



Superresolution Imaging

from Equations to Embedded Applications

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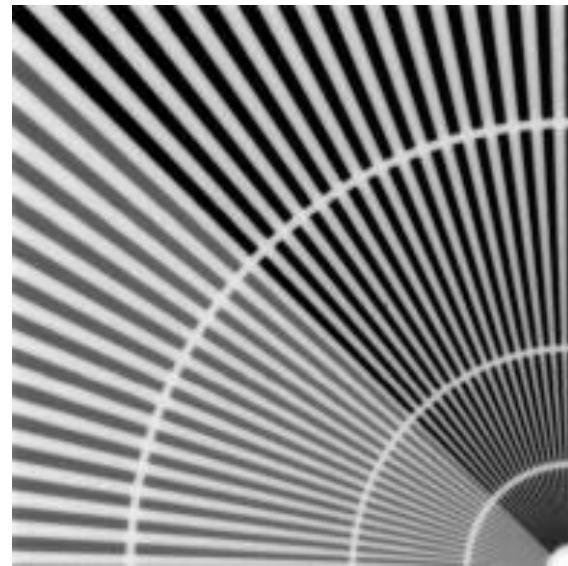
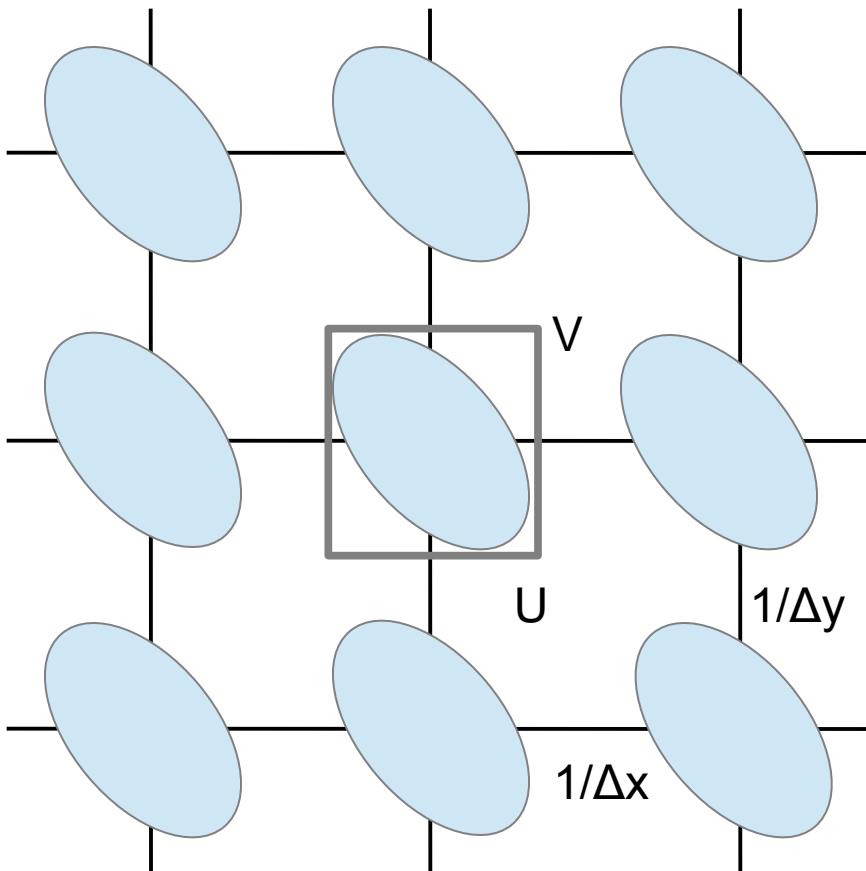


Superresolution





Recalling Nyquist



$$\Delta x \leq \frac{1}{2U}$$

$$\Delta y \leq \frac{1}{2V}$$



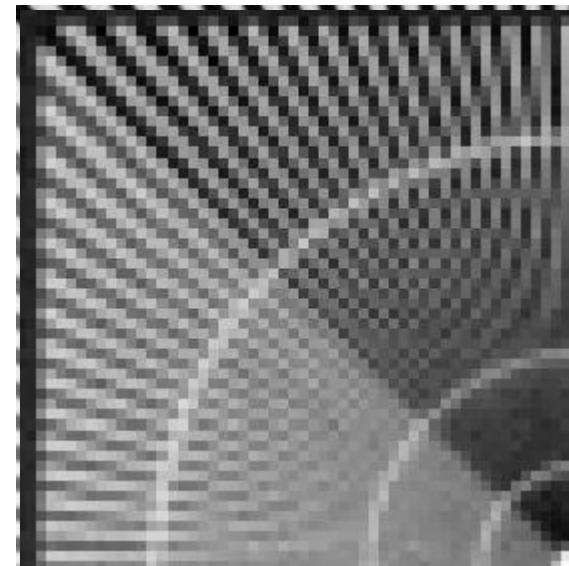
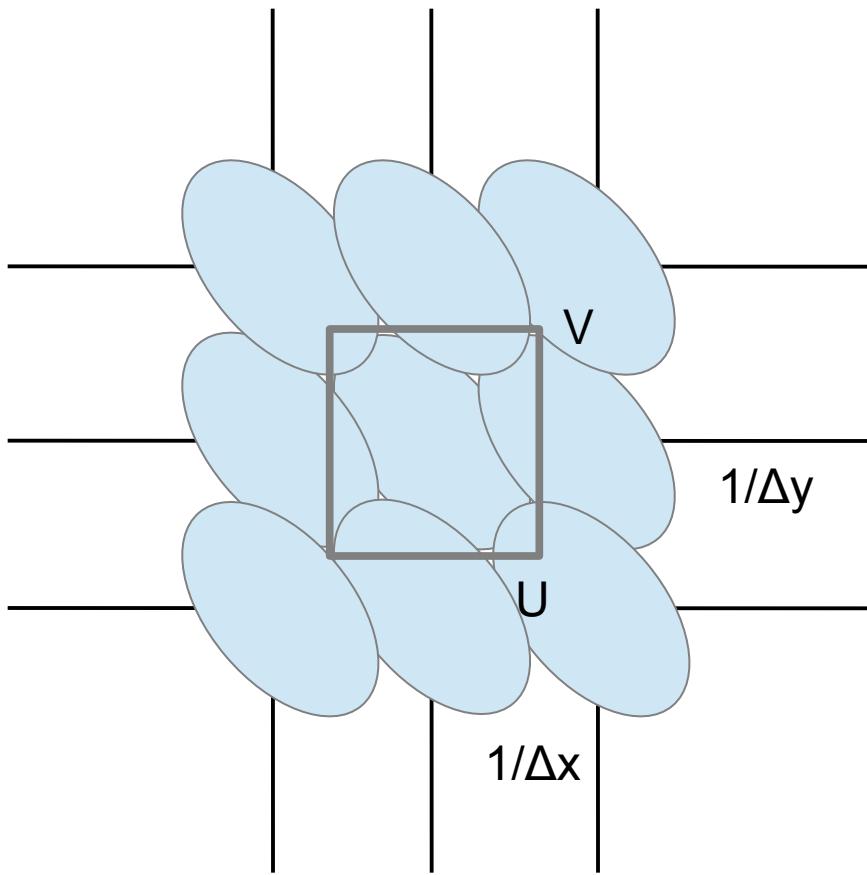
Nyquist Sampling

- Nyquist sampling → an "ideal" image, no frequencies are missed.
- Superresolution = scaling + interpolation





Recalling Nyquist



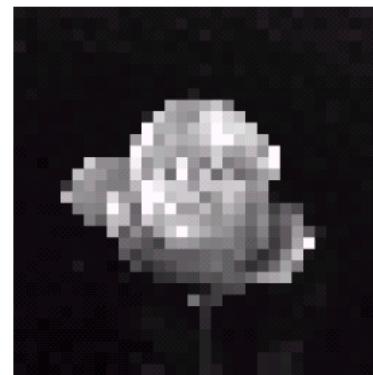
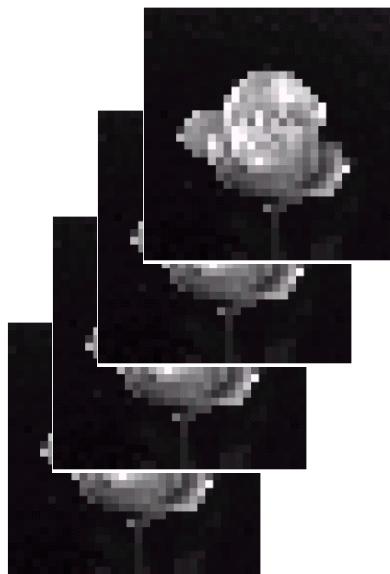
$$\Delta x > \frac{1}{2U}$$

$$\Delta y > \frac{1}{2V}$$



Superresolution

- Sub-Nyquist sampling → aliasing → high frequencies are lost or modified
- Superresolution can recover aliased data



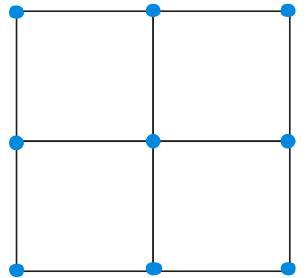
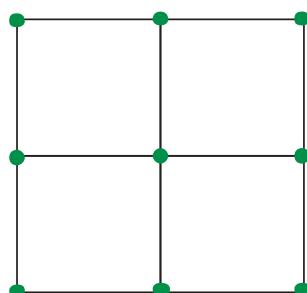
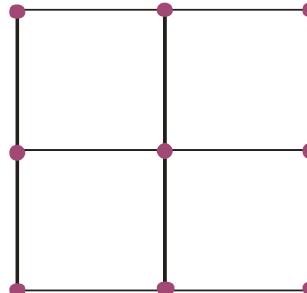
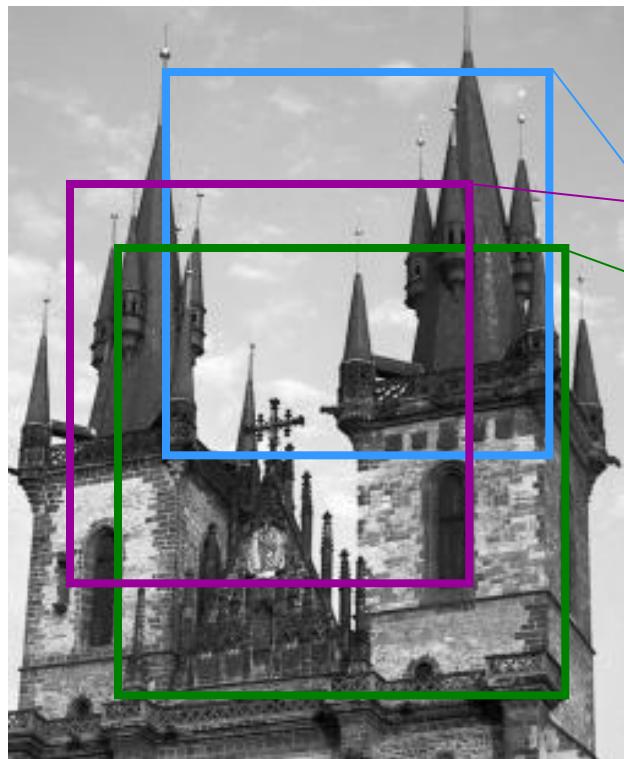
interpolation



SR

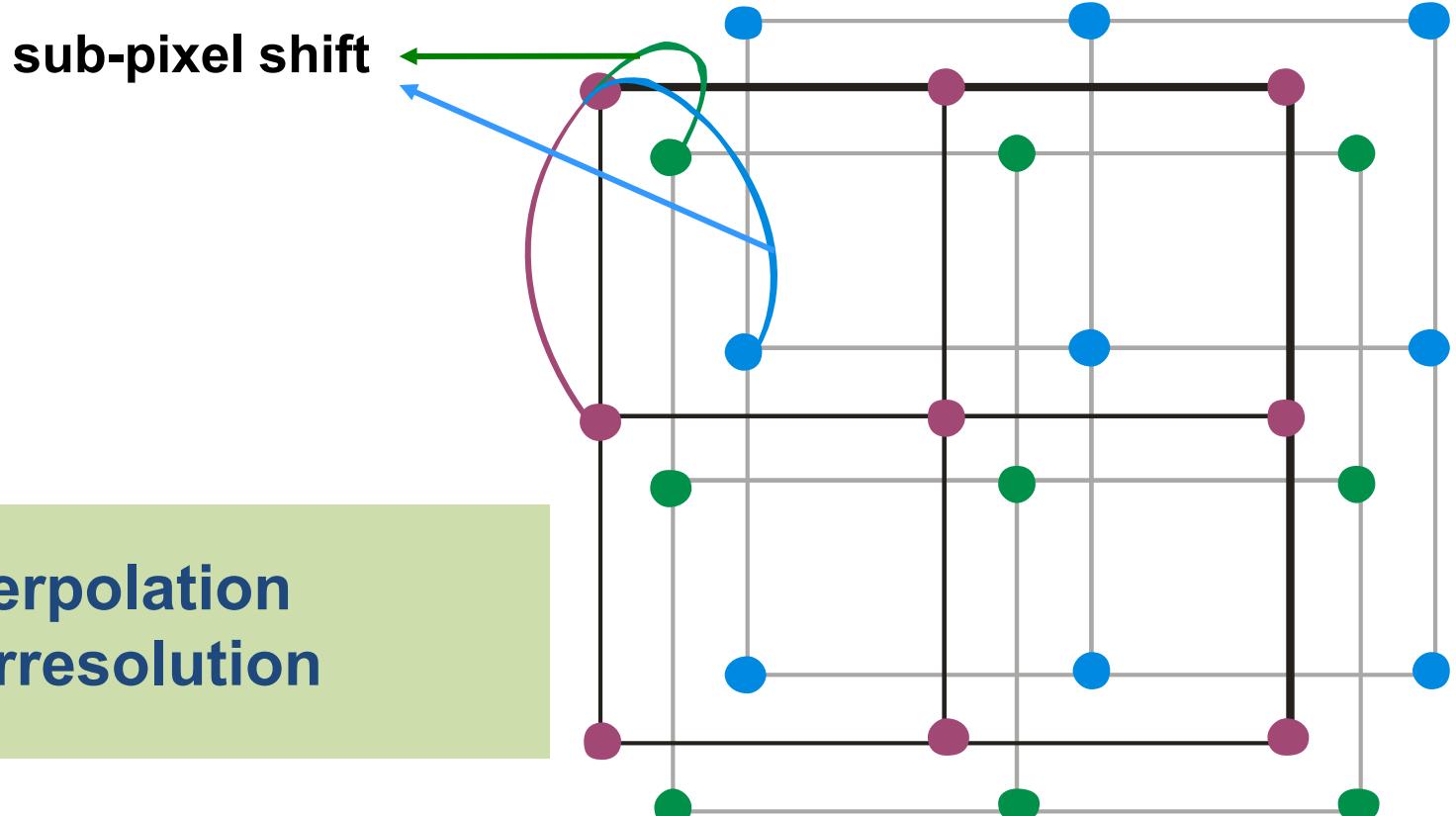


Traditional superresolution sub-Nyquist sampling



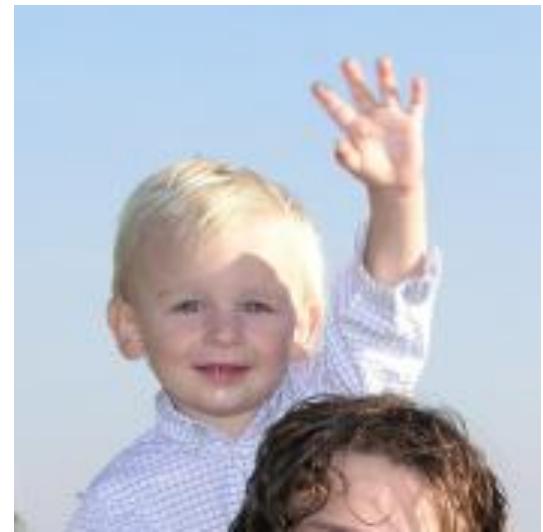
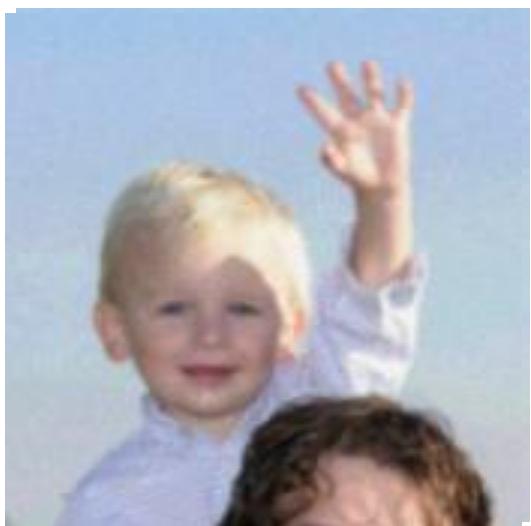
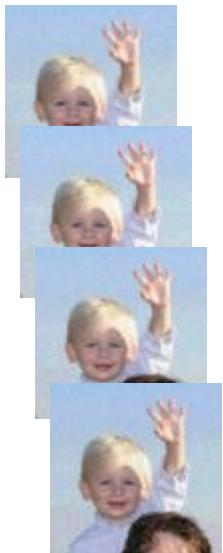


Traditional superresolution





Realistic Superresolution

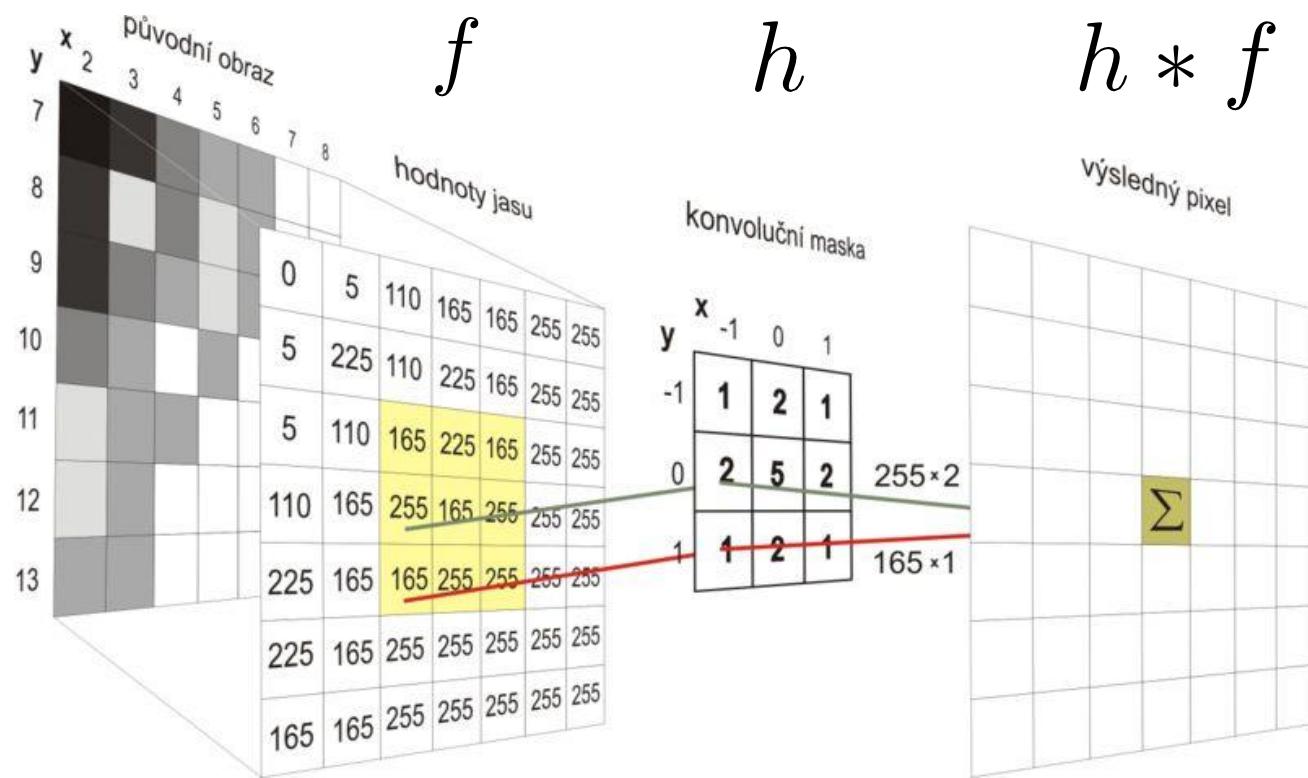


Deconvolution



Convolution

$$h * f(x) = \int_{-\infty}^{\infty} h(x - \tau) f(\tau) d\tau$$

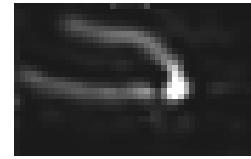




Motion Blur



*



==

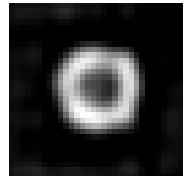




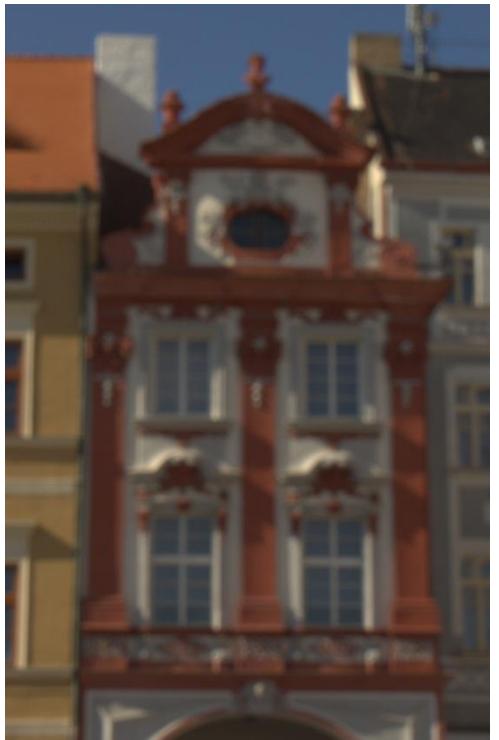
Out-of-focus Blur



*



=

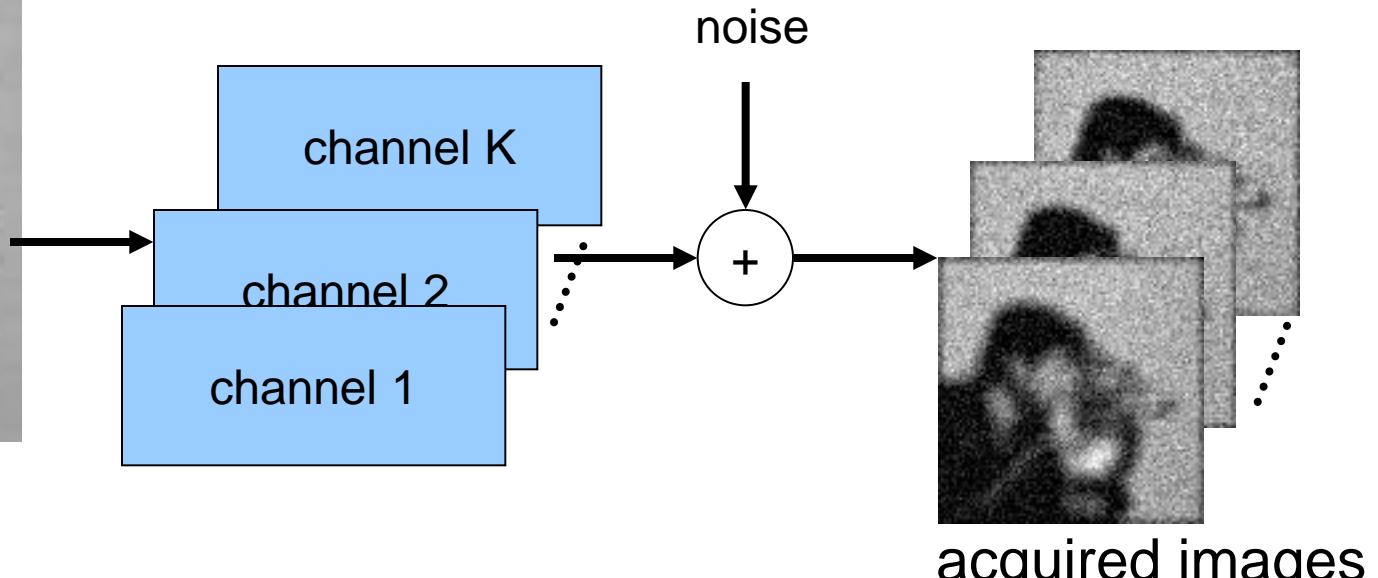




Multichannel Acquisition Model



original image



$$D[u] * h_k(x) + n_k(x) = z_k(x)$$



Realistic superresolution

- Acquisition model:
 - + Noise
 - + Blur
 - + Shift
 - + Downsampling
- Reconstruction method:
 - + Multichannel blind deconvolution
 - + Shift compensation
 - + Resolution enhancement



Superresolution & Blind Deconv.

- Acquisition model

$$z_k = D(h_k * u) + n_k$$

- Optimization problem

$$F(u, \{h_k\}) = \frac{1}{2} \sum_{k=1}^K \|z_k - D(h_k * u)\|^2 + \lambda Q(u) + \gamma R(\{h_k\})$$

↓ ↓ ↓

Data term Image regularization term Blur Regularization term

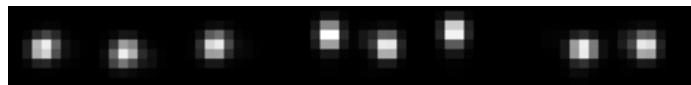
L2 norm L1 norm positivity



Superresolution



rough registration



Superresolved image (2x)

Optical zoom (ground truth)



Space-variant Case





Space-variant Case

- Video with local motion
 - Masking
- Slowly changing PSFs and/or misregistered images
 - Patch-wise approach



interpolated



SR



interpolated

SR



t-2

t-1

t

t+1

t+2



interpolated



SR



SR + masking



t-2



t-1



t



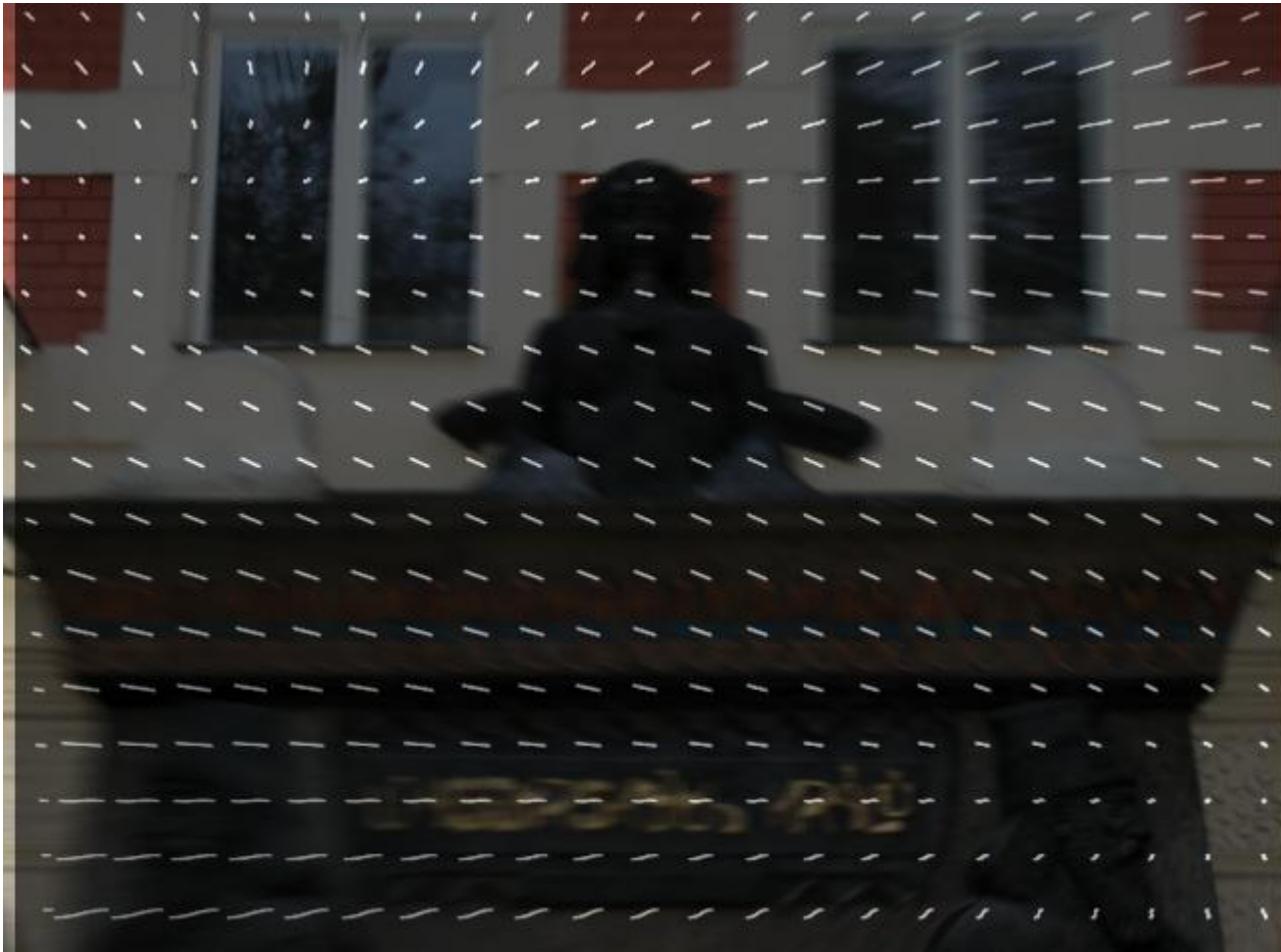
t+1



t+2

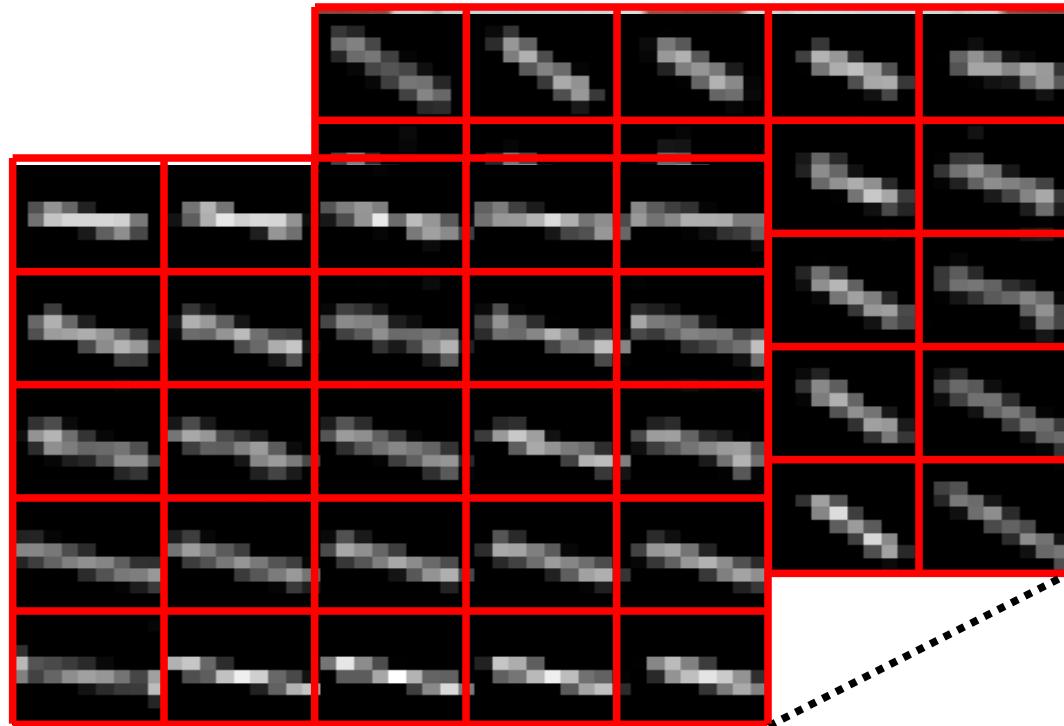


Camera-motion Blur





Space-variant Superresolution







Close-up

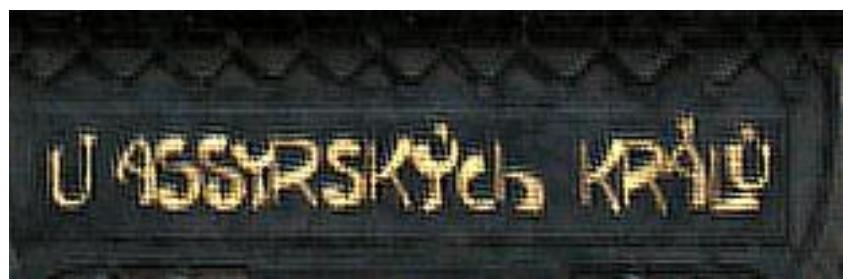
Input LR



Original



Space-variant
Reconstruction



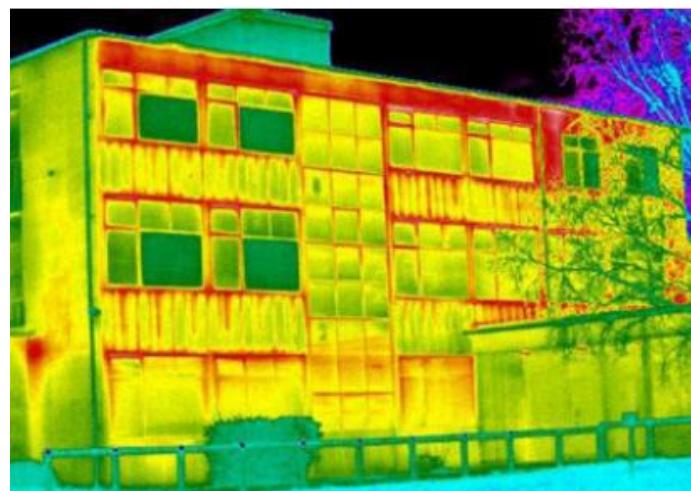
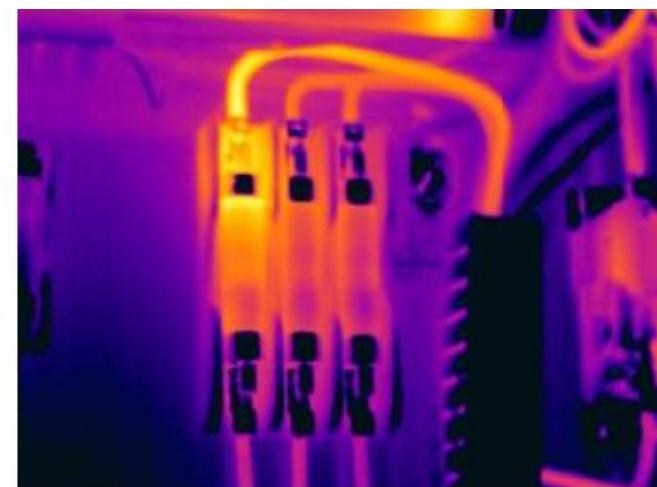
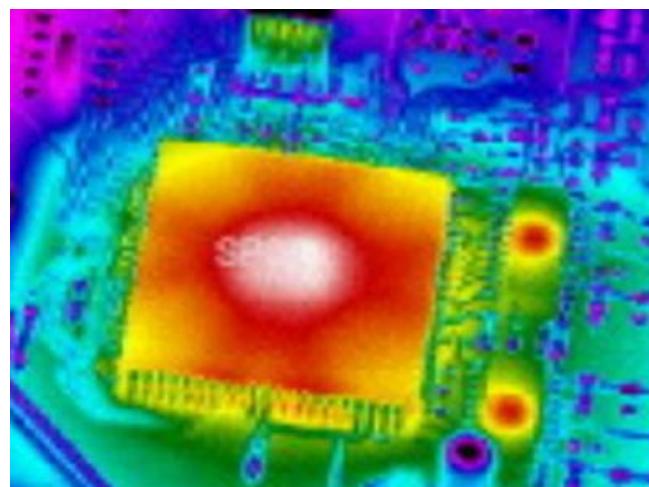
Space-invariant
Reconstruction

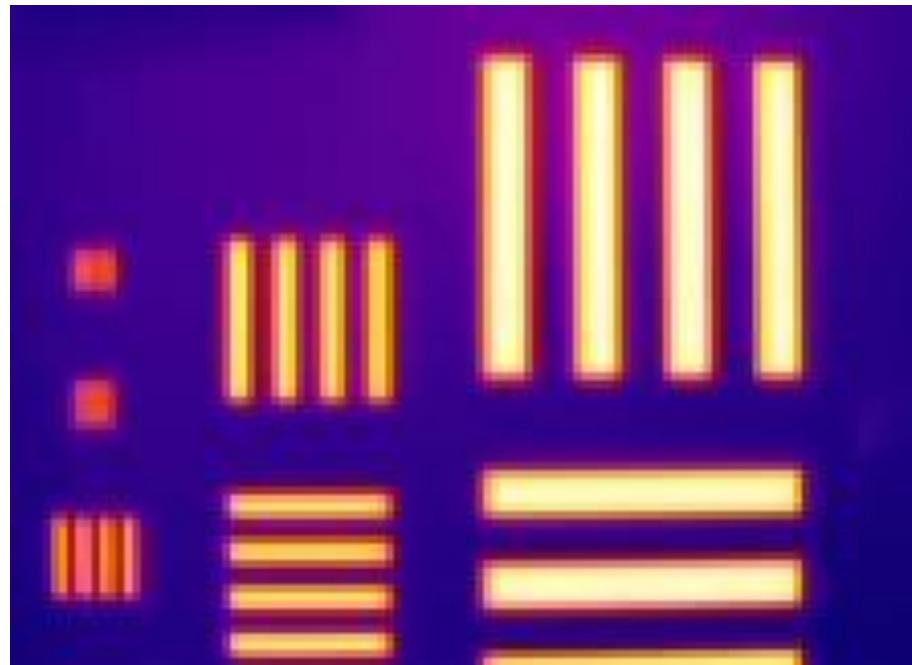


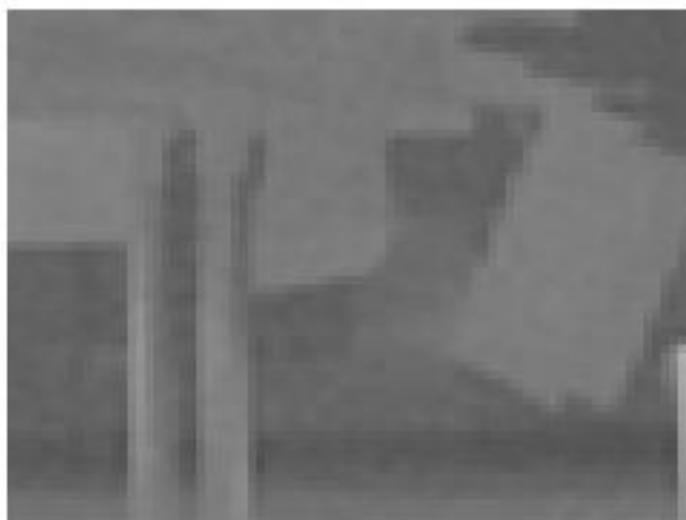
Infrared video super-resolution

- Handheld IR camera
 - 160 x 120, 9 fps
- Real-time super-resolution
 - with factor 2 (320 x 240)
 - computed directly inside the camera using DSP











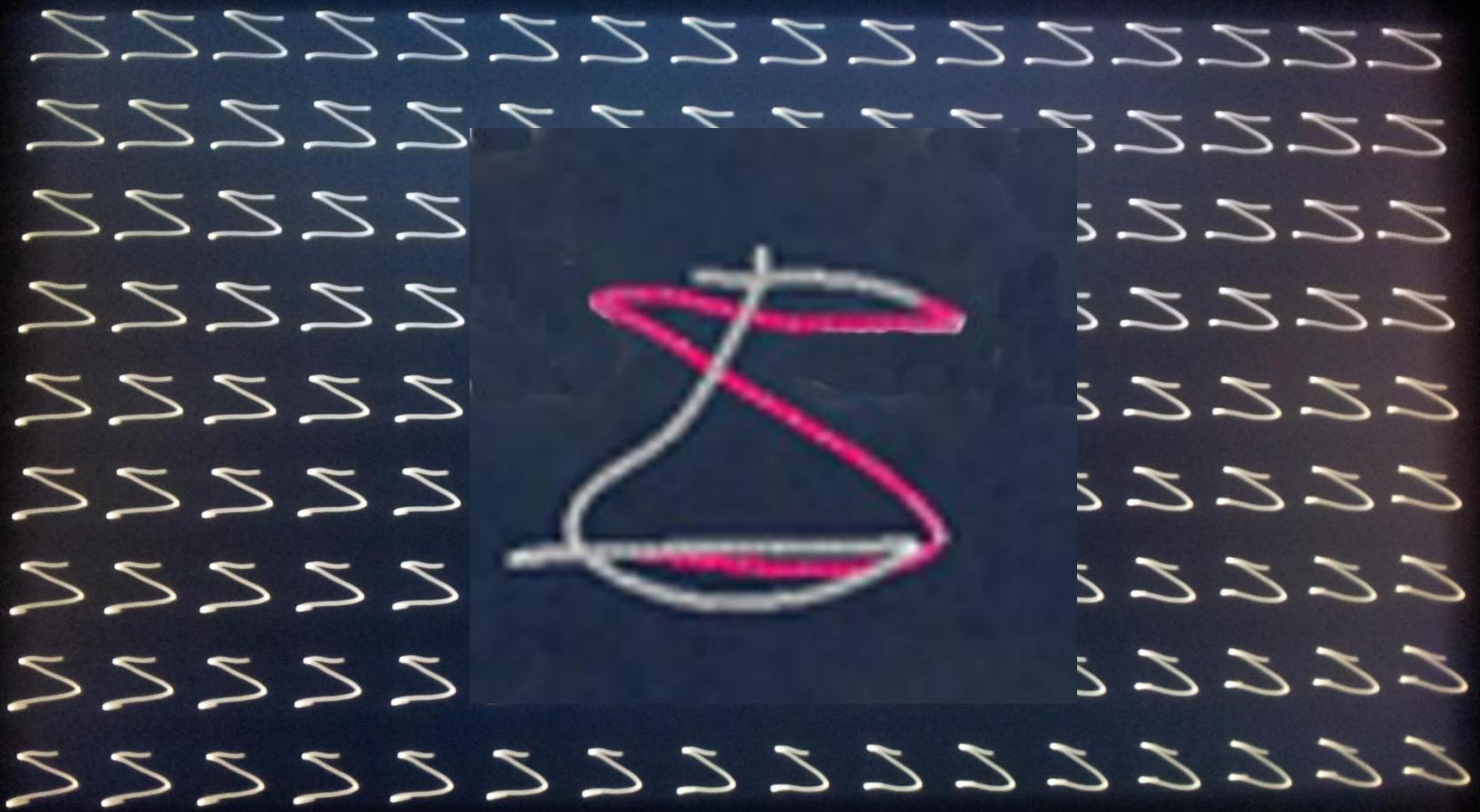
“Blind” Deconvolution on Smartphones



Using accelerometers and/or gyroscopes

Rotation and translation of the phone







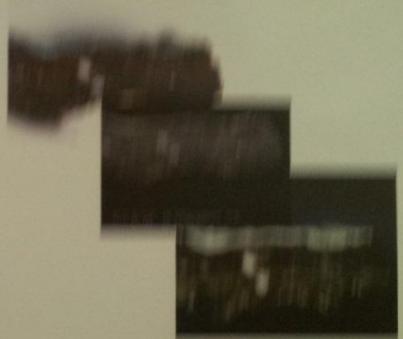
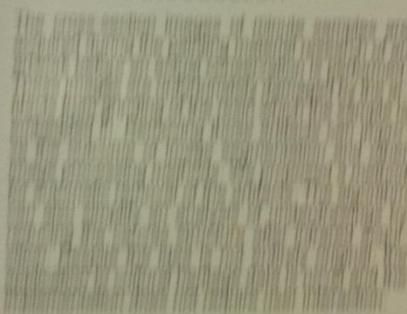
Wiener Filtering on Android Smartphones

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Introduction



Artifacts removing

→ reduce noise component and in form of parallel lines



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Introduction

The cross-section images of minute samples are acquired during the painting material research of an artwork before an actual conservation is performed. These images are unfortunately damaged by the artifacts from grinding of the resin which the sample is embedded in. Removing those artifacts can improve the outcome of image segmentation and other image processing methods. We proposed a method for automatic removal of the artifacts. The algorithm can also simplify an analysis of underdrawings by reducing the canvas structure after infrared acquisition. Despite the idea is not entirely original, the application to cultural heritage data is novel and the implementation does not require user interaction.



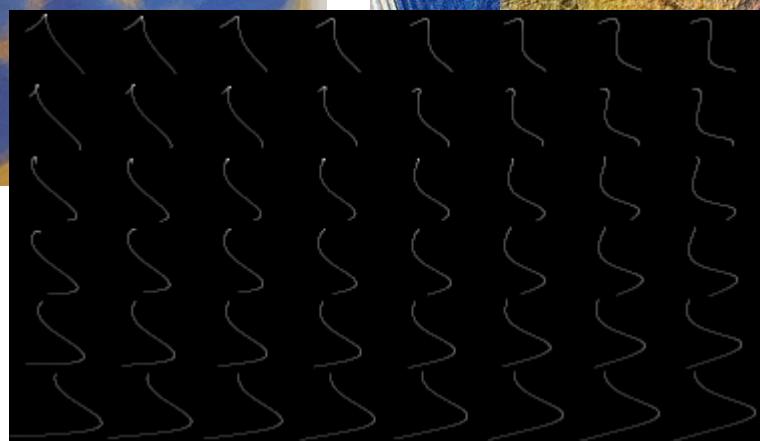
Artifacts removing

→ artifacts are omnipresent and in form of parallel lines





Wiener Filtering on Android Smartphones



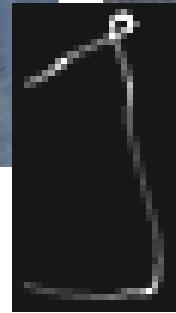
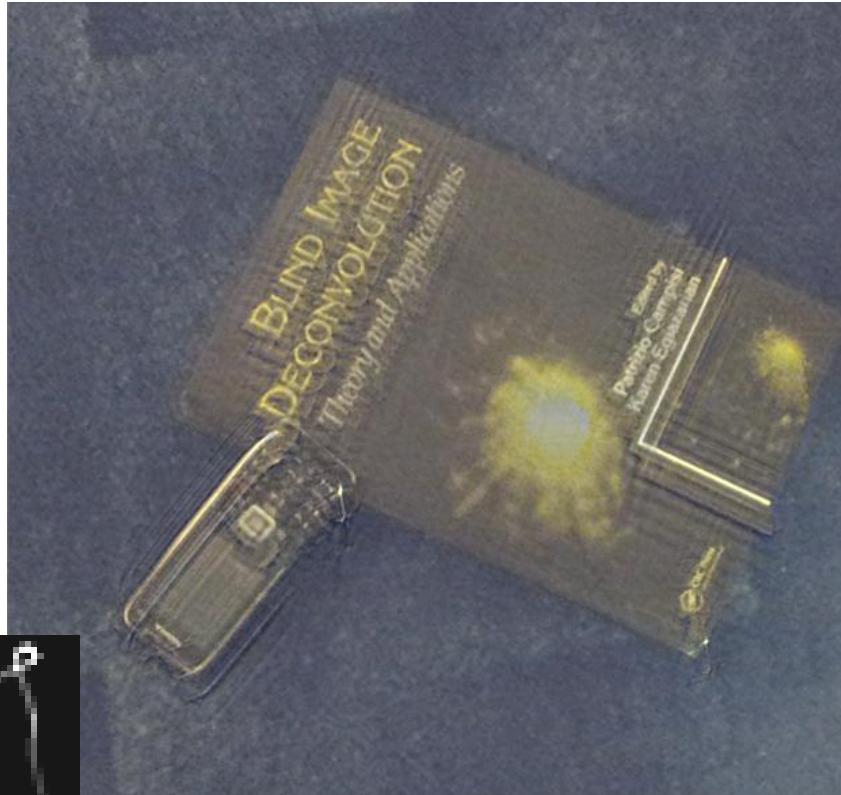


Thank You...

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Wiener Filtering on Android Smartphones





Regularization Terms

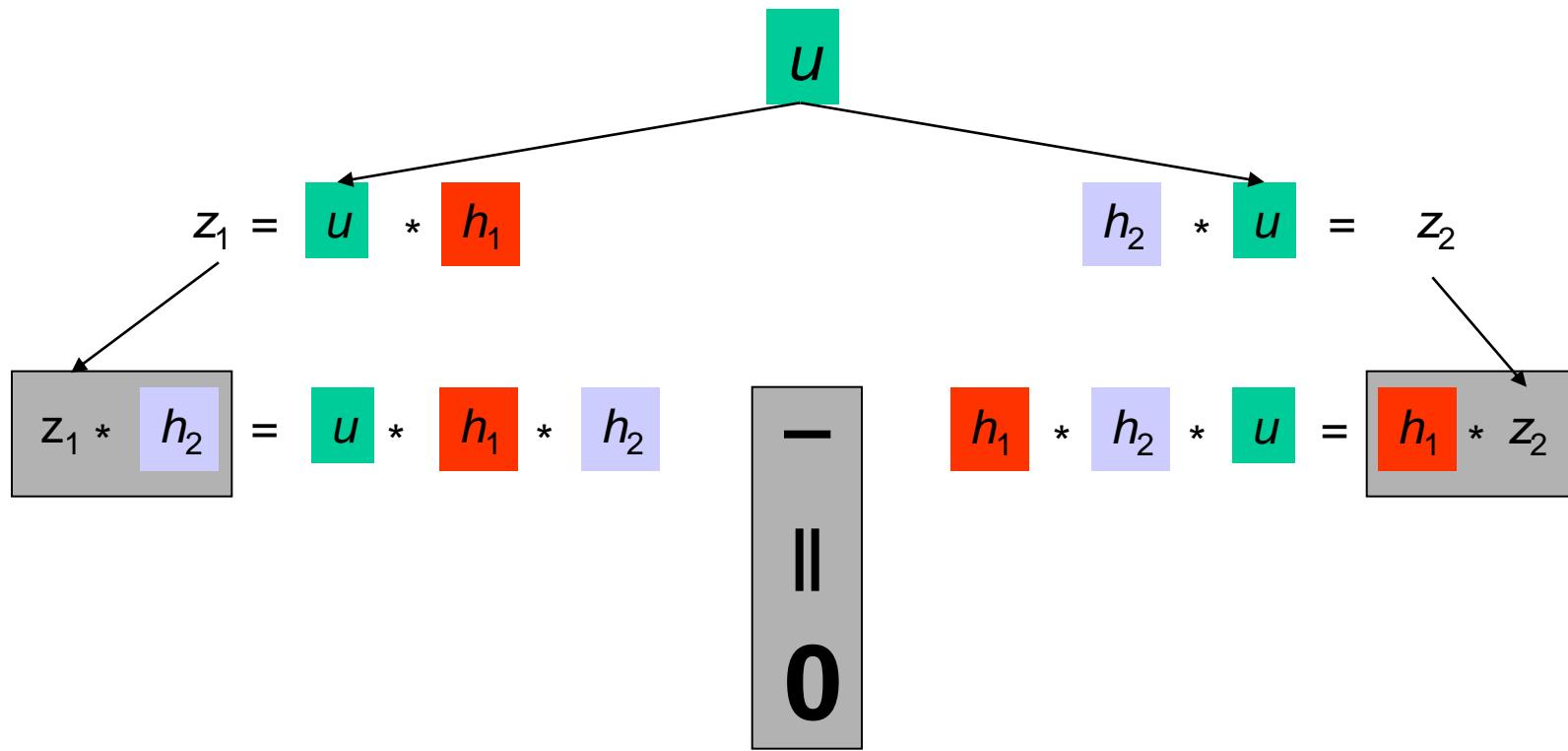
$$F(u, \{h_k\}) = \frac{1}{2} \sum_{k=1}^K \|z_k - D(h_k * u)\|^2 + \boxed{\lambda Q(u)} + \boxed{\gamma R(\{h_k\})}$$

$$Q(u) = \int \phi(|\nabla u(x)|) dx$$

$$R(\{h_i\}) = \frac{1}{2} \sum_{1 \leq i, j \leq K} \|z_i * h_j - z_j * h_i\|^2$$



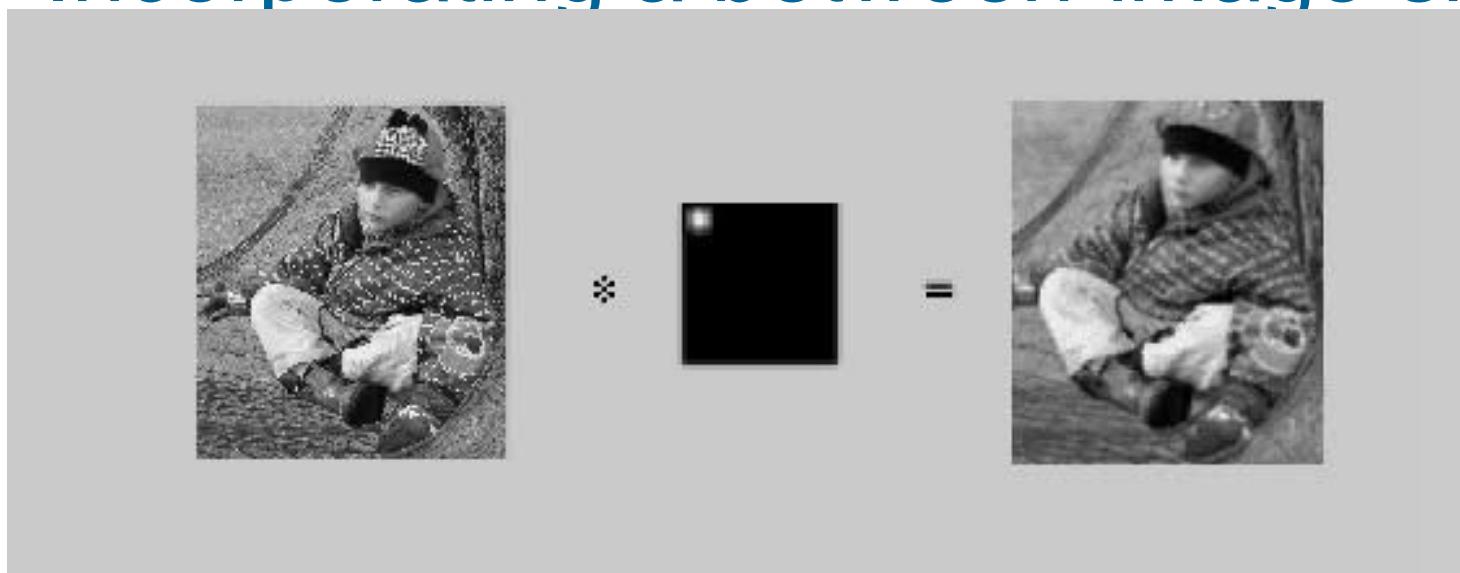
PSF Regularization



$$R(\{h_i\}) = \frac{1}{2} \sum_{1 \leq i, j \leq K} \|z_i * h_j - z_j * h_i\|^2$$



Incorporating a between-image shift



$$[u * h_k](\tau_k(x, y)) + n_k(x, y) = z_k(x, y)$$

$$[u * g_k](x, y) + n_k(x, y) = z_k(x, y)$$



Alternating Minimization

$$\min_{u,h} \frac{1}{2} \|z - D(h * u)\|_2^2 + \lambda \|\nabla u\|_1 + \gamma R(h)$$

- ***u*-step**

$$\min_u \frac{1}{2} \|z - D(h * u)\|_2^2 + \lambda \|\nabla u\|_1$$

- ***h*-step**

$$\min_h \frac{1}{2} \|z - D(h * u)\|_2^2 + \gamma R(h)$$



Variable Splitting

$$\min_{u,h} \frac{1}{2} \|z - D(h * u)\|_2^2 + \lambda \|\nabla u\|_1 + \gamma R(h)$$

- ***u*-step**

$$\min_{u,v} \frac{1}{2} \|z - D(h * u)\|_2^2 + \lambda \|v\|_1 \quad \text{s.t. } v = \nabla u$$

- ***h*-step**

$$\min_{h,w} \frac{1}{2} \|z - D(h * u)\|_2^2 + \gamma R(w) \quad \text{s.t. } w = h$$



Augmented Lagrangian Method

$$\min_{u,h} \frac{1}{2} \|z - D(h * u)\|_2^2 + \lambda \|\nabla u\|_1 + \gamma R(h)$$

- **u -step**

$$\min_{u,v} \frac{1}{2} \|z - D(h * u)\|_2^2 + \lambda \|v\|_1 - \frac{\alpha}{2} \|\nabla u - v - a\|^2$$

- **h -step**

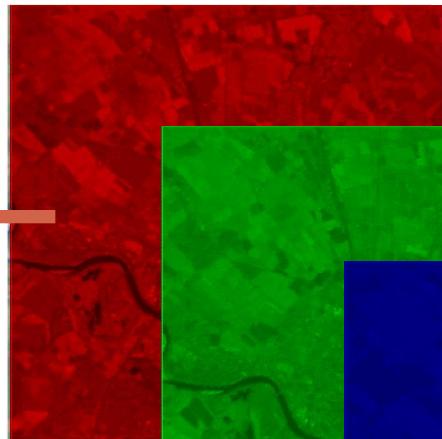
$$\min_{h,w} \frac{1}{2} \|z - D(h * u)\|_2^2 + \gamma R(w) + \frac{\beta}{2} \|h - w - b\|^2$$



IWT

Panchro

replace



spectral

Fused image





Wiener Filtering in Android Smartphones

