flusser@utia.cas.cz

www.utia.cas.cz/people/flusser

Prof. Ing. Jan Flusser, DrSc.

Dekonvoluce obrazu

Metody a využití

Convolution in image processing

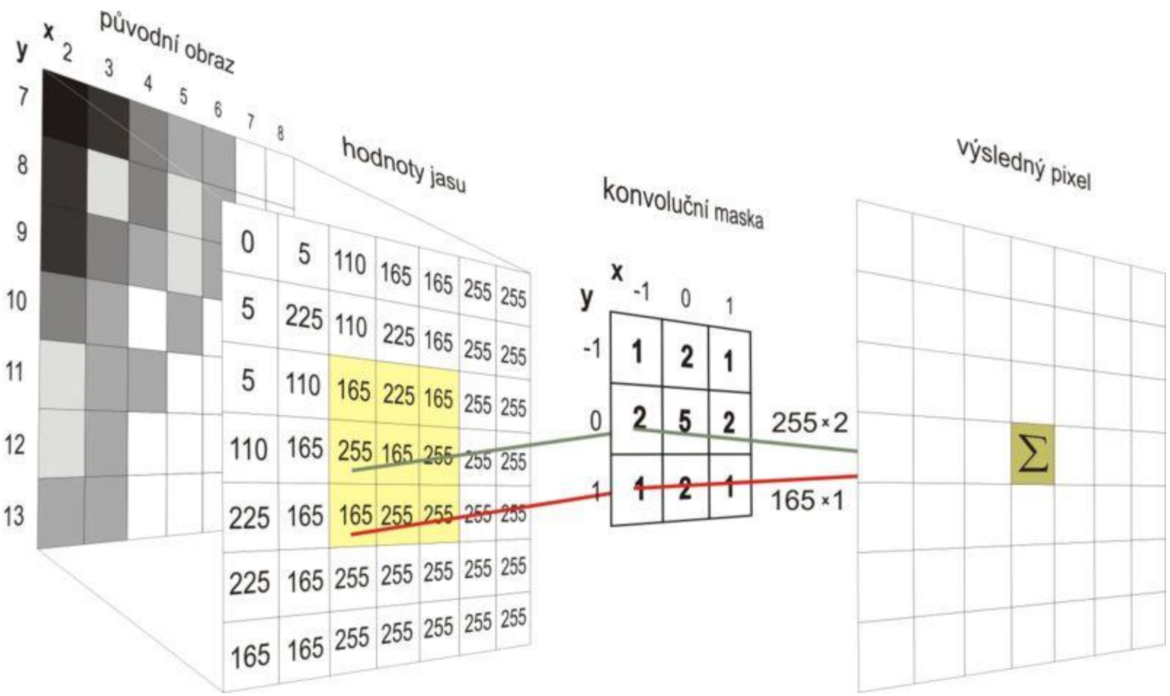


Image formation model

original *u(x)*

acquired blurred image *z(x)*

$$z(x) = (h * u)(x) + n(x)$$

h(x,y) is a PSF of the camera

Typical blur sources

Camera shake/motion
Object motion
Wrong focus
Diffraction
Atmospheric turbulence

An inverse problem

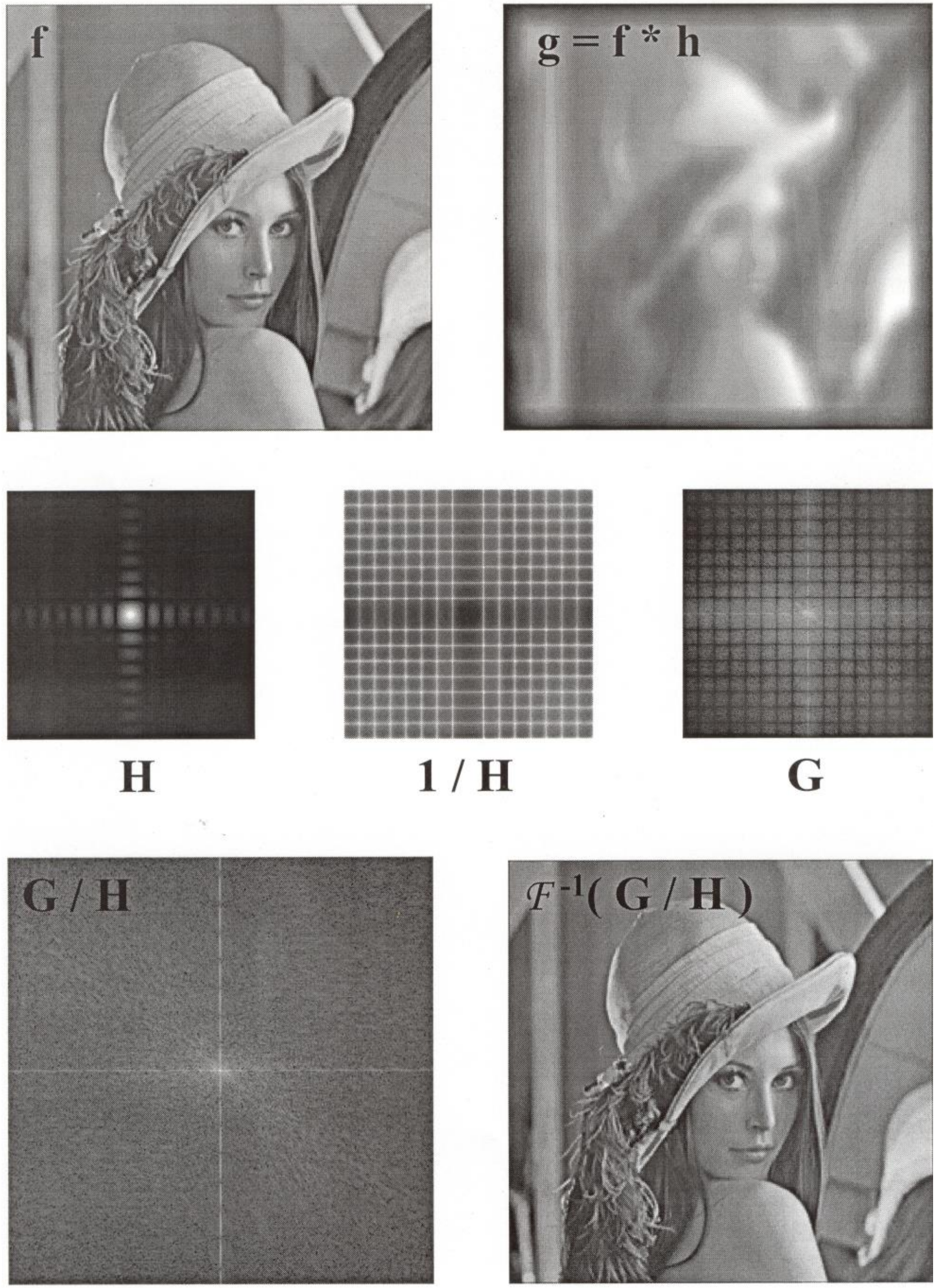
How to get from
the acquired image

back to (or close to)
the original?

Intuitive solution to the inverse problem

- No noise, PSF known – Fourier transform

$$G = F \cdot H$$

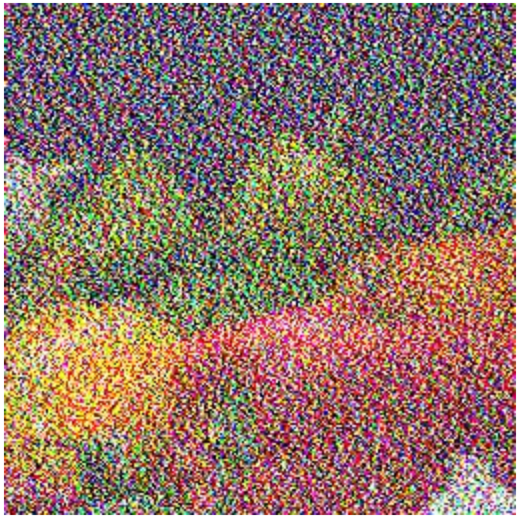

f
g = f * h
H
1 / H
G
G / H
ℱ⁻¹(G / H)

Intuitive solution to the inverse problem

... does not work on real images

$$G = F \cdot H + N$$

$$F = \frac{G}{H} - \frac{N}{H}$$



Blind deconvolution

$$z(x) = (h * u)(x) + n(x)$$

- an ill-posed problem

Multichannel deconvolution

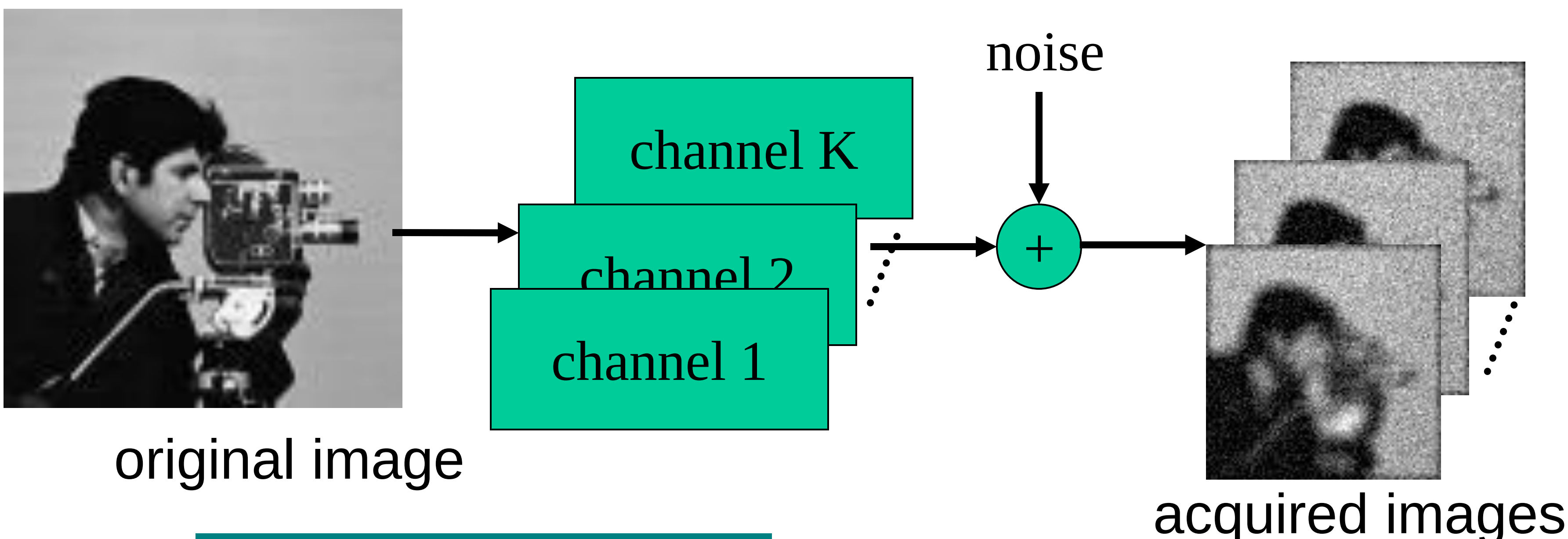
Assumptions:

Several input images of the same scene are available

They are blurred by convolution with different convolution kernels

The original scene does not change during the acquisitions

Multichannel acquisition model



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

Multichannel Blind Deconvolution

- System of integral equations

  (ill-posed, underdetermined)

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

- Energy minimization problem (well-posed)

$$E(u, \{h_i\}) = \frac{1}{2} \sum_{i=1}^{K} \|h_i * u - z_i\|^2 + \lambda Q(u) + \gamma R(\{h_i\})$$

Regularization terms

$$E(u,\{h_i\}) = \frac{1}{2}\sum_{i=1}^{K}\|h_i * u - z_i\|^2 + \lambda Q(u) + \gamma R(\{h_i\})$$

$$Q(u) = \int_{\Omega} \phi(|\nabla u|)$$

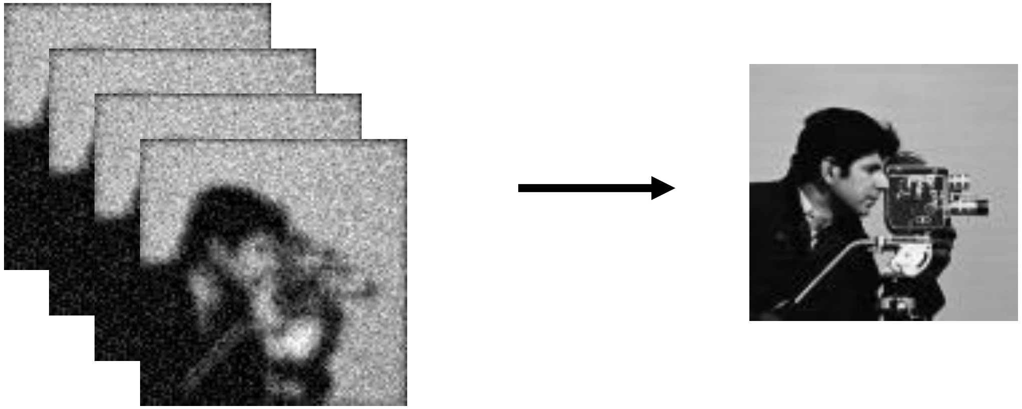
$$R(\{h_i\}) = \frac{1}{2}\sum_{1\le i,j\le K}\|z_i * h_j - z_j * h_i\|^2$$

Alternating Minimization (AM) of *E*

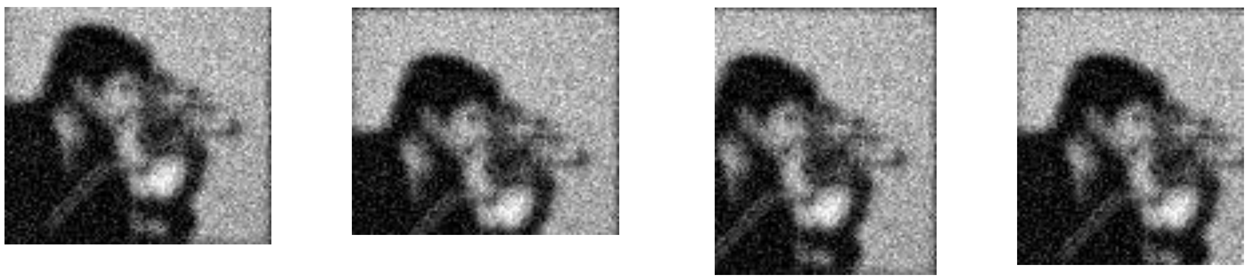
AM of $E(u,\{h_i\})$ over u and h_i

Input: Blurred images and estimation of the PSF size

Output: Reconstructed image and the PSF's

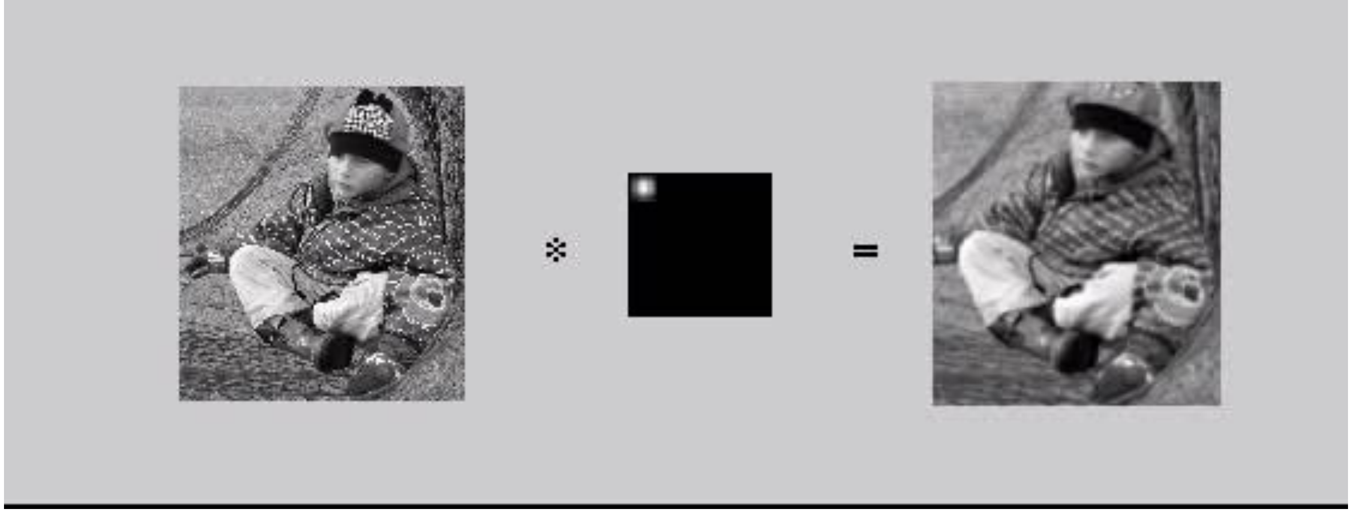


Misregistration of the channels



... leads to artefacts if not handled properly

Handling a between-image shift



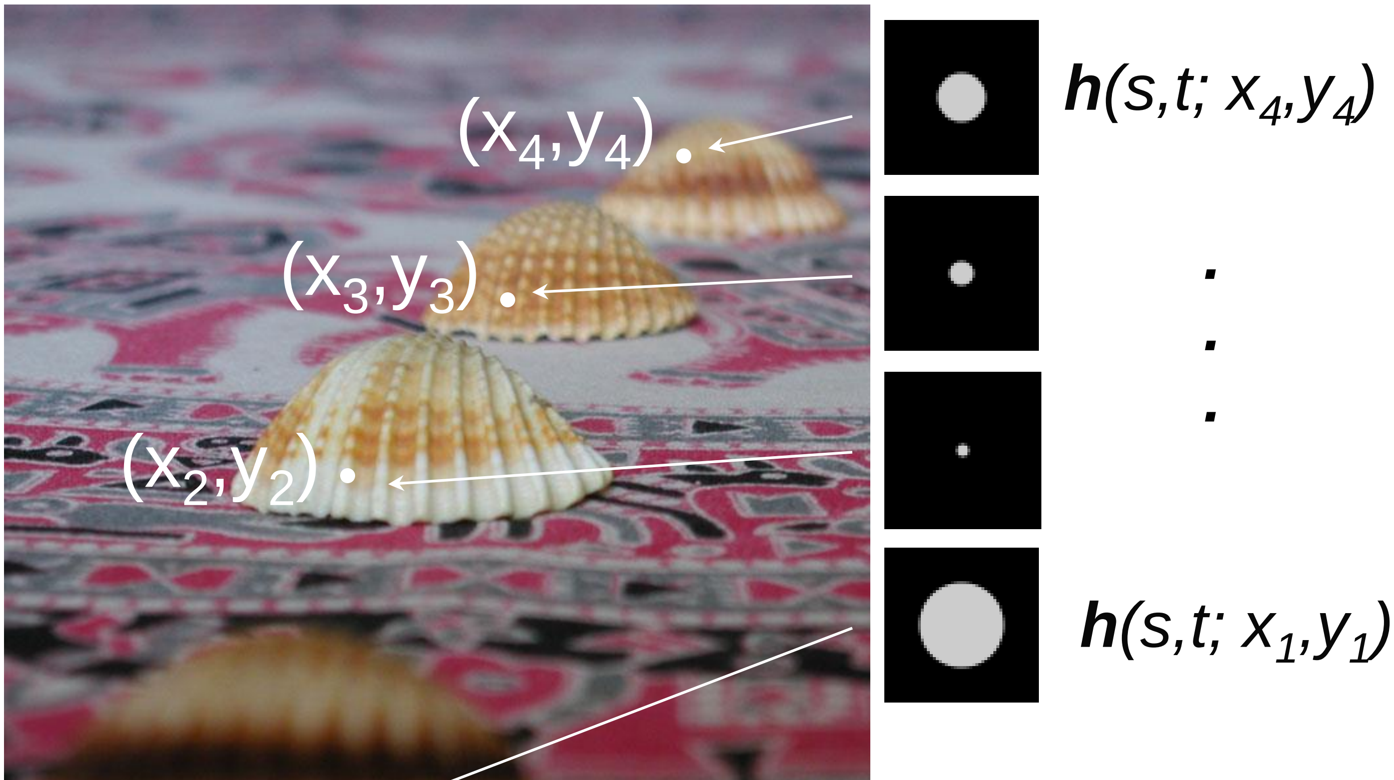
original image PSF degraded image

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

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

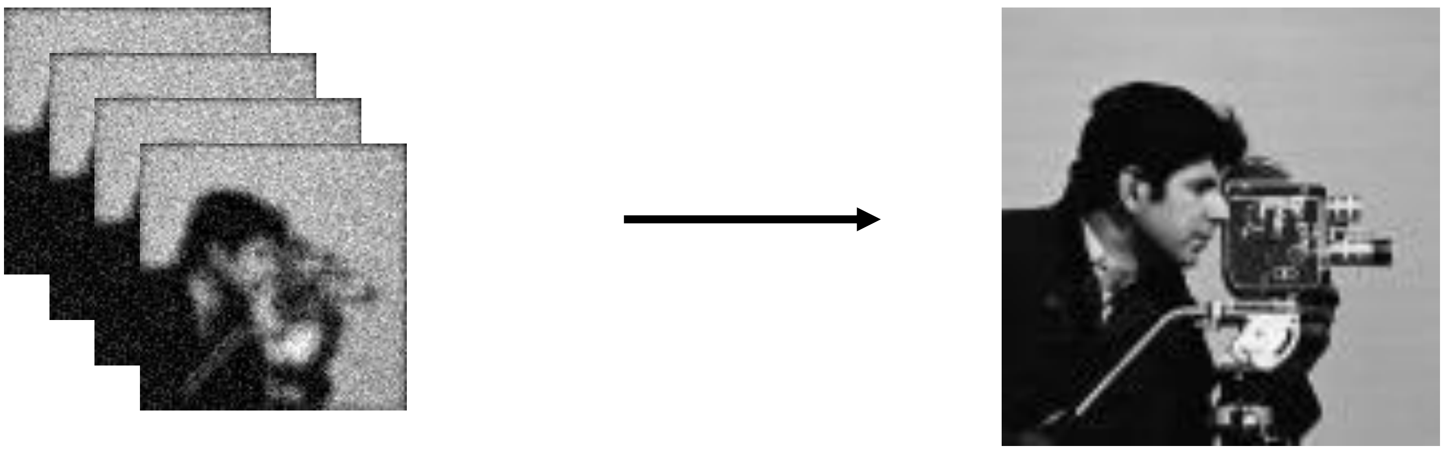
Long-time exposure I

Space-variant PSF



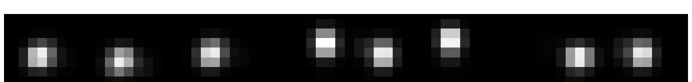
$$\mathbf{z}(x,y) = \int_{\Omega} \mathbf{u}(x-s, y-t)\mathbf{h}(s,t; x-s, y-t)\, ds dt + \mathbf{n}(x,y)$$

Deconvolution and superresolution



$$E(u,\{g_i\}) = \frac{1}{2}\sum_{i=1}^{K} \|D(g_i * u) - z_i\|^2 + \lambda Q(u) + \gamma R(\{g_i\})$$

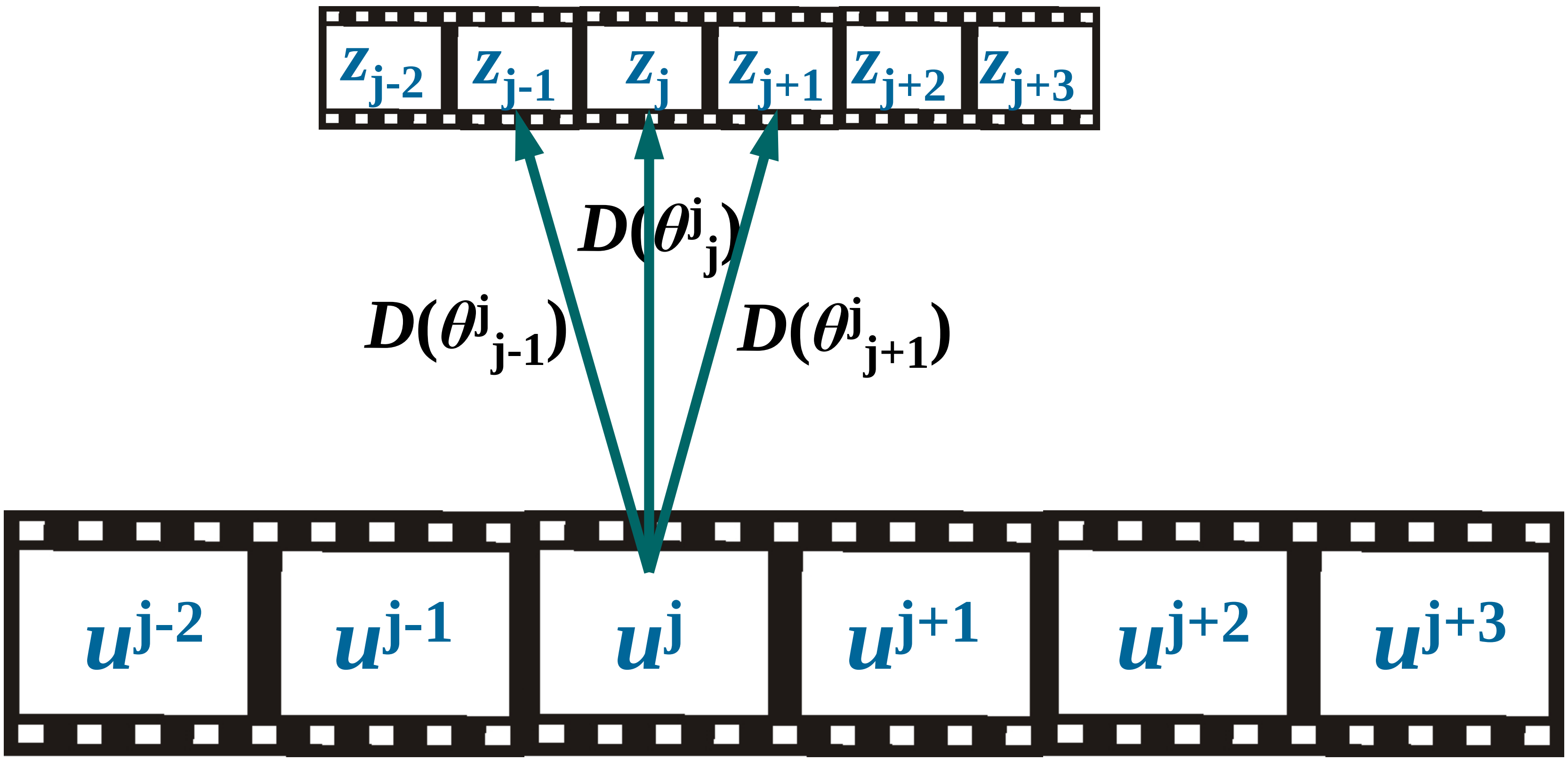
Superresolution



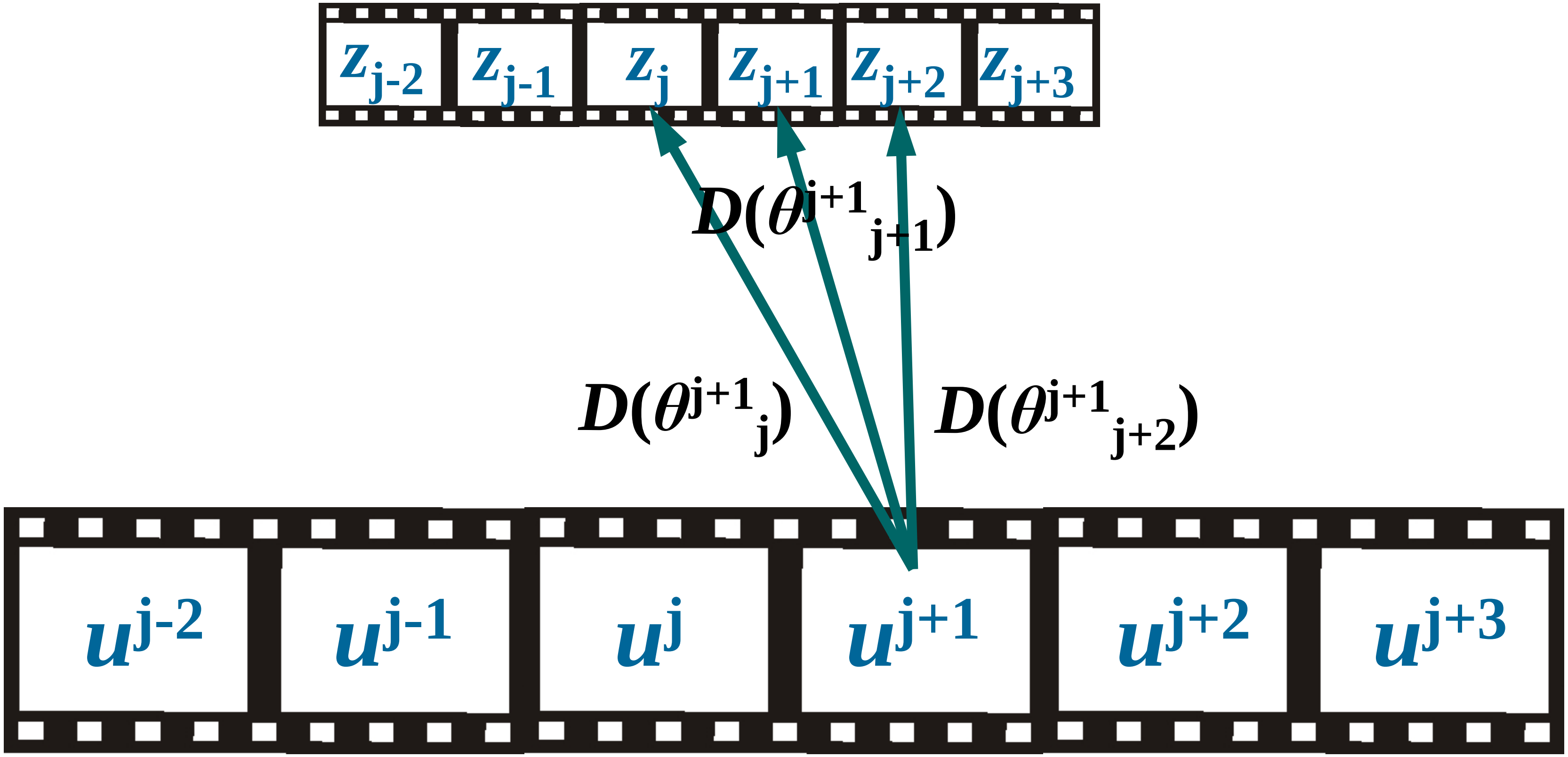
optical zoom (ground truth)

SR image (2x)

Superresolution of a video



Superresolution of Video



The challenge: Embedded applications

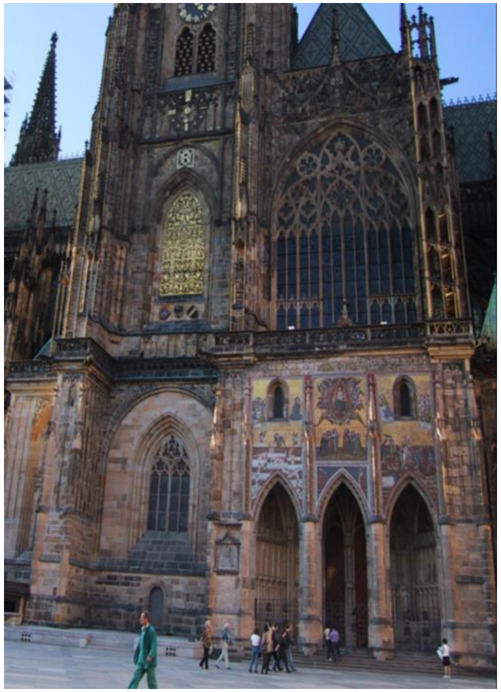
Requirements:

- On-chip implementation,
  no off-line computer processing

- Real-time (almost) performance

Cell-phone images

Primary degradation is a camera-shake blur, secondary degradation is wrong focus



PSF estimation in smartphones

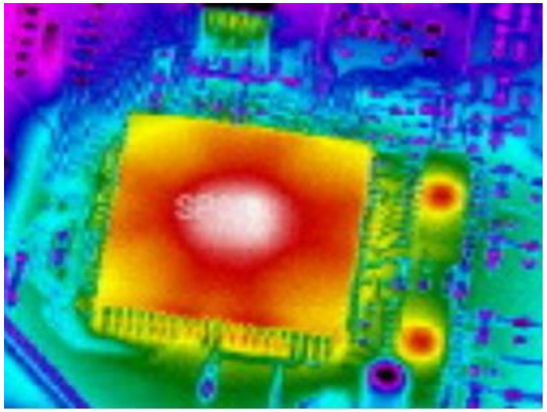
Using accelerometers and/or gyroscopes

Rotation and translation of the phone

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 on a DSP

It’s time for questions …