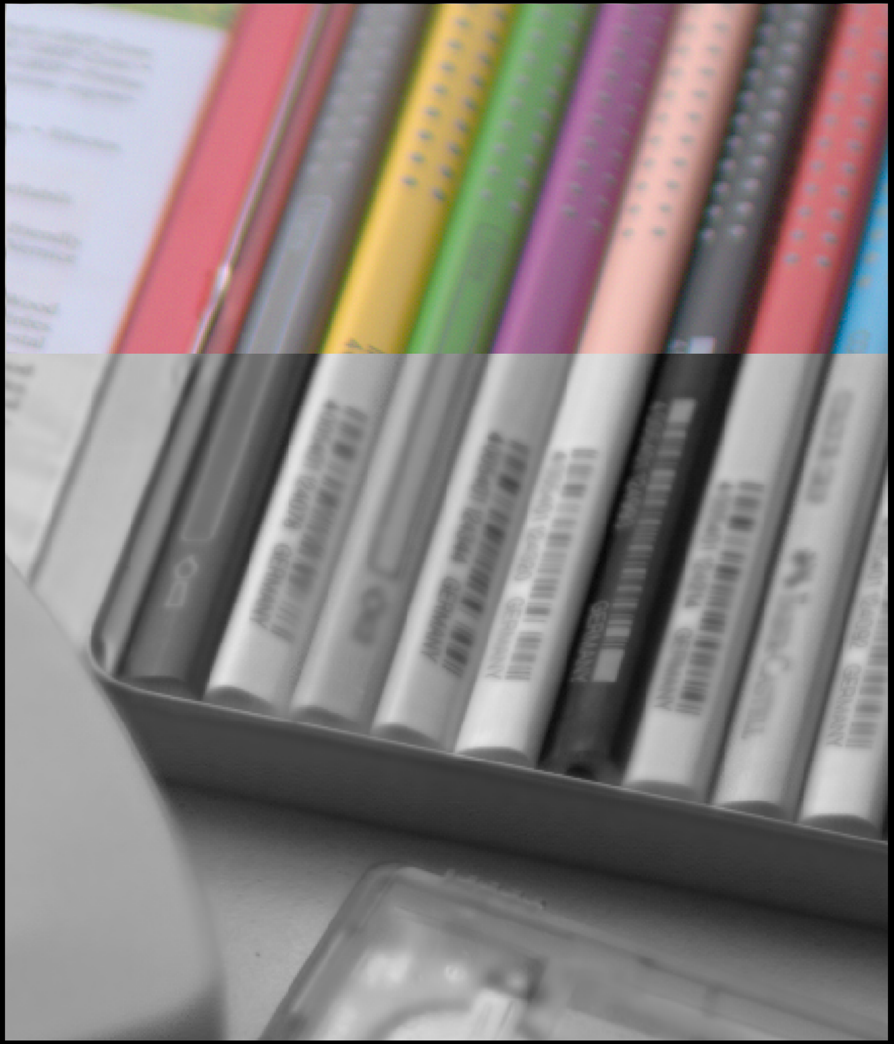
Green

Gradient difference

An example of spectral correlations

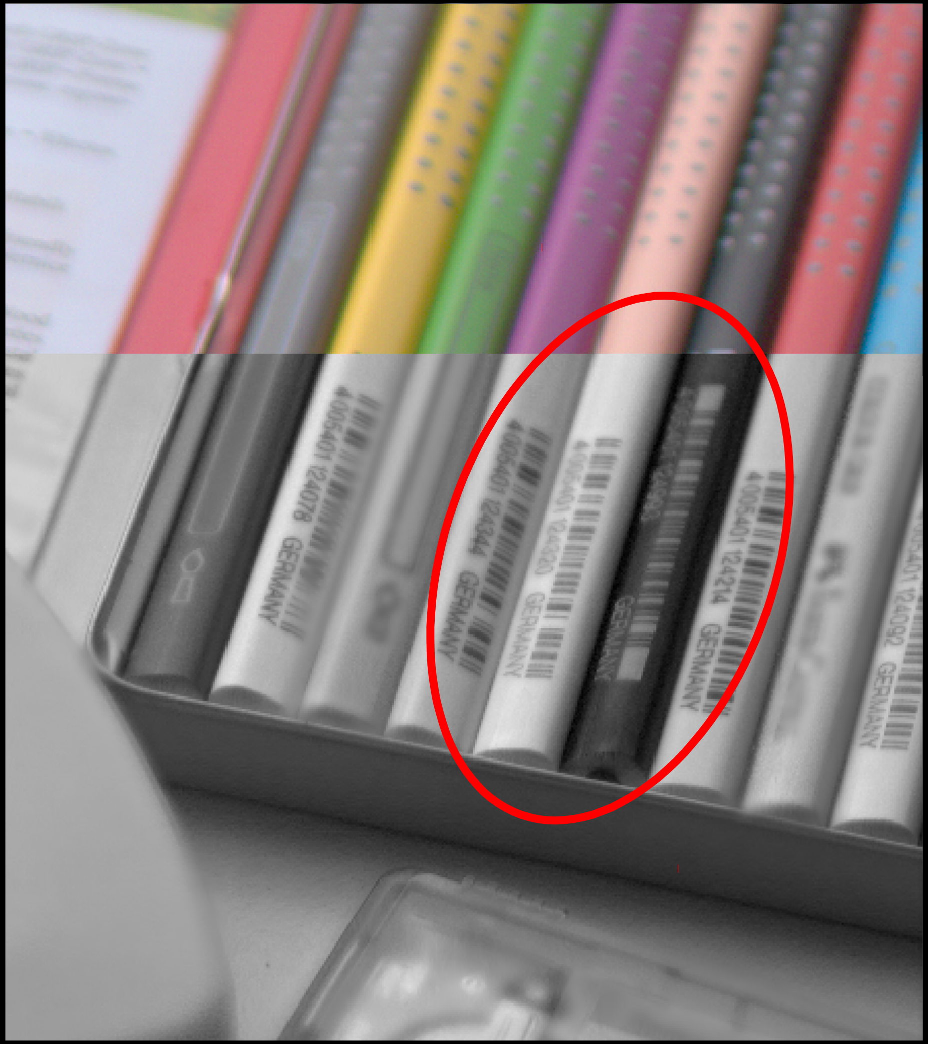


NIR deblurred from R channel

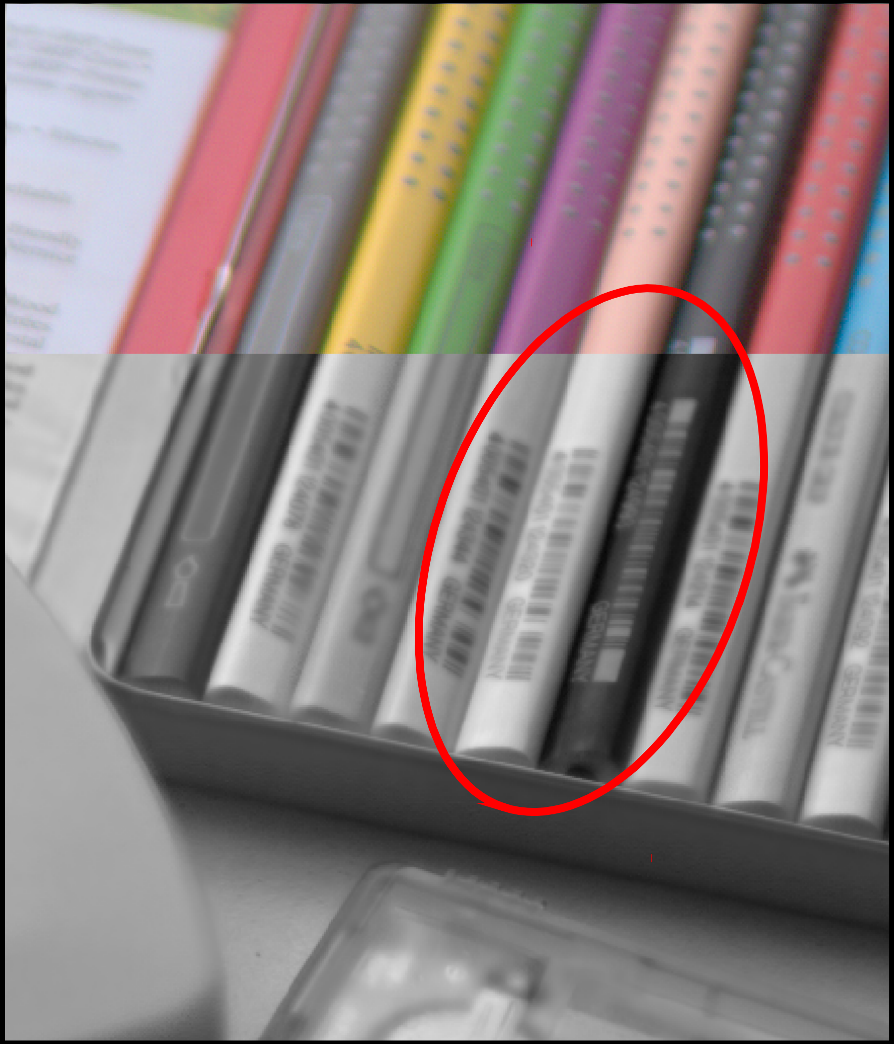


NIR deblurred from Y channel

An example of spectral correlations



NIR deblurred from R channel



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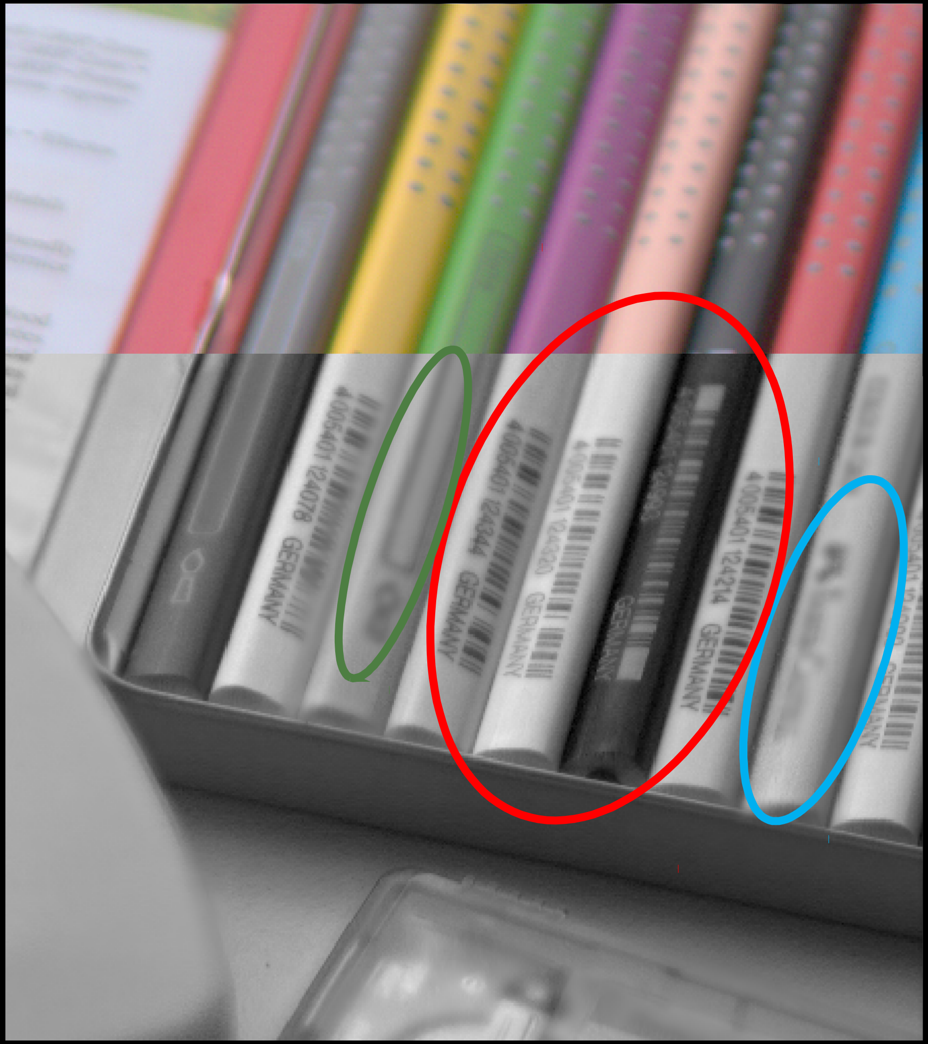
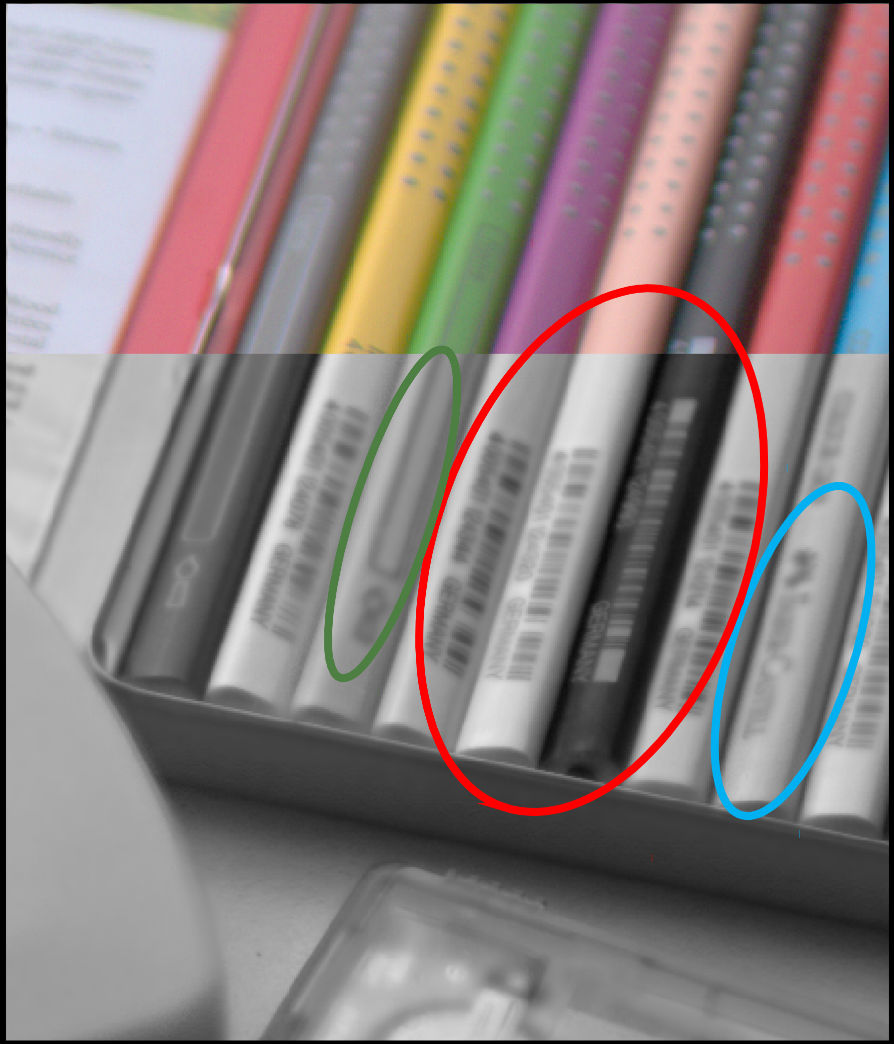
An example of spectral correlations



NIR deblurred from R channel



NIR deblurred from Y channel

Objective

Leverage spectral-spatial correlations,

making use of the best information for deblurring

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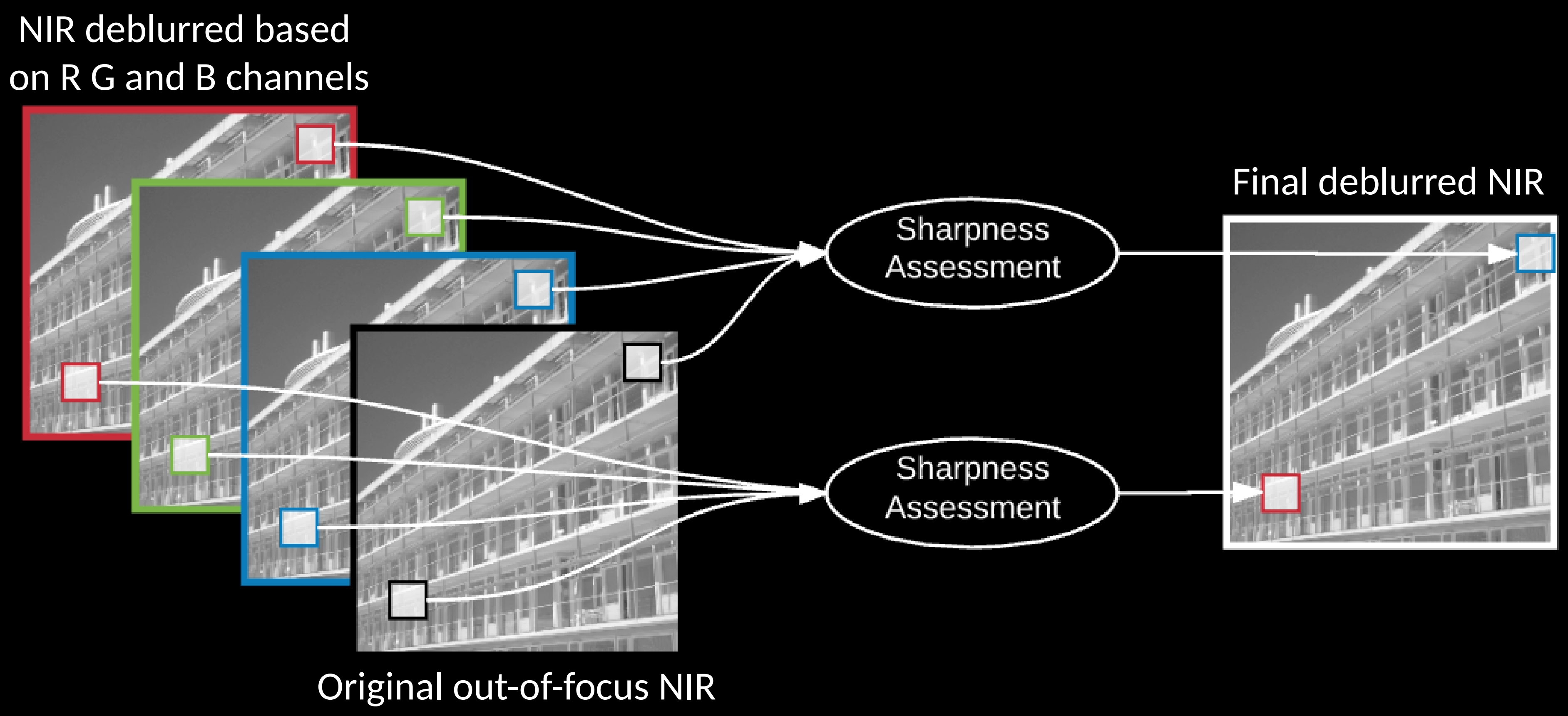
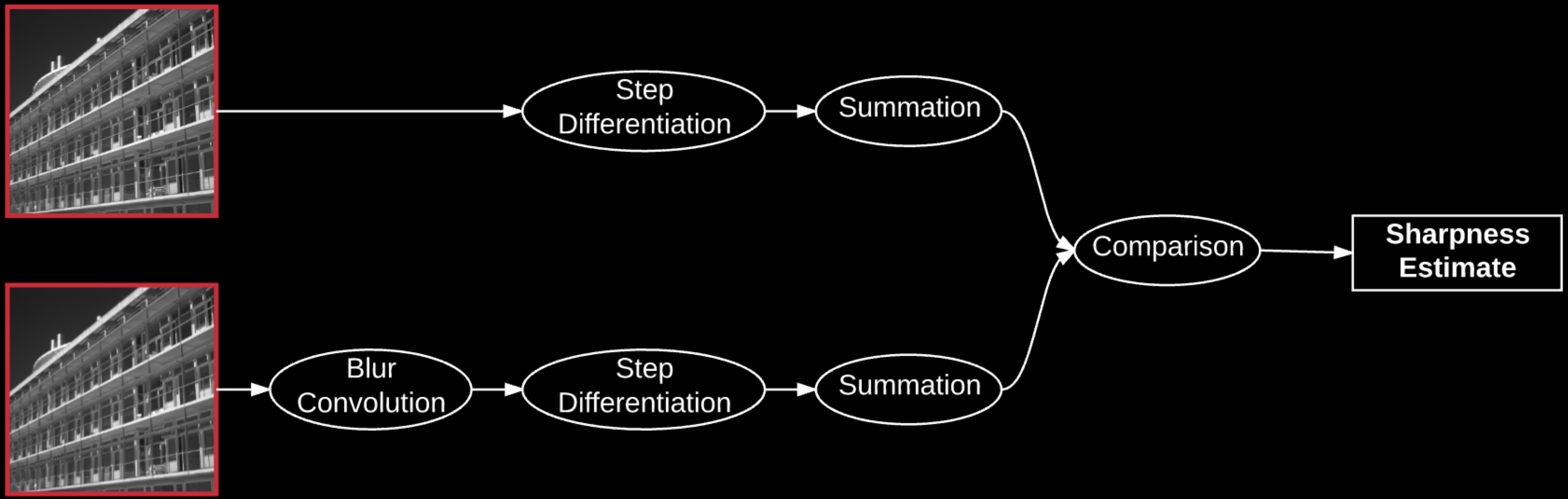
Constraint: no *apriori* knowledge on what spectral information is the most relevant for every spatial location

Combine advantages of each channel



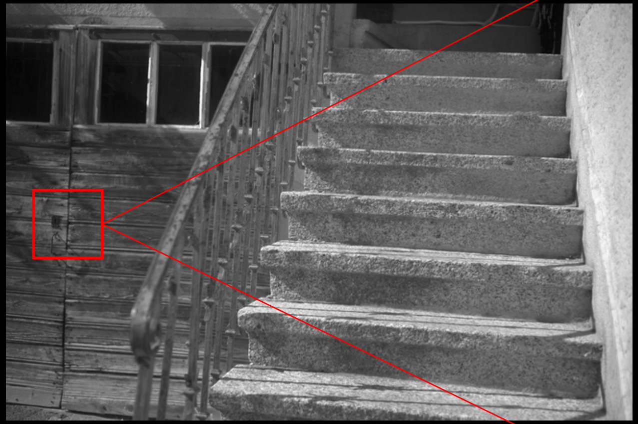
Sharpness assessment [2]



[2] F. Crete, et al. "The blur effect: perception and estimation with a new no-reference perceptual blur metric." *International Society for Optics and Photonics*, 2007.

Deblurring results

State of
the art [1]:



Ours:

Deblurring results

State of
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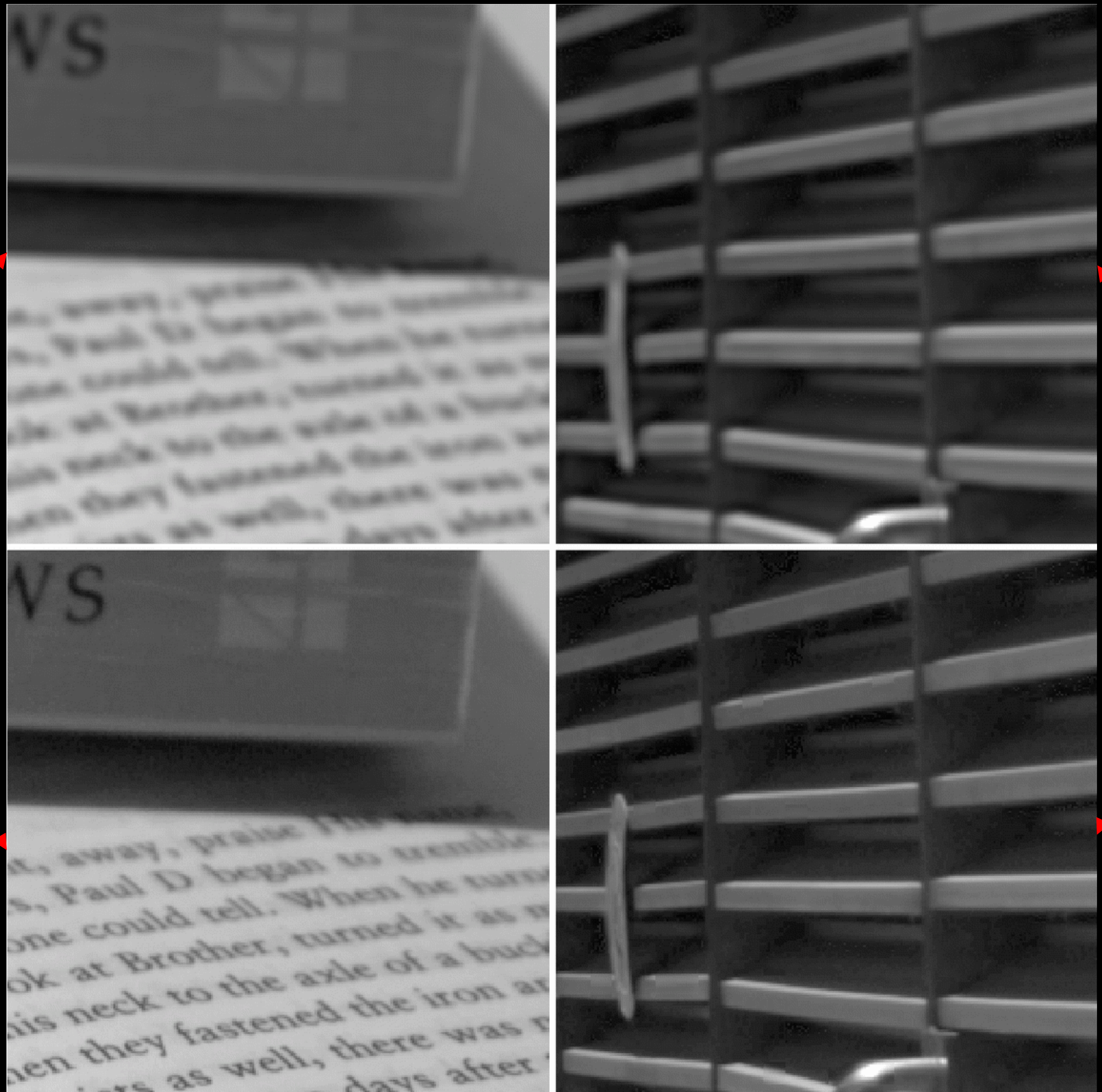
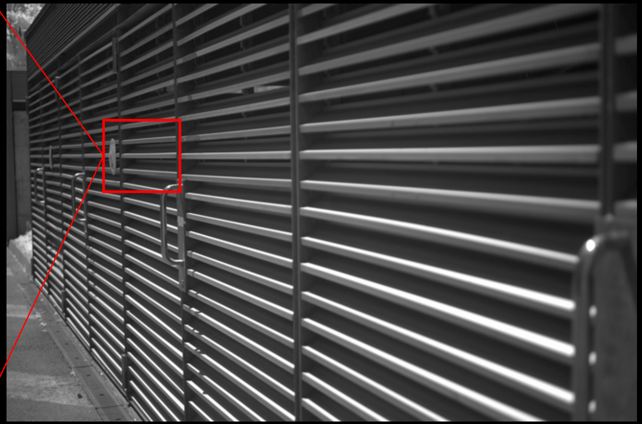
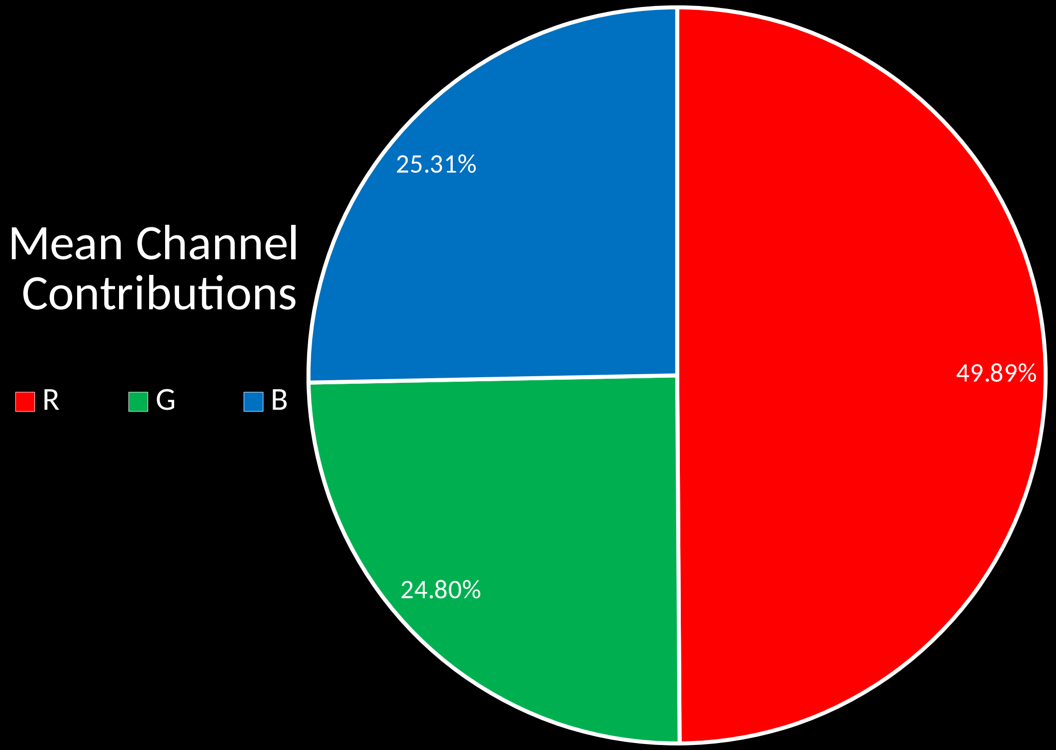




Ours:

Recombining from RGB



Simpler is better: any band combination loses high frequency

Conclusion

- 48.8% increase in sharpness (Crete)

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- Increased depth of field

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- 48.8% increase in sharpness (Crete)
- Increased depth of field
- Due to chromatic aberration and reflectance properties, spectral averaging causes a spatial low-pass filtering

Thank you for your attention

Code, explanations, datasets, papers:

ivrl.epfl.ch

majedelhelou.github.io

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