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Fusion for Restoration and Superresolution

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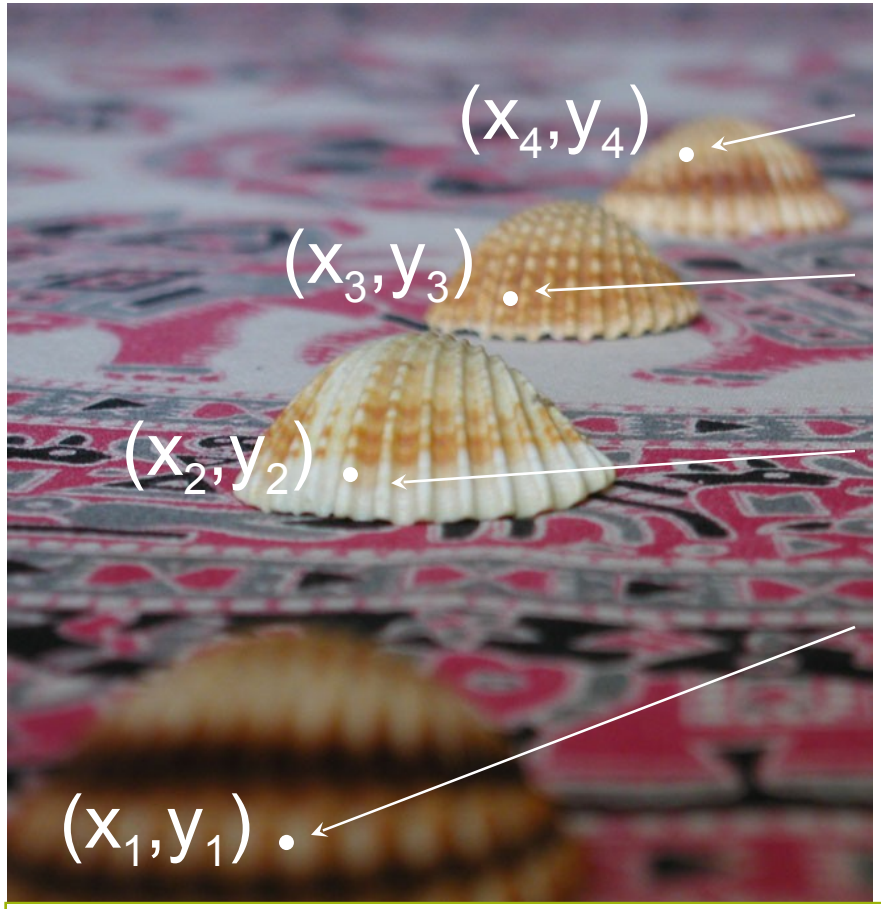
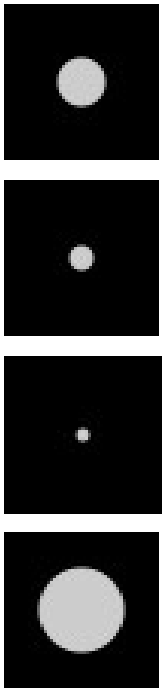
Space-variant PSF





$h(s,t; x_4,y_4)$

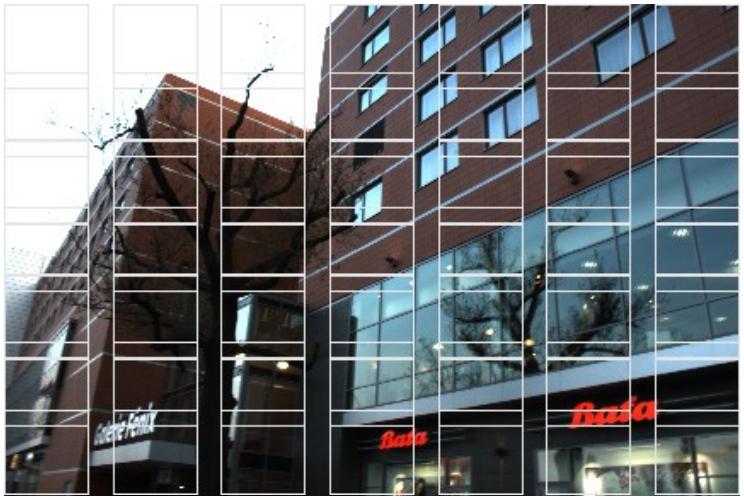
$h(s,t; x_1,y_1)$

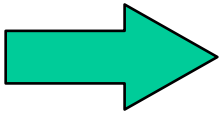
$$\mathbf{z}(x,y) = \int_{\Omega} \mathbf{u}(x-s, y-t)\mathbf{h}(s,t; x-s, y-t)\, dsdt + \mathbf{n}(x,y)$$

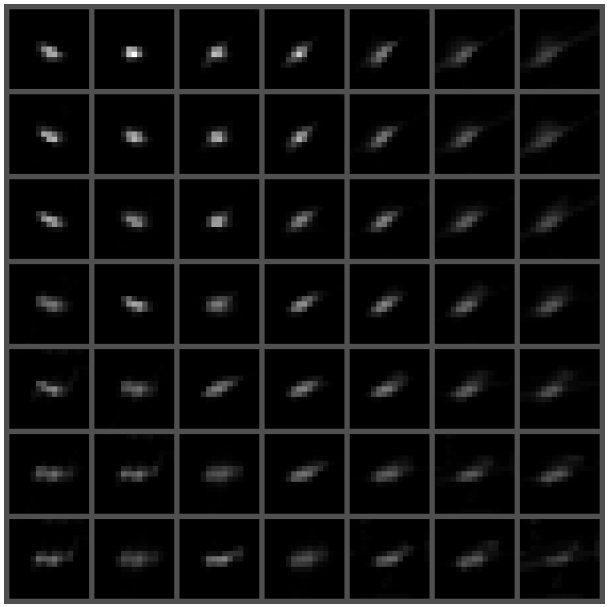
Camera Translation

depth map

Camera Rotation







Restoration

- Minimization of

$$E(\mathbf{u}) = \frac{1}{2}\|\mathbf{u} *_v h - \mathbf{z}\|^2 + \lambda \int |\nabla \mathbf{u}|$$

$$\mathbf{u} *_v \mathbf{h}\ [x, y] = \int_\Omega \mathbf{u}(x-s, y-t)\mathbf{h}(s, t; x-s, y-t)\, dsdt$$

- PSF h interpolated from estimated convolution kernels

Sorel et al., IEEE TIP 17(2), 2008

Galerie Fénix
Galerie Fénix
Galerie Fénix
Bata
Bata
Bata

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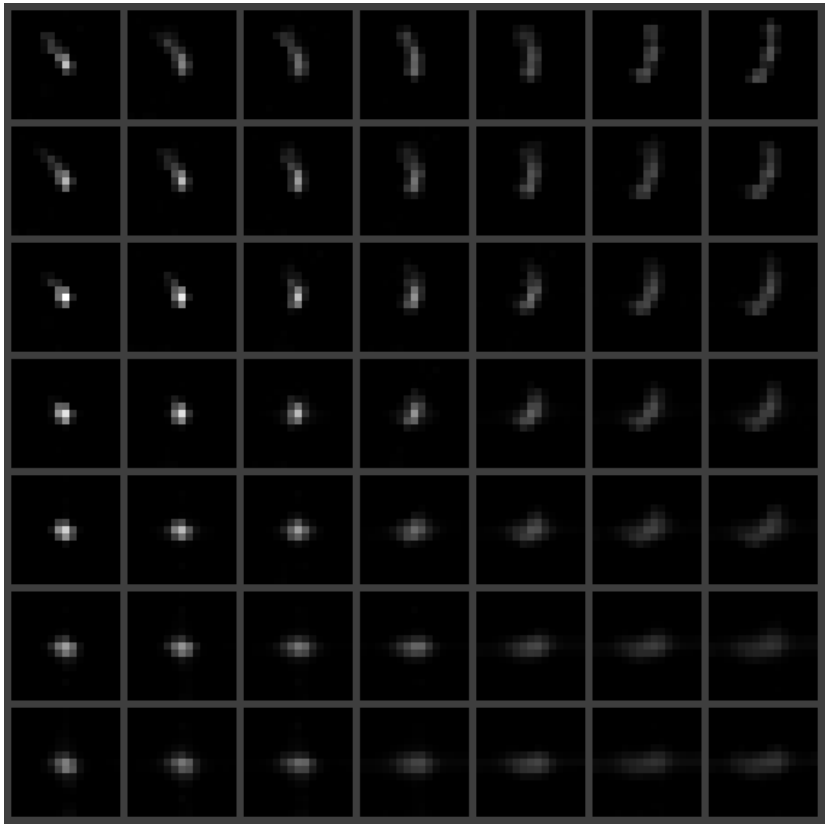
SVĚTOVÁ POHOŘÍ
PRŮVODCE CESTOVATELE
UNIVERSUM
Jan Hocek
nejhezčí túry SVĚTA
Petr Dvořák Letecká meteorologie
Lexikon přežití
OUTDOOR LEADERSHIP
NEKONEČNÝ UZEL
Ladakhi – English – Urdu Dictionary
Cvičebnice francouzské gramatiky
POLYGLOT
FRAUS



Ivan Dieška
Václav Širl
Horolezectví zblízka
Letecká meteorologie
Lexikon přežití
TECHNIQUES, COMMON SENSE & SELF-CONFIDENCE
GRAHAM
СПОРТИВНЫЙ МАССАЖ
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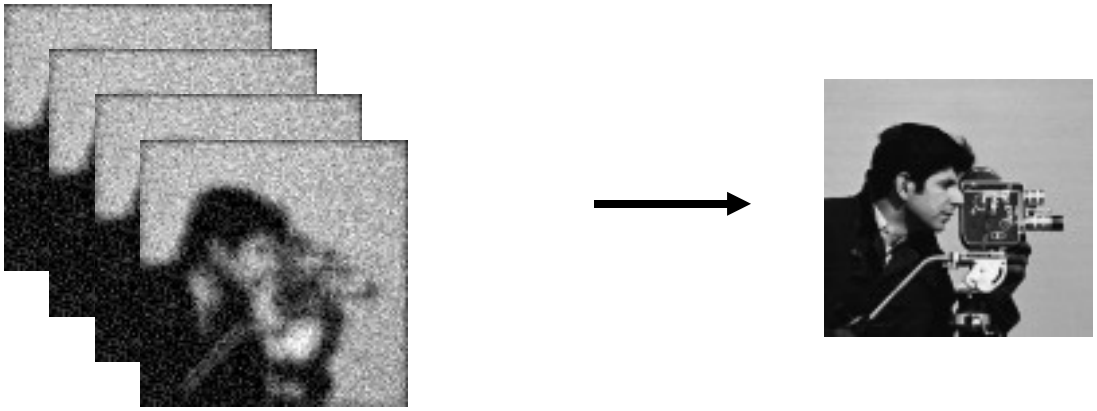
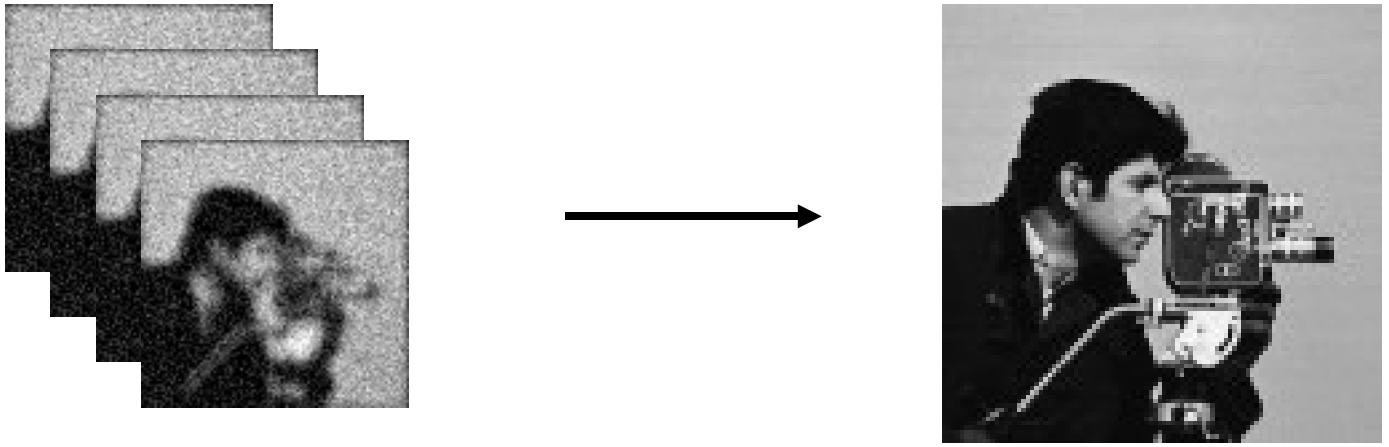
Ladakhi – English – Urdu
TESTS IN ENGLISH
STRUČNÁ MLUVNICE FRANCOUZŠTINY
ncouzské gramatiky

Multichannel deconvolution

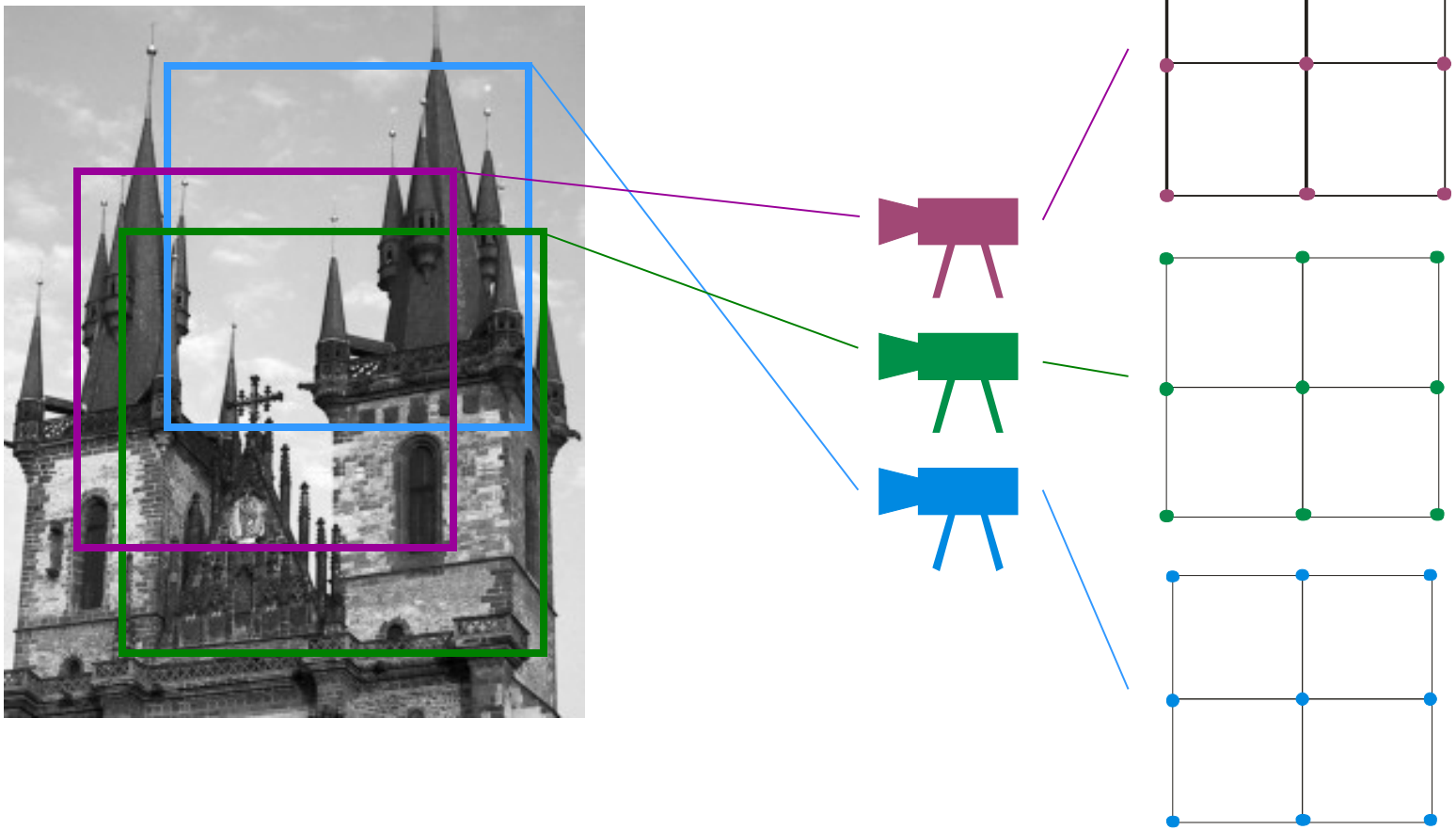


Superresolution

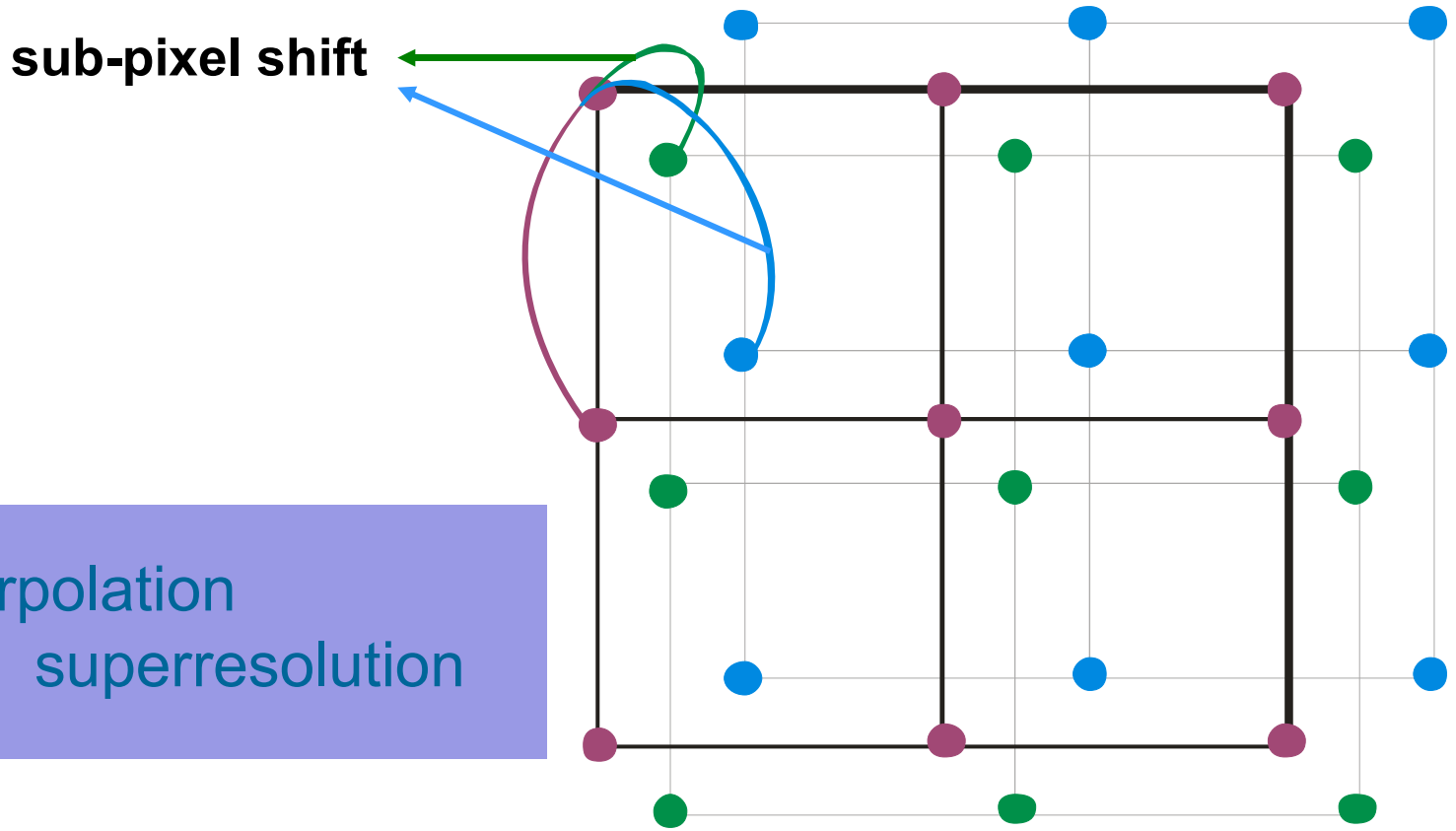


Traditional Superresolution

No blur is present

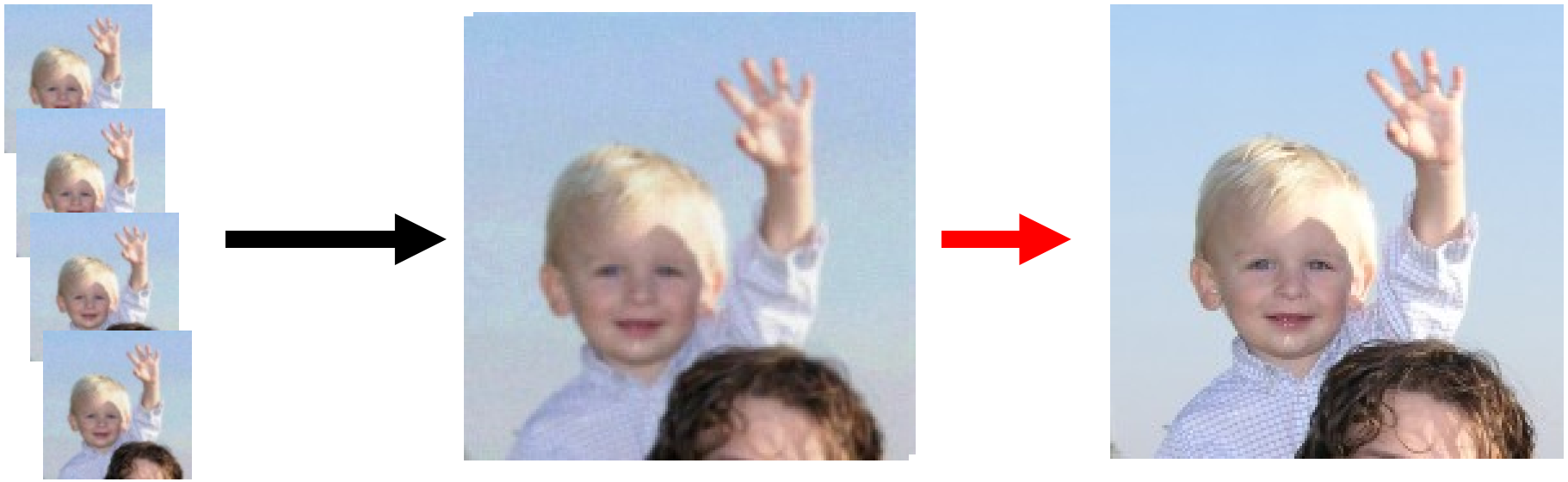


Traditional Superresolution



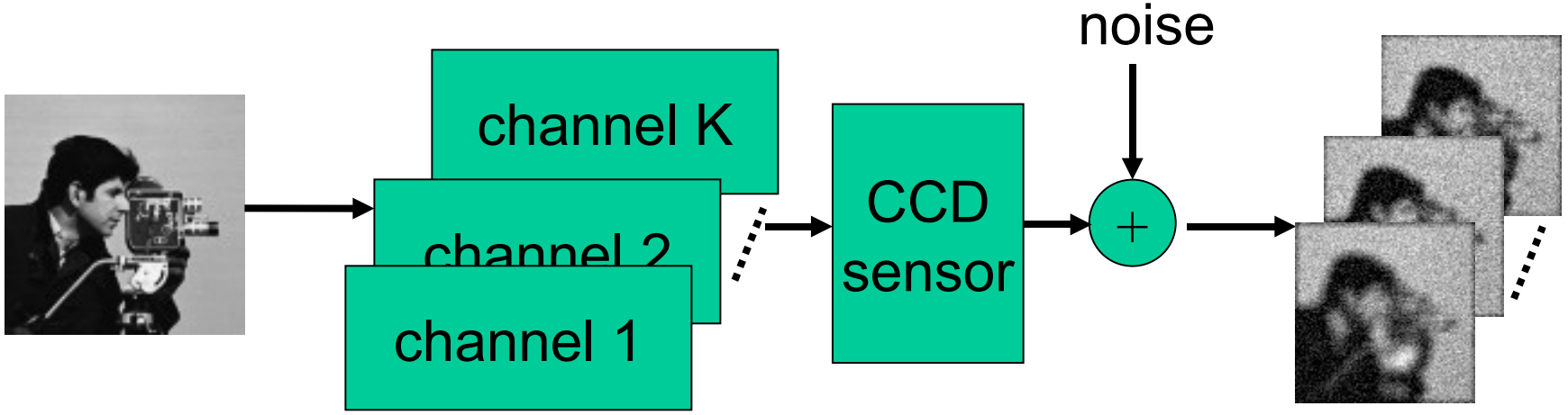
pixel interpolation
→ superresolution

Traditional Superresolution



deconvolution is important

Acquisition Model



original image

acquired images

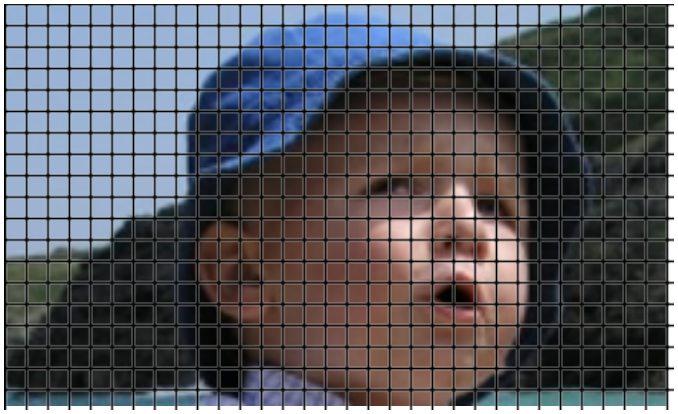
$$D\big([u * h_k](x, y)\big) + n_k(x, y) = z_k(x, y)$$

Decimation Operator D

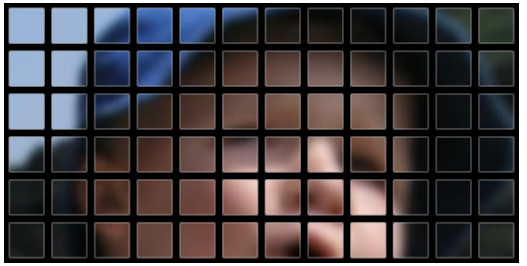
- Convolution with the sensor PSF
  - Modeling CCDs
- Registration
  - Adjusting sensor PSFs
- Downsampling
  - e.g. take every second pixel
- Masking
  - Eliminating erroneous pixels
    (e.g. registration is inaccurate or impossible)

Decimation Operator D

original HR image



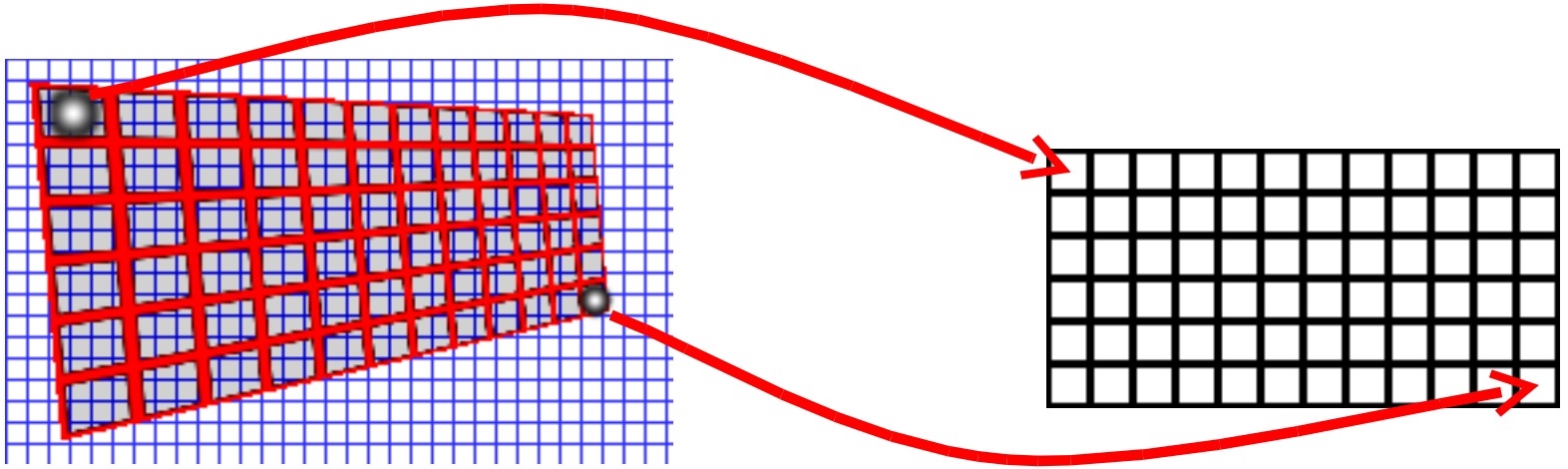
recorded LR image



Decimation Operator D

original HR image

recorded LR image



Volatile blurs h

- Compensates for misalignment

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

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

Sroubek et al., IEEE TIP 16(9), 2007

- Other methods:
  - Optimization with respect to registration parameters
  - Marginalization (eliminating registration parameters)

    Pickup et al., EURASIP Journal on App. Sig. Proc., 2007.

Blind superresolution

- System of integral equations

(ill-posed, underdetermined)

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

- Energy minimization problem (well-posed)

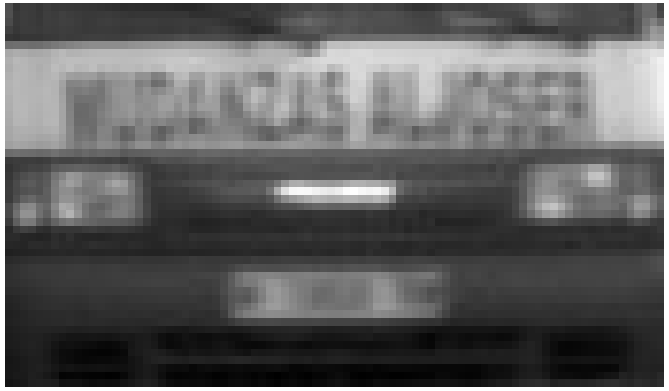
$$E(u, \{h_k\}) = \frac{1}{2} \sum_{k=1}^{K} \|D[h_i * u] - z_k\|^2 + \lambda Q(u) + \gamma R(\{h_k\})$$

AM algorithm

- Alternating minimizations of $E(u,\{h_k\})$
- Input: blurred LR images and estimation of PSF size
- Output: HR image and PSFs
- **Blind deconvolution in the SR framework**

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

Moving Car



Scaled LR input images

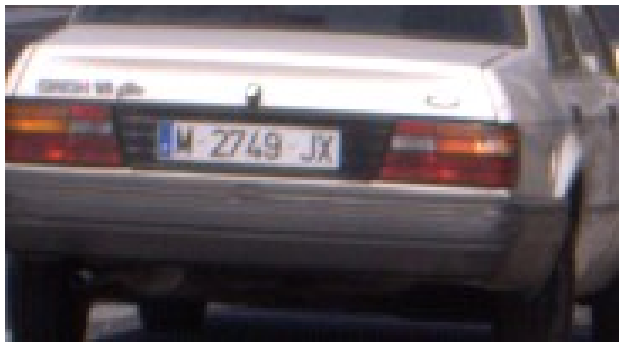
MBD+SR

PSFs

Still car & moving camera

rough registration

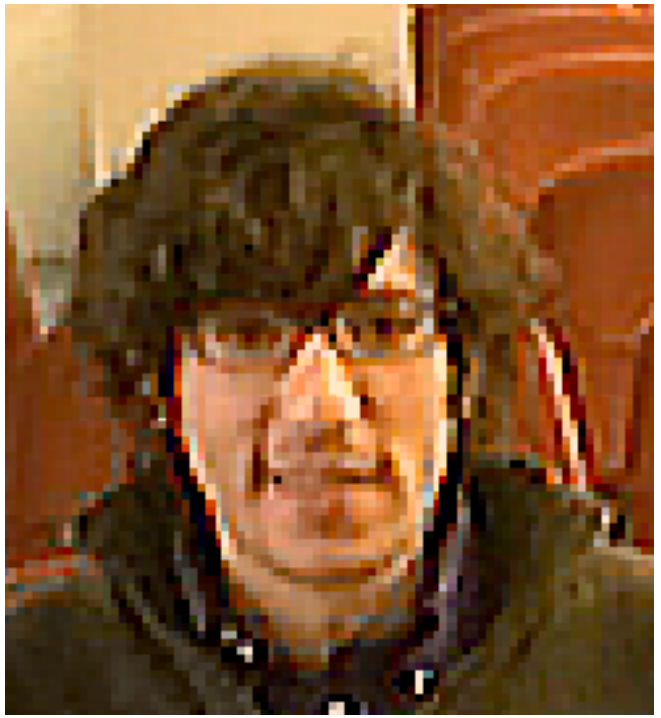
Superresolved image (2x)



Optical zoom (ground truth)

Webcamera Images

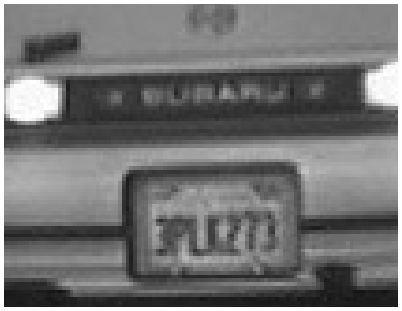
LR input frame

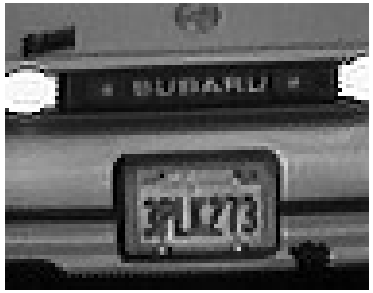


Superresolution image (2x)

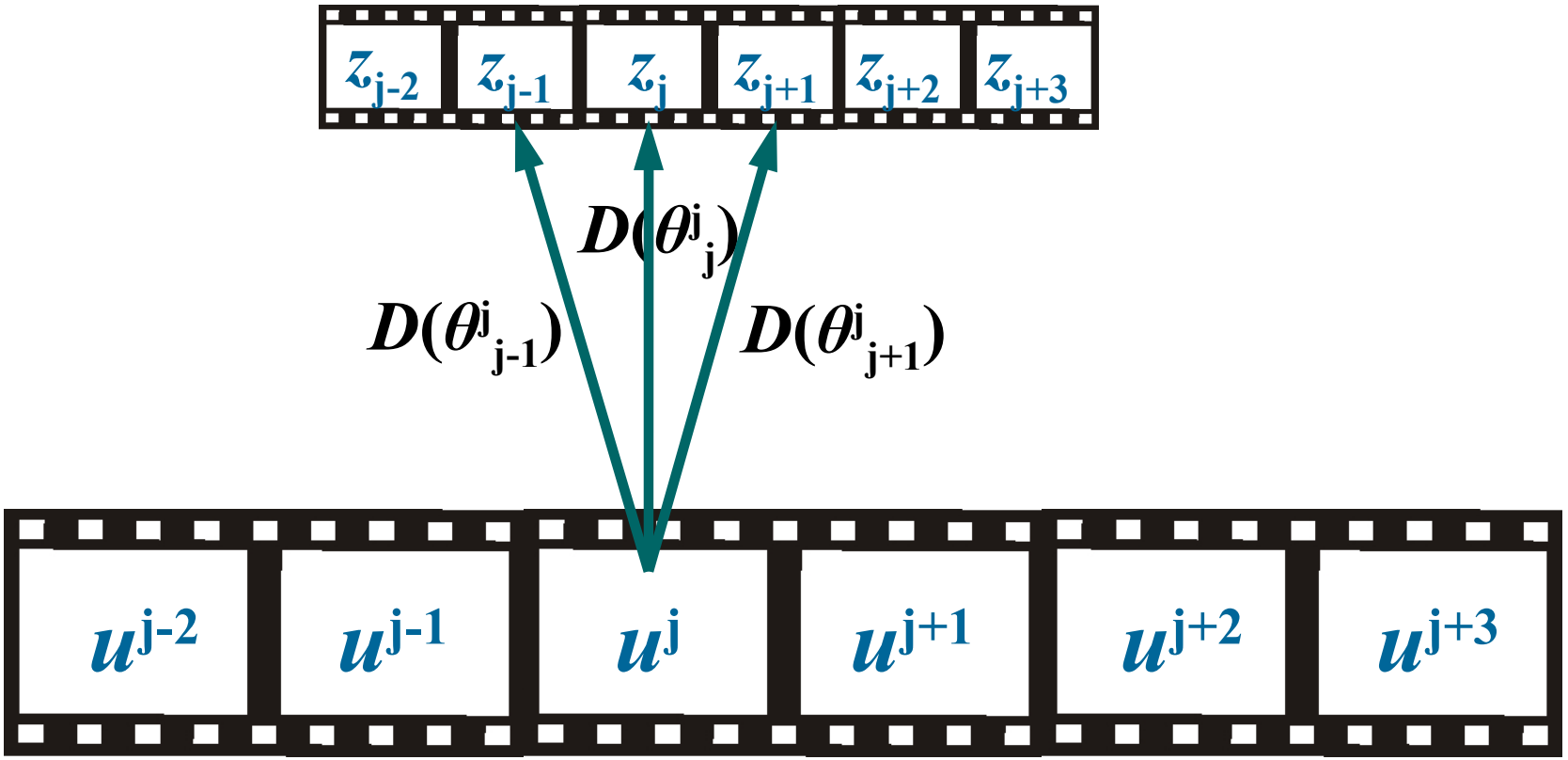
Payman Milanfar's data

http://www.soe.ucsc.edu/~milanfar/DataSets/

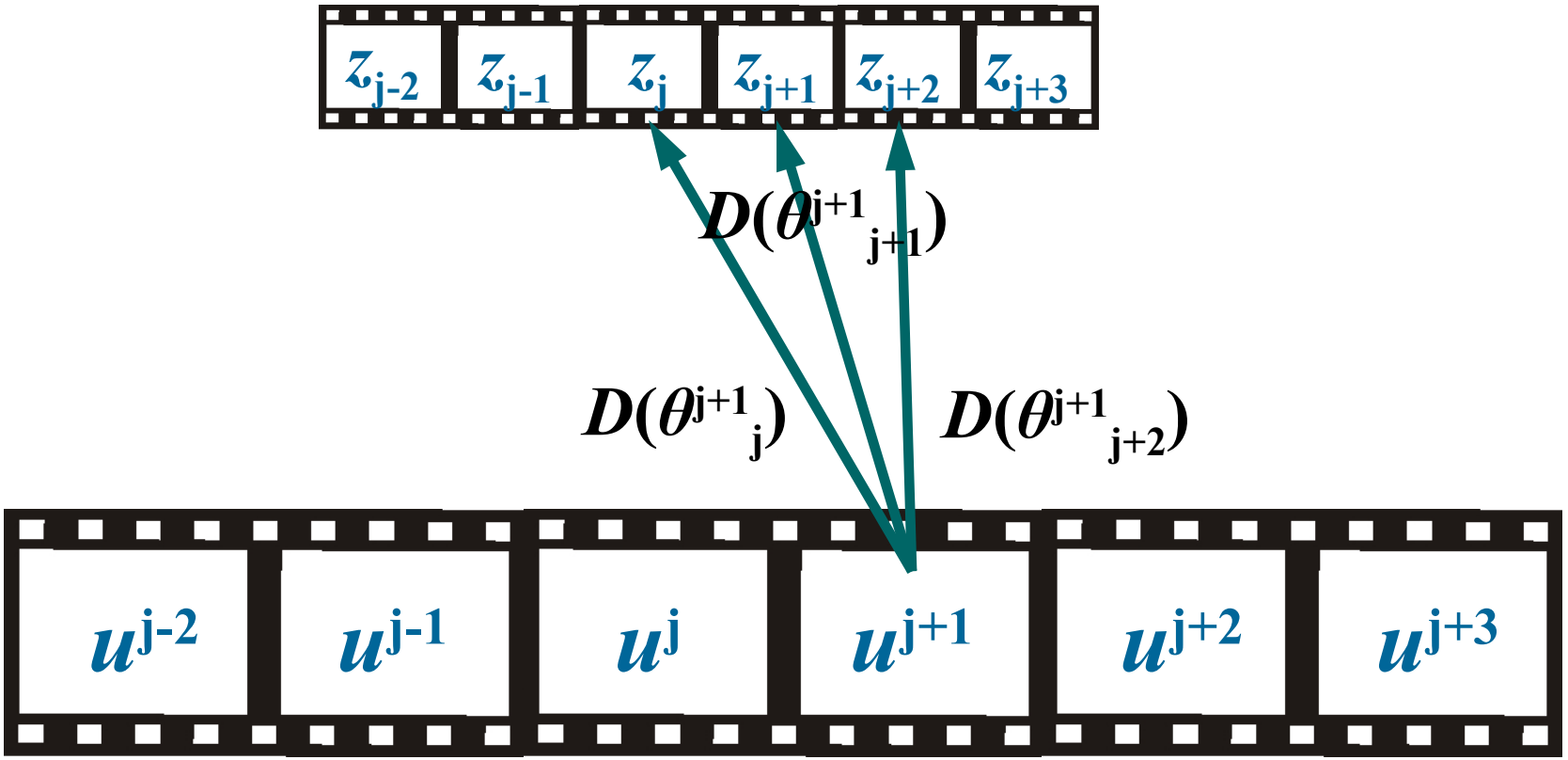




Superresolution of Video



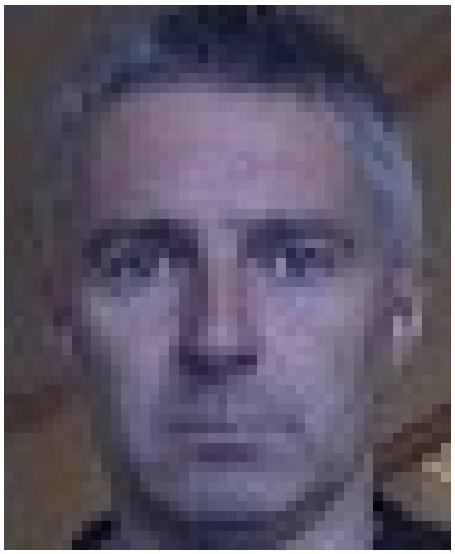
Superresolution of Video



Video Sequence

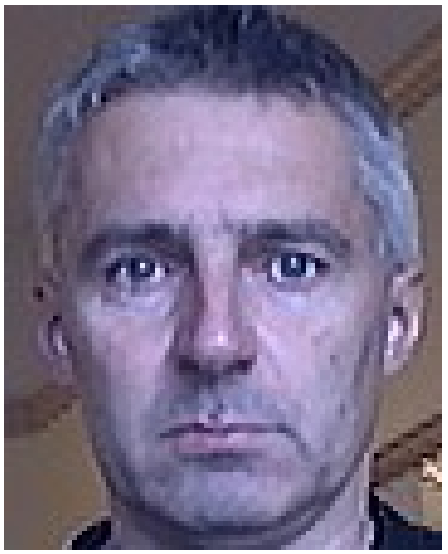
160x120, 30fps

Video Sequence



original

LR video



reconstructed

HR video

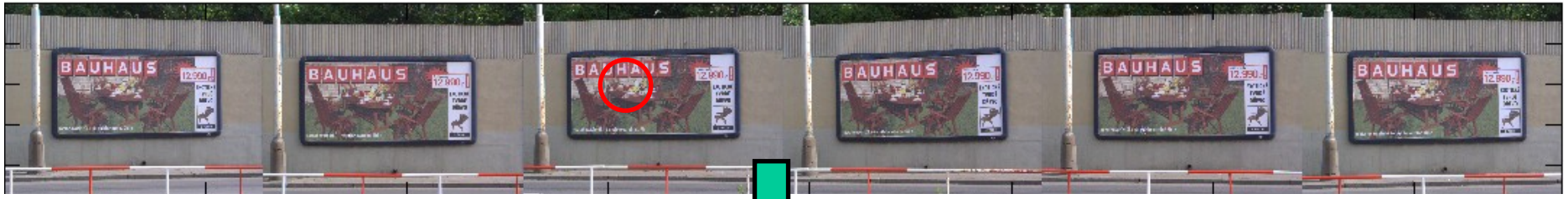
Video with local motion

interpolated

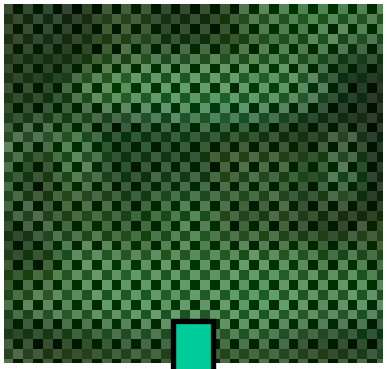
SR

SR + masking

SR limitations



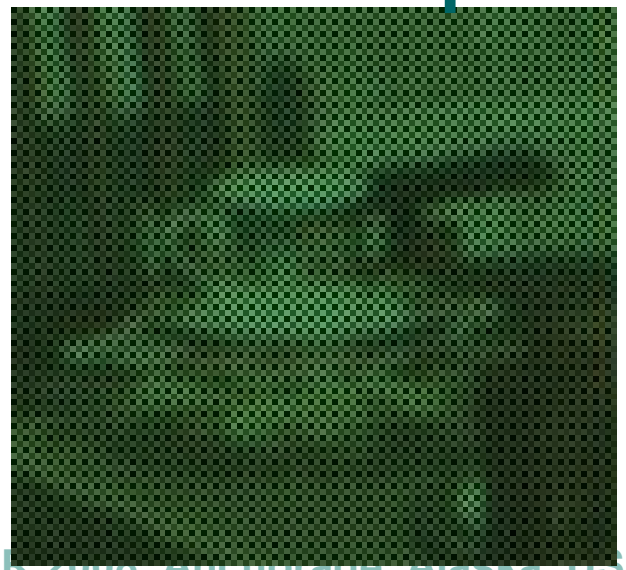
Color Filter Array (CFA)



CFA interp. input

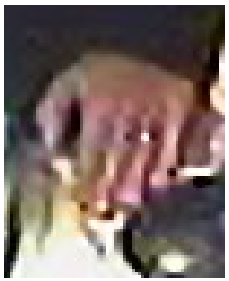
SR 1.5x

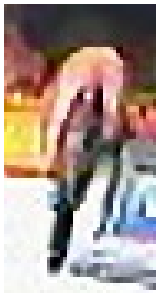
Raw CFA input



SR 3x

Challenges





- Slow frame rate
- Compression

Thank you

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