Fusion for Image Restoration

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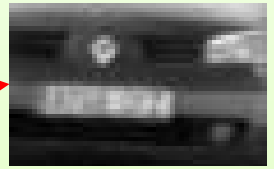
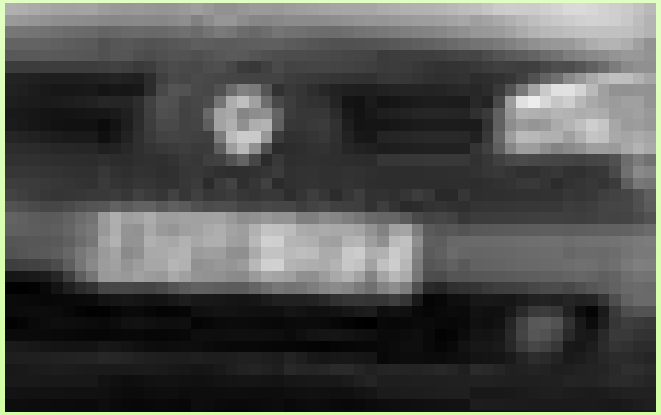
Traffic surveillance - can we read the license plates?



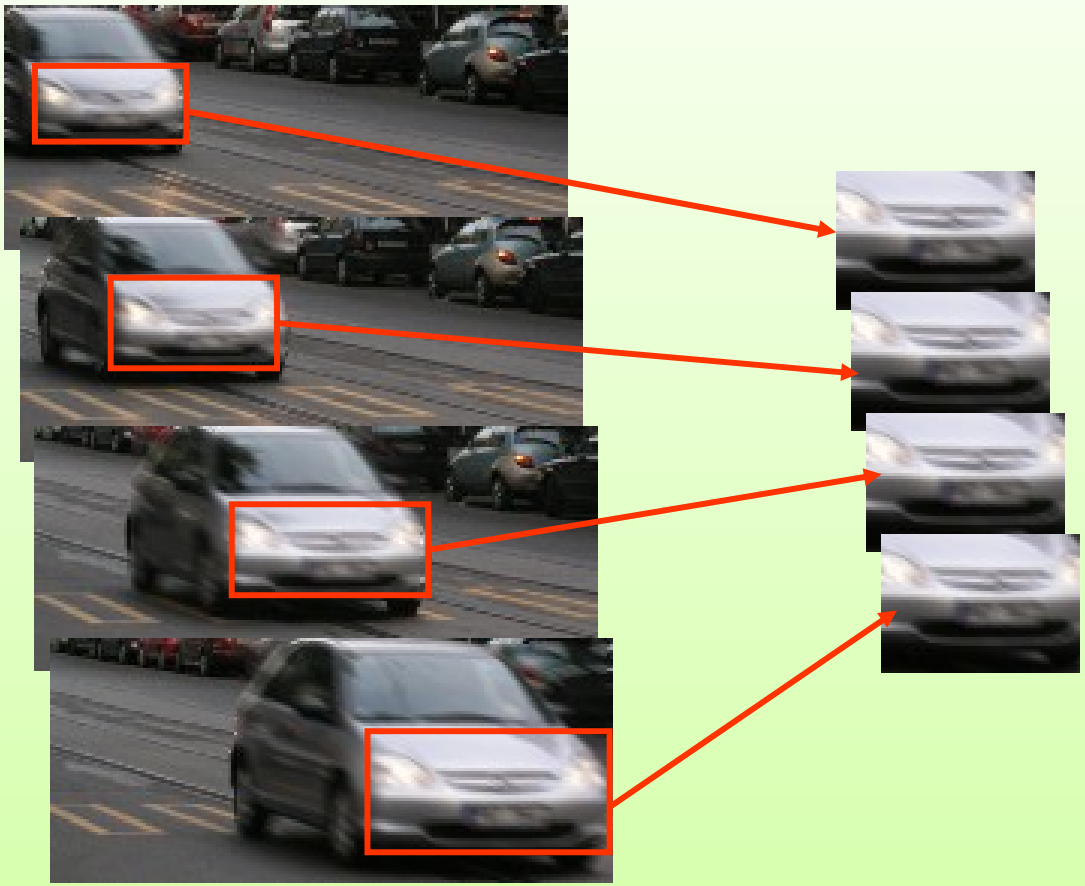


Empirical observation

- **One image is not enough**
  - ill-posed problem
- **Solution**
  - strong prior knowledge of blurs and/or the original image

  OR
  - more images
  - techniques how to combine them

Realistic multiframe imaging

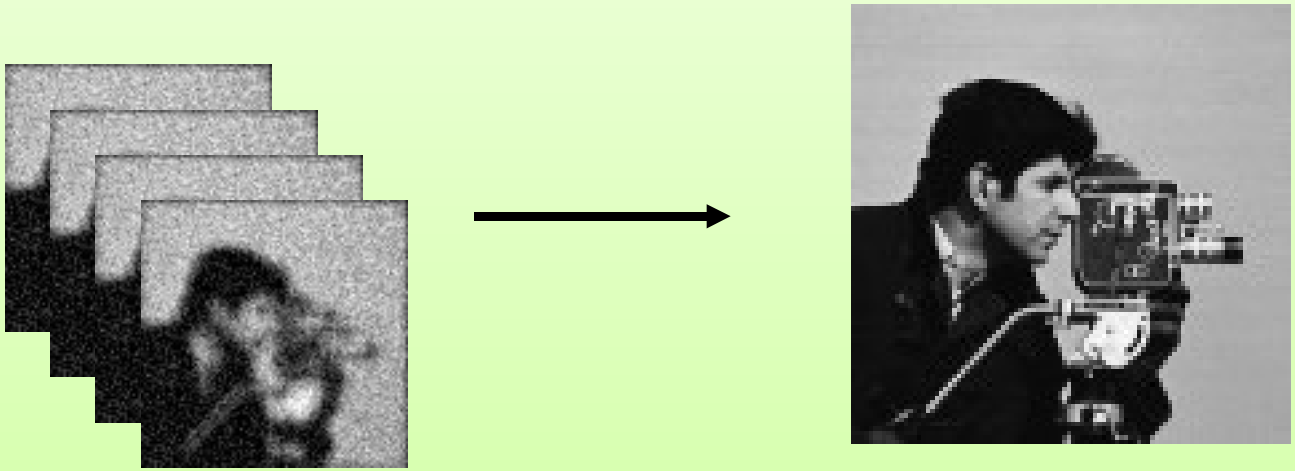


registration

image restoration

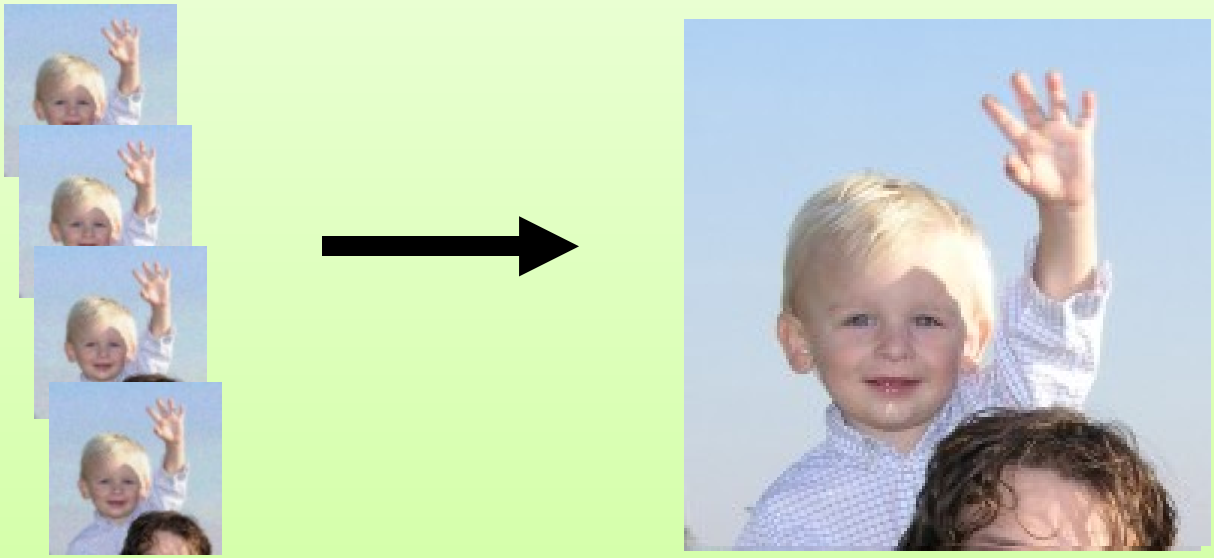
Superresolution

Goal: Obtaining a high-res image from several low-res images



Traditional superresolution

Method: interpolating LR images on a HR grid



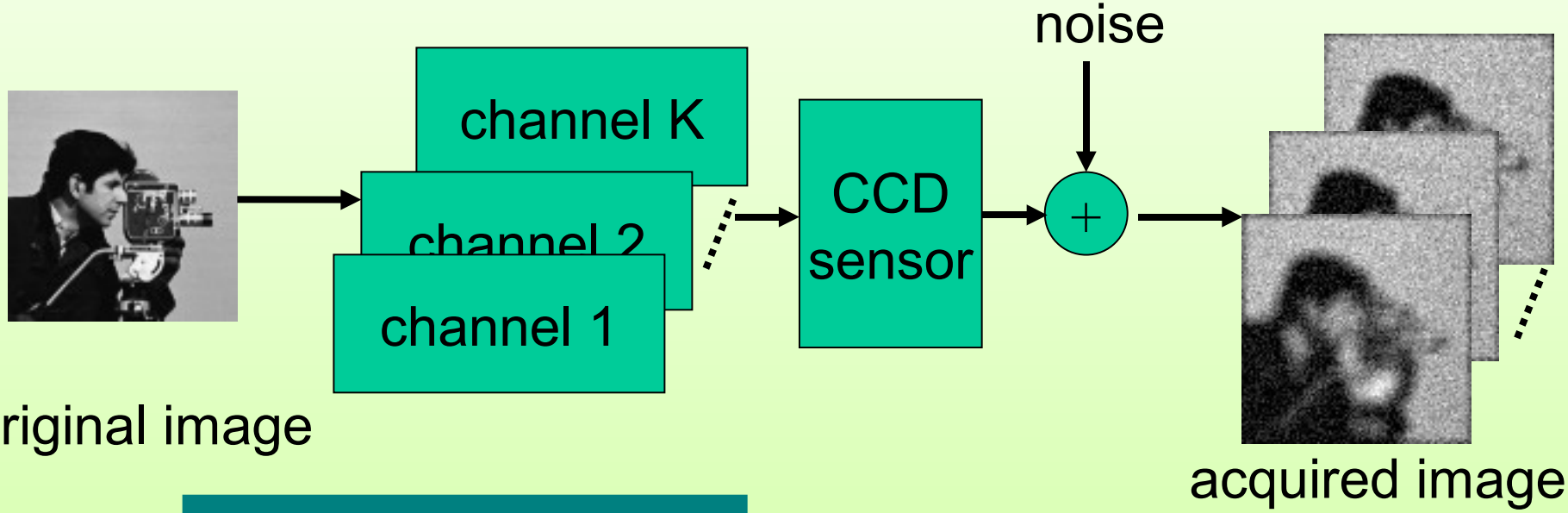
Fusion for image restoration

- Idea: Each image consists of “true” part and “degradation”, which can be removed by fusion

- Types of degradation:
  - additive noise: image denoising
  - blurring: blind deconvolution
  - resolution decimation: superresolution

Sroubek, Cristobal, Flusser, IEEE TIP, Sep 2007

Realistic acquisition model



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

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)

Misregistration

- Optimization with respect to registration parameters
- Marginalization (eliminating registration parameters)

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

- Incorporating between-image shift

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

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

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)

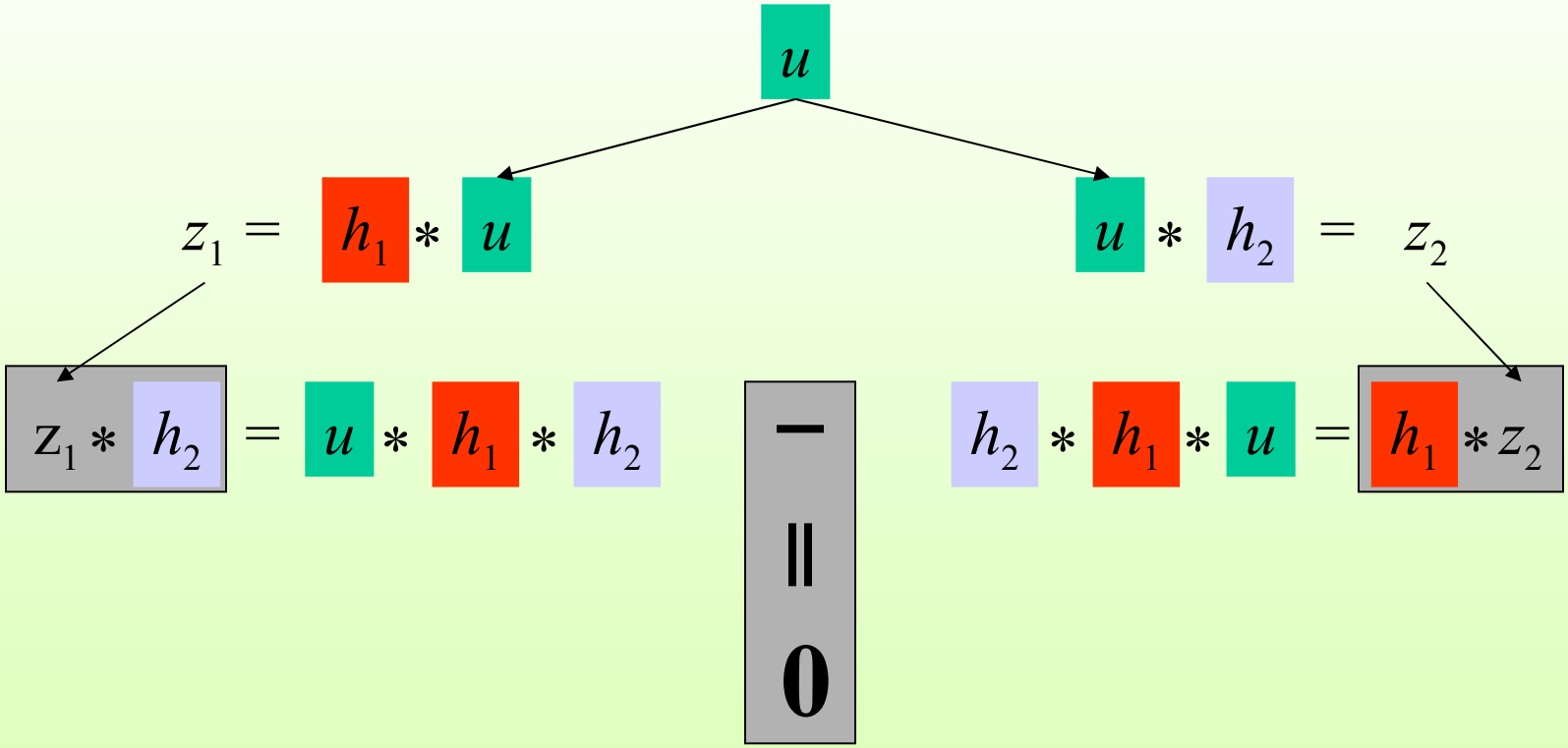
$$E(u, \{h_k\}) = \frac{1}{2} \sum_{k=1}^{K} \|D[h_i * u] - z_k\| + \lambda Q(u) + \gamma R(\{h_k\})$$

Image Regularization

- $Q(u)$ captures local characteristics of the image => Markov Random Fields

- Identity: $\int_\Omega |u|^2$
- Tichonov (GMRF): $\int_\Omega |\nabla u|^2$
- Variational integral: $\int_\Omega \phi(|\nabla u|)$
- Huber MRF, bilateral filters, …

PSF Regularization



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

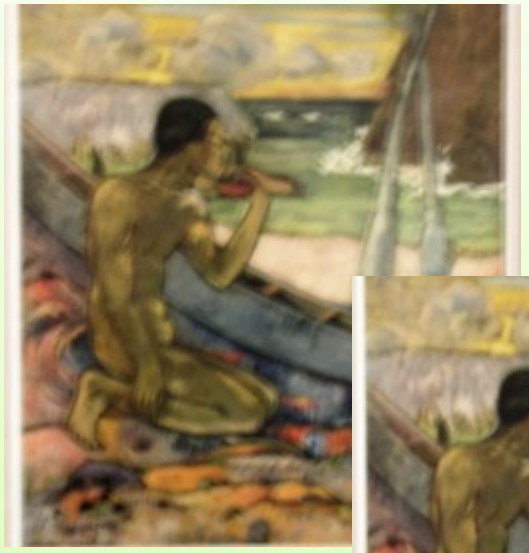
with one additional constraint $0 \le h_i(x) \le 1, \quad \forall x, i$

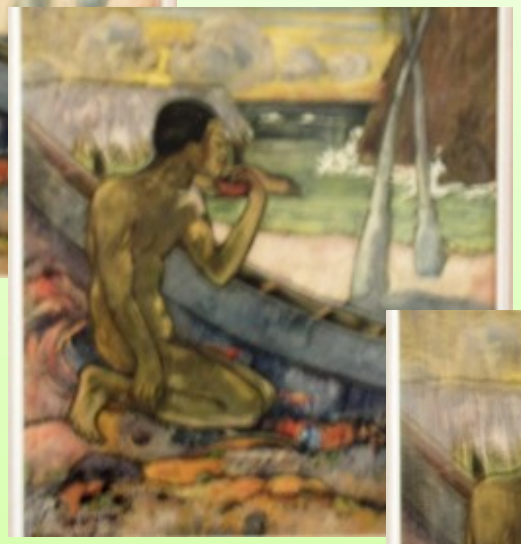
AM algorithm

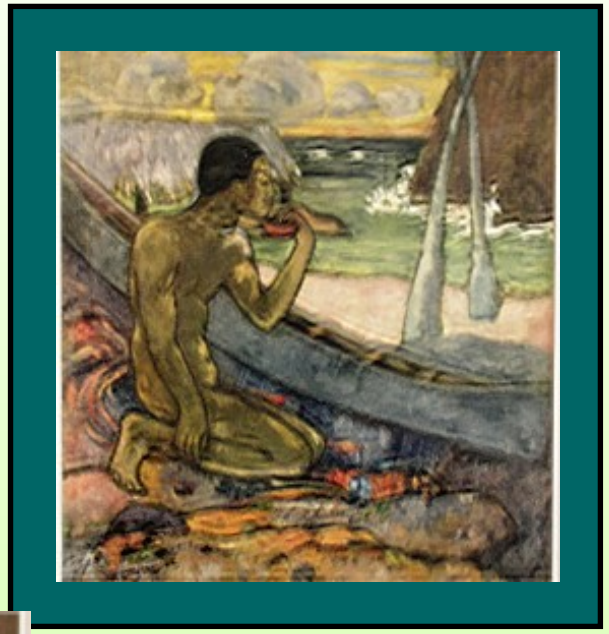
- Alternating minimizations of $E(u,\{h_k\})$
- Input: blurred LR images and estimation of PSF size
- Output: HR image and PSFs
- **Blind deconvolution in the SR framework**

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

Taking pictures in a museum

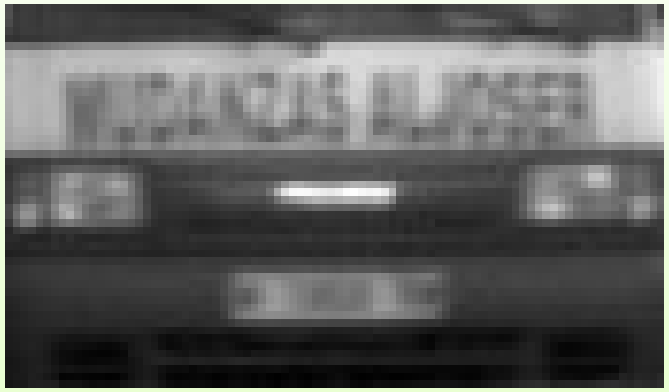






Long-time exposure

Moving car



Scaled LR input images

MBD+SR

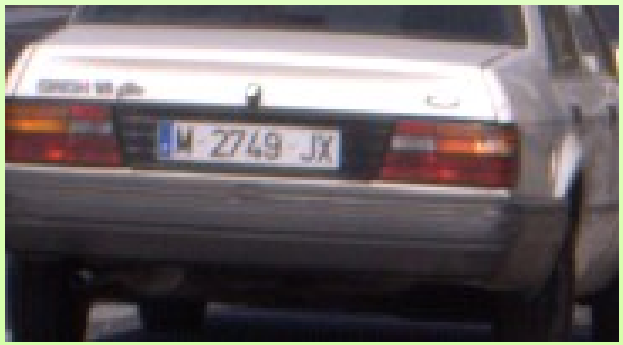
PSFs

Reprinted from Sroubek, *et al.*, IEEE TIP, Sep 2007.

Still car & moving camera

rough registration

Superresolved image (2x)

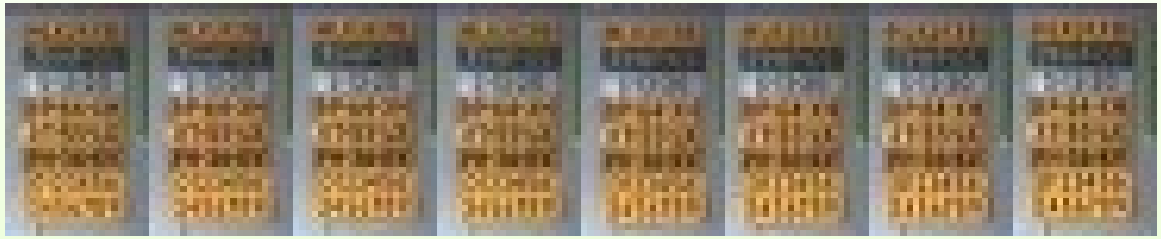


Optical zoom (ground truth)

Reprinted from Sroubek, *et al.*, IEEE TIP, Sep 2007.

Superresolution with High Factor

Input LR frames



interpolated

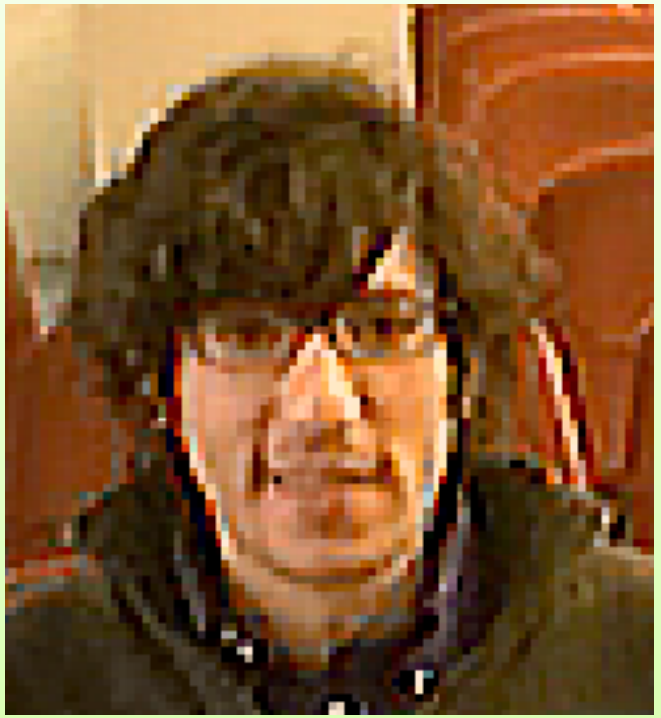
SR

Original frame

Reprinted from Sroubek, *et al.*, IEEE TIP, Sep 2007.

Webcam images

LR input frame



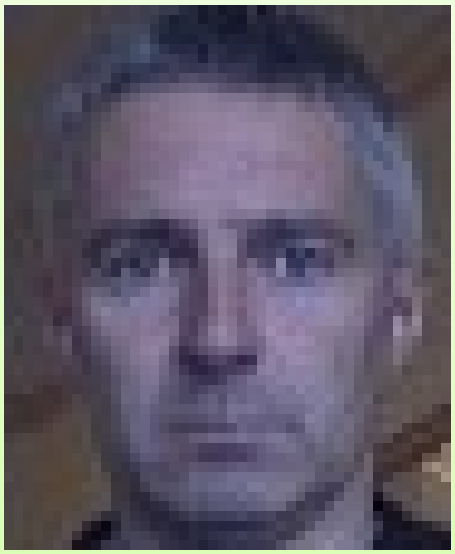
Superresolution image (2x)

Reprinted from Sroubek *et al.*, "Imaging for Detection and Identification", NATO Advance Study Institute, 2006

Video sequence

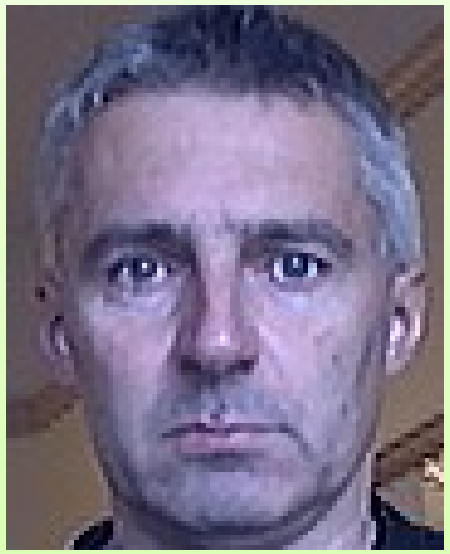
160x120, 30fps

Video sequence



original

LR video



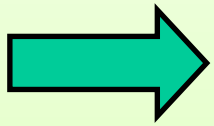
reconstructed

HR video

Challenges

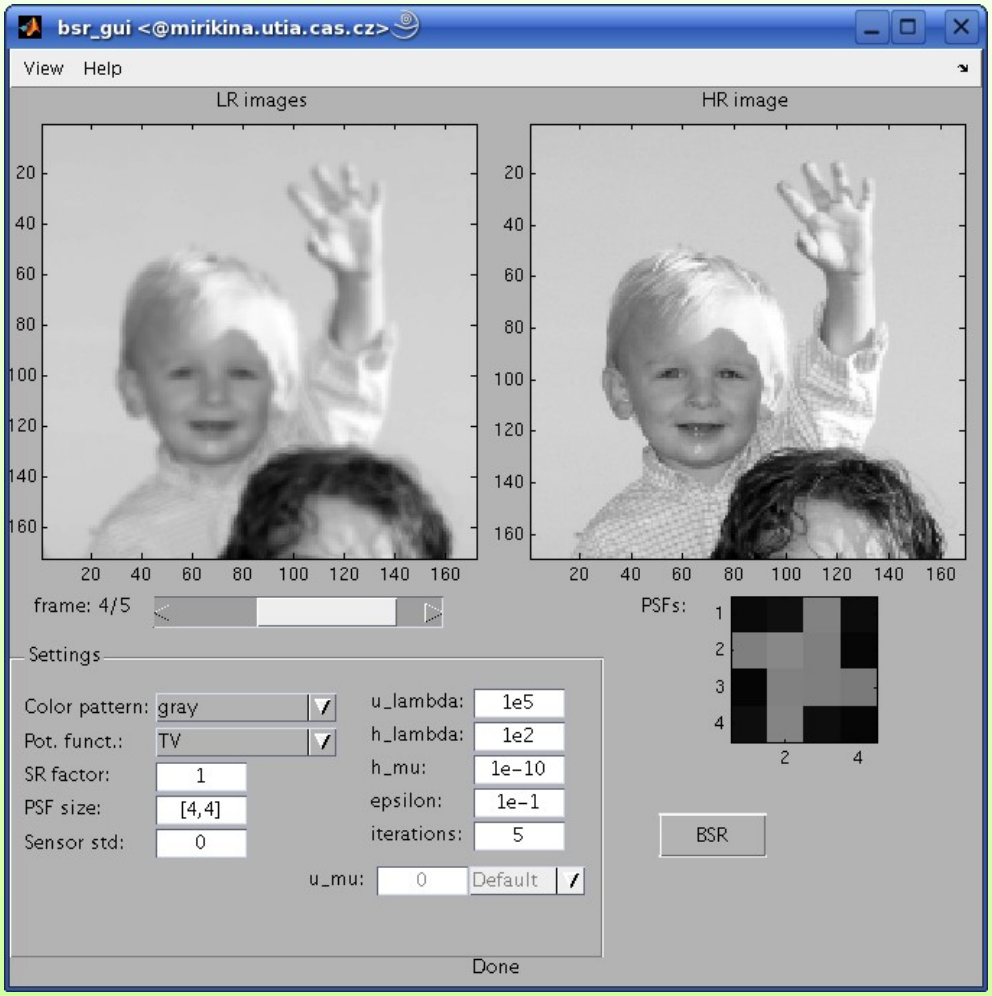
Challenges

- 3D scene
- objects having different motion
- improving registration



- space-variant deblurring
- motion field
- minimization over registration param.

Matlab GUI


bsr_gui <@mirikina.utia.cas.cz>
View Help
LR images
HR image
frame: 4/5
PSFs:
Settings
Color pattern: gray
Pot. funct.: TV
SR factor: 1
PSF size: [4,4]
Sensor std: 0
u_lambda: 1e5
h_lambda: 1e2
h_mu: 1e-10
epsilon: 1e-1
iterations: 5
u_mu: 0 Default
BSR
Done

Any questions ?

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