flusser@utia.cas.cz

Prof. Ing. Jan Flusser, DrSc.

Digitální zpracování obrazu

Lecture 4

Potlačení šumu v obraze

- **Modely šumu**
- **Lineární filtrace**
- **Nelineární metody**

Image noise

Apparent in low-light scenes taken at high ISO and/or long exposure

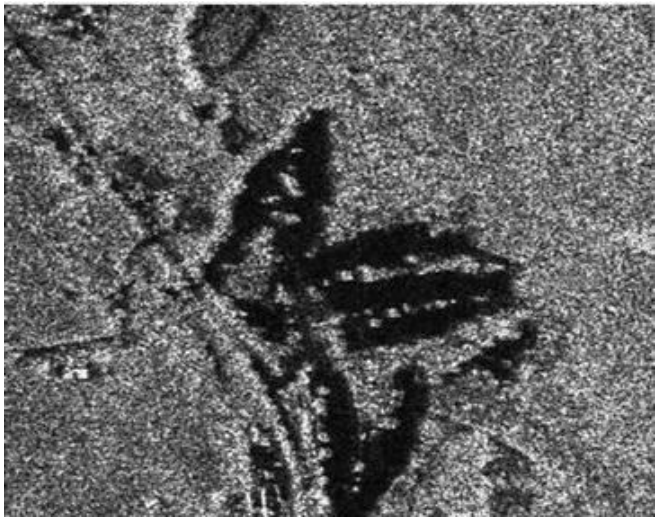
Noise sources

- Background electronic and thermal noise (additive Gaussian)
- Shot noise (photon noise) – Poisson, approx. multiplicative Gaussian
- Random errors of A/D converter, transmission errors (impulse noise)
- Wavefront interference noise (speckle noise)

Gaussian

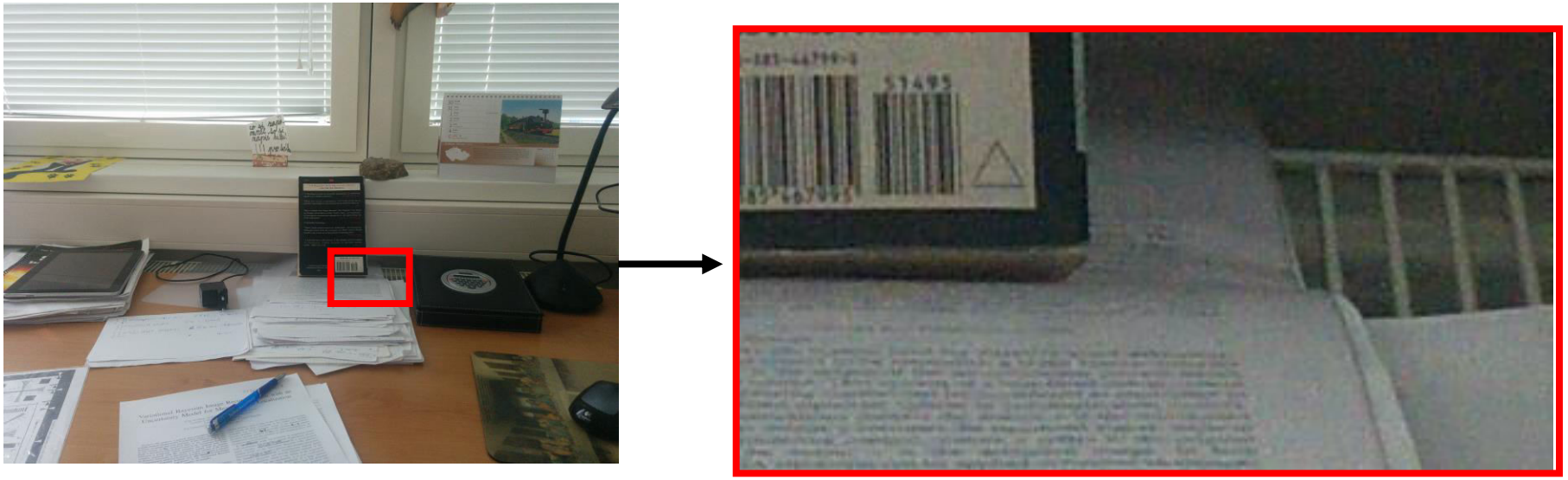
Impulse

Poisson

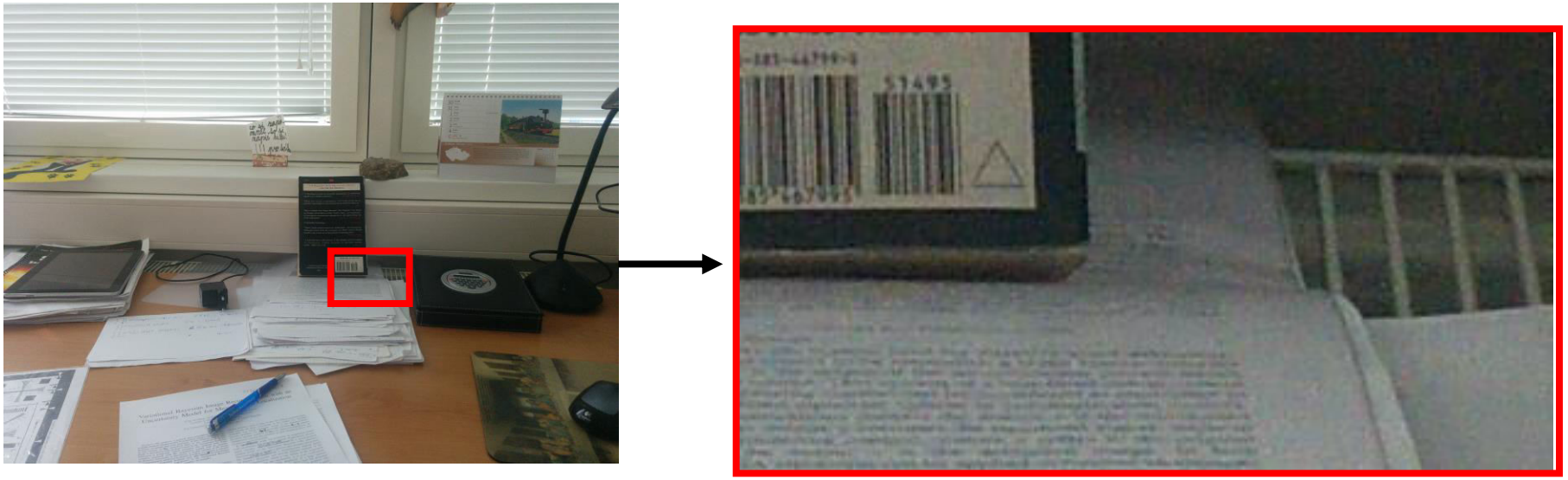


Speckle noise in satellite radar image

Real camera compound noise



Real camera compound noise



Noise models

Non-specific or compound noise is mostly modelled as an additive, signal-independent white Gaussian noise (AWGN)

$$g = \mathcal{D}(f) + n$$

Modely šumu

- **Aditivní náhodný šum**

$$g = f + n$$

- **Gaussovský bílý šum (AGWN)**

- **Impulsní šum (sůl a pepř)**

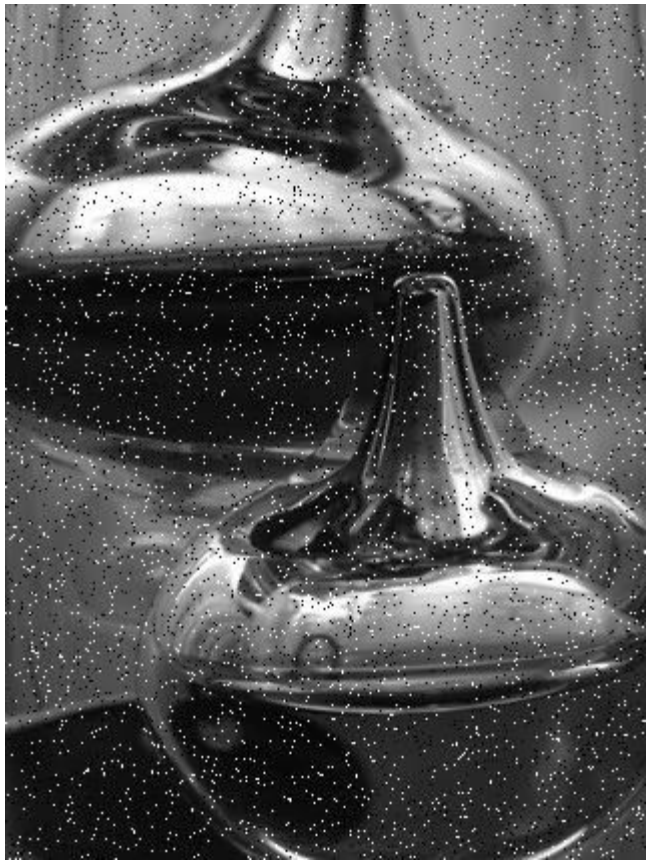
Modely šumu

- **Gaussovský bílý šum (AGWN)**
  - **frekvence ?**
  - **korelovanost ?**

Modely šumu

- **Impulsní šum (sůl a pepř)**

- **P(f) = 1- *K***
- **P(1)= *K/2***
- **P(0)=*K/2***



Míra šumu v obraze

- **Rozptyl**

- **Signal-to-noise ratio (SNR)**

$$SNR = 10 \log (D(f)/D(n)) \qquad [dB]$$

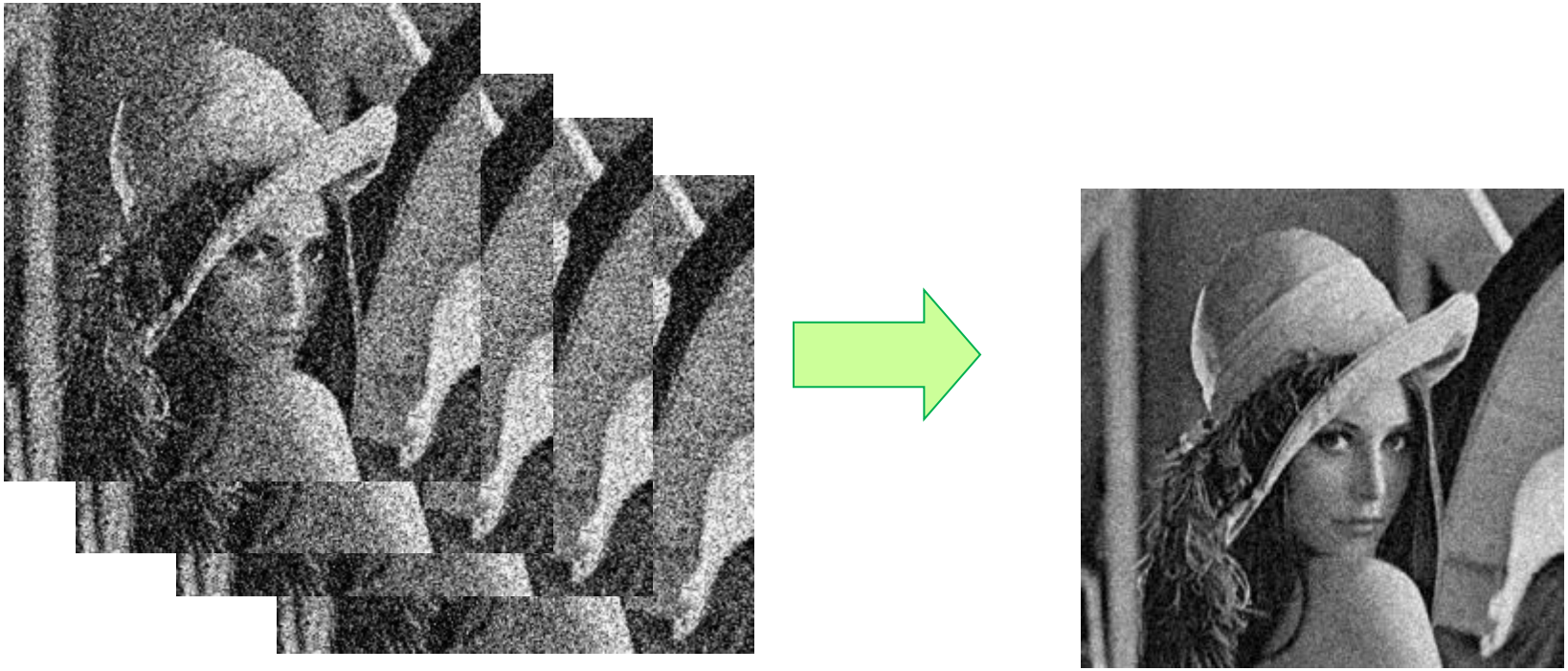
Gaussovský bílý šum

20 dB

10 dB

0 dB

Průměrování v čase



Průměrování v čase

4 8

šum

16 32 64

Průměrování v čase

$g_1, \cdots, g_N$ – nezávislá pozorování

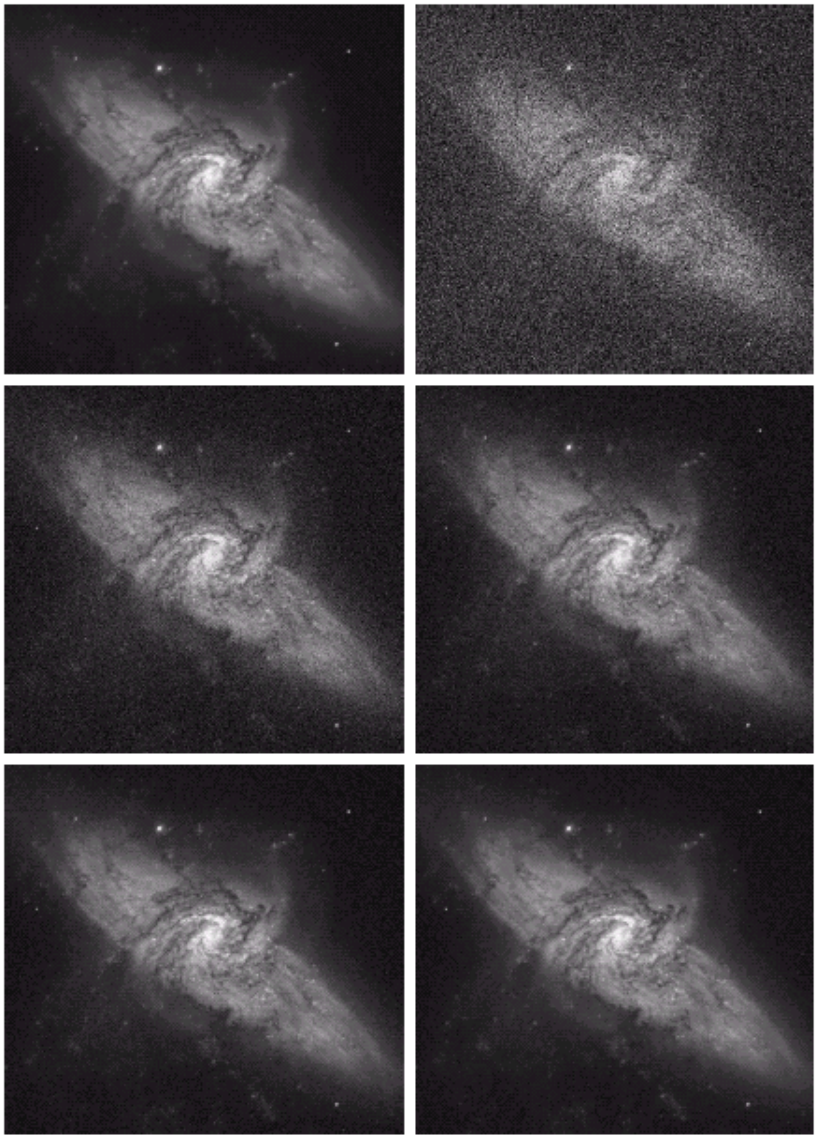
$$g_k = f + n_k$$

$$n_k \sim p(0, \sigma^2)$$

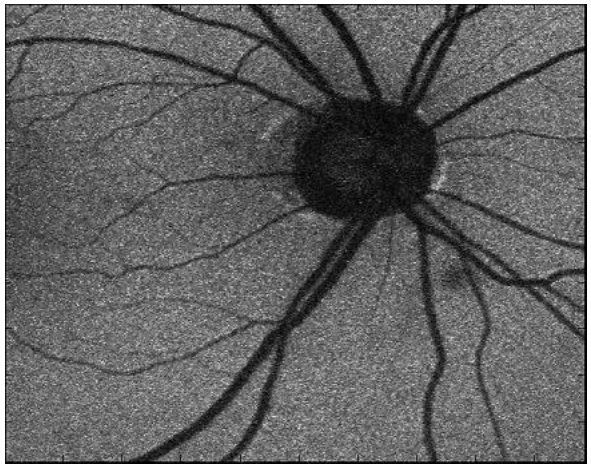
$$g = \frac{1}{N} \sum_{k=1}^{N} g_k = f + n$$

$$n \sim p(0, \sigma^2/N)$$

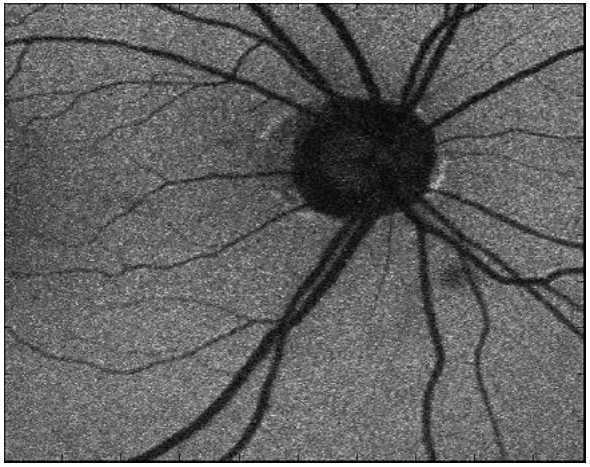
Průměrování v čase



Průměrování v čase

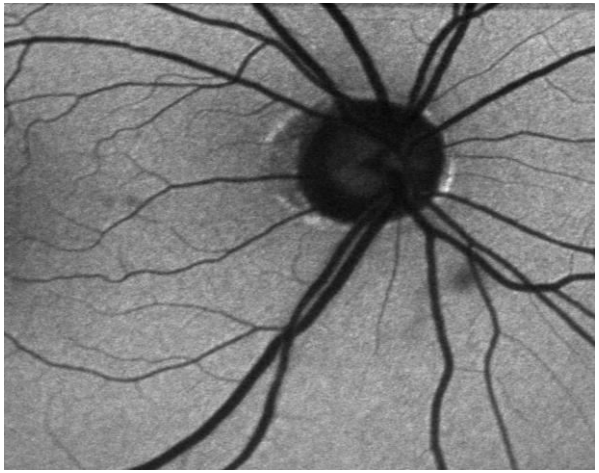


Before registration



After registration

Averaging



Konvoluční filtry

- **Průměrování (prosté a vážené)**
- **Průměrování podél hran**
- **Rotující okno**
- **Filtry ve frekvenční oblasti**

Průměrování v obraze

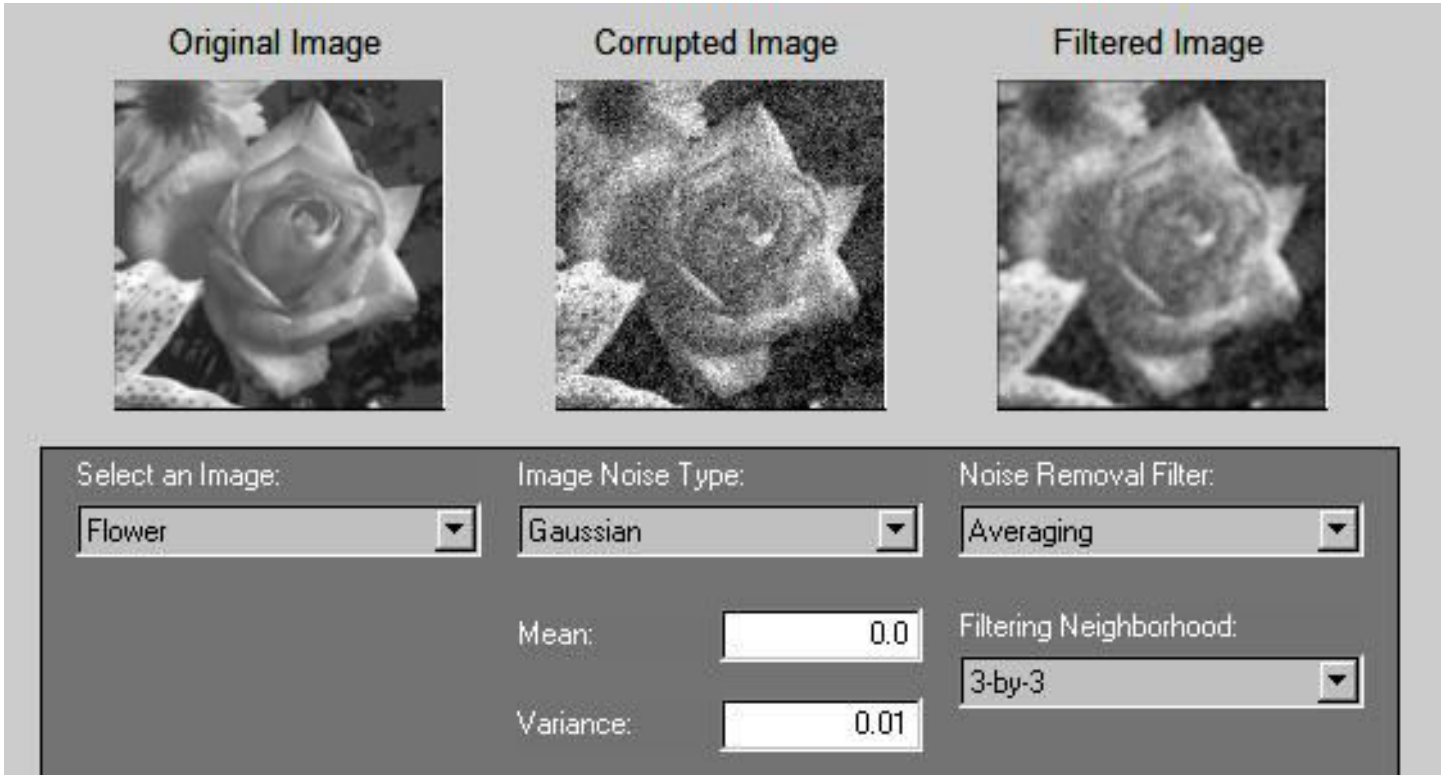
šum

3x3

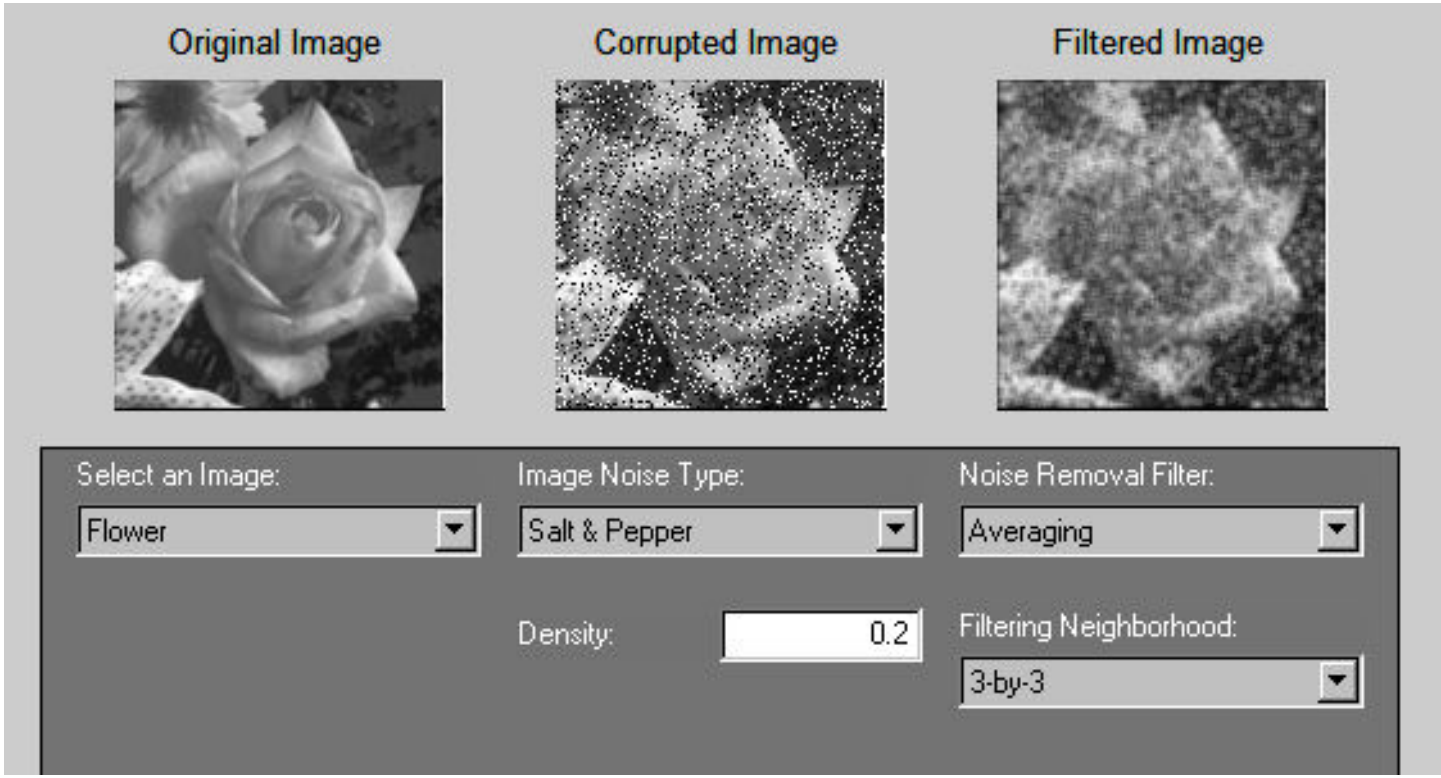
5x5

7x7

Průměrování v obraze

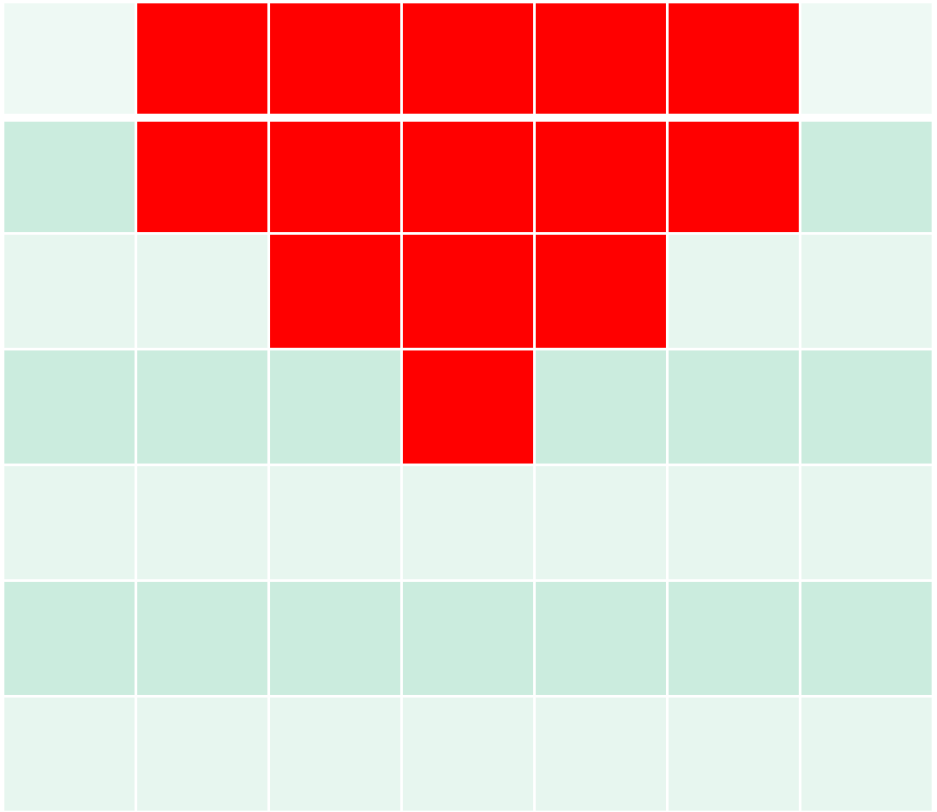


Průměrování v obraze



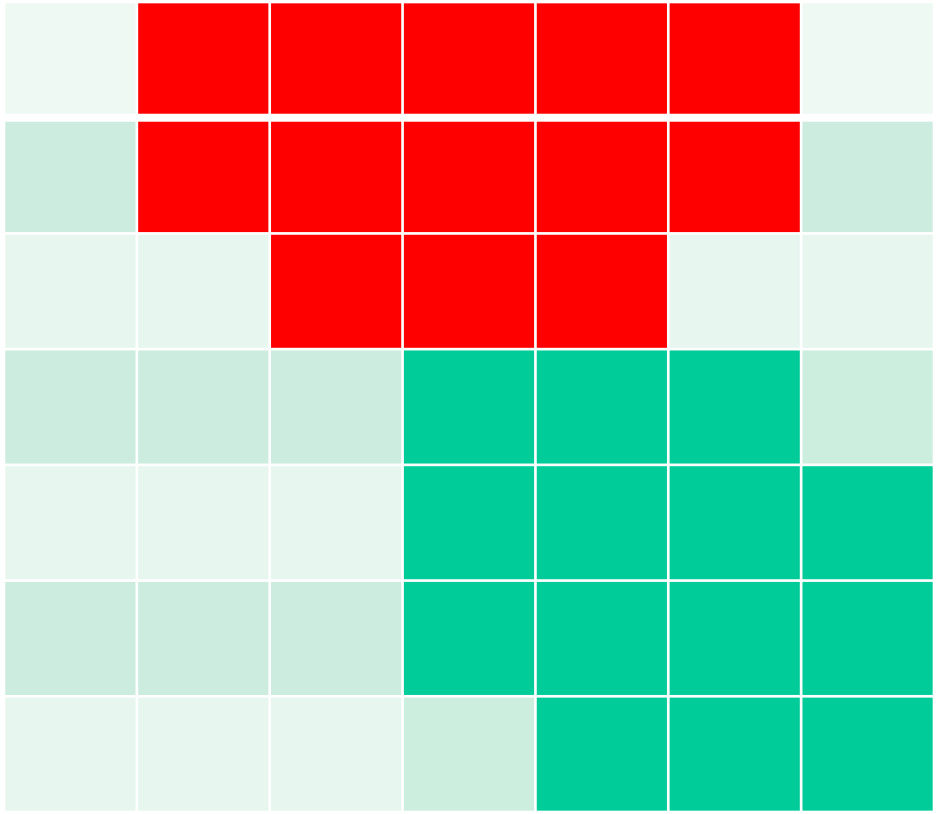
Konvoluční filtry

- **Rotující okno**

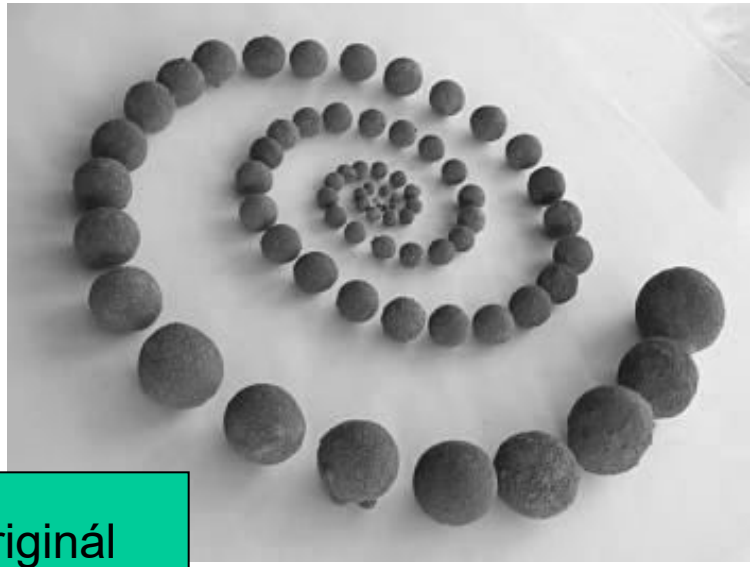


Konvoluční filtry

- **Rotující okno**

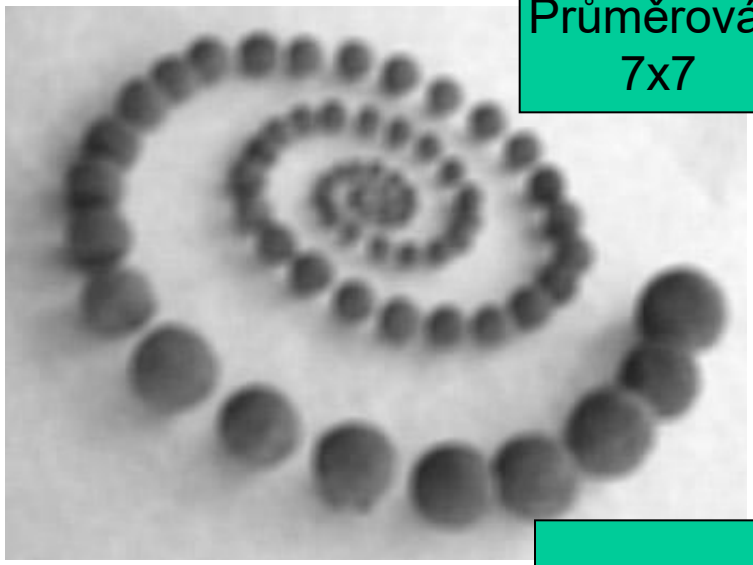


Rotující okno

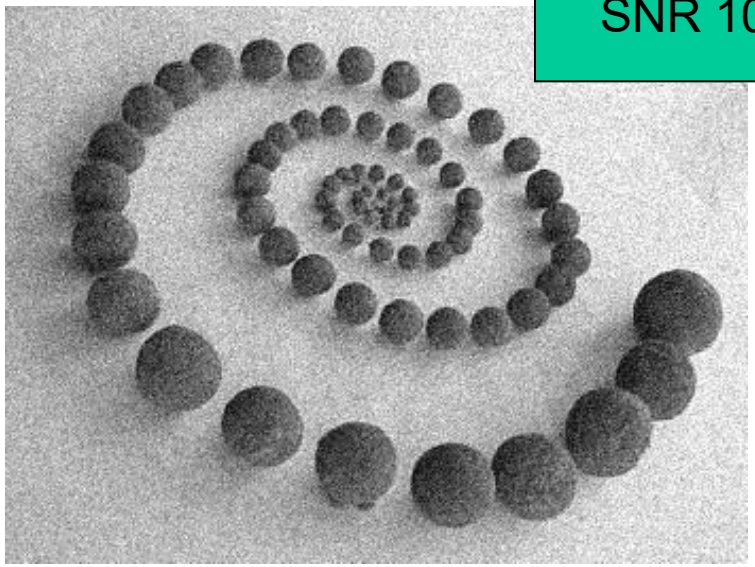


Originál

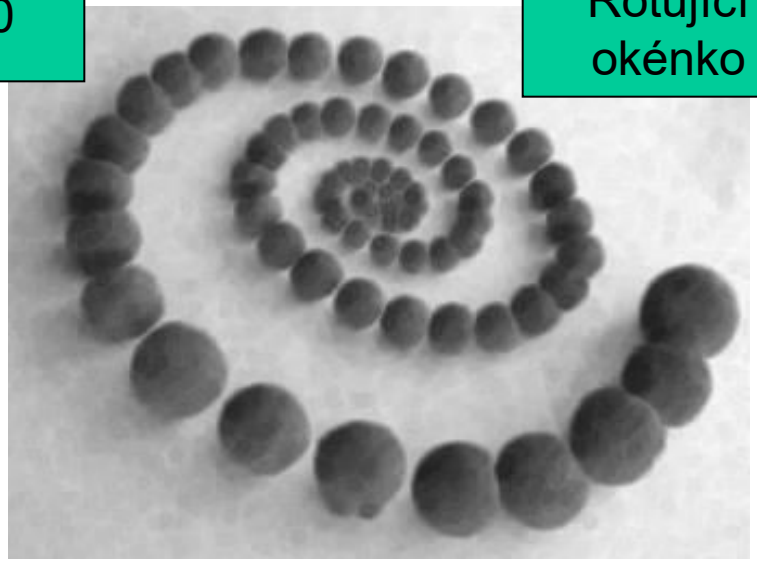
Průměrování 7x7



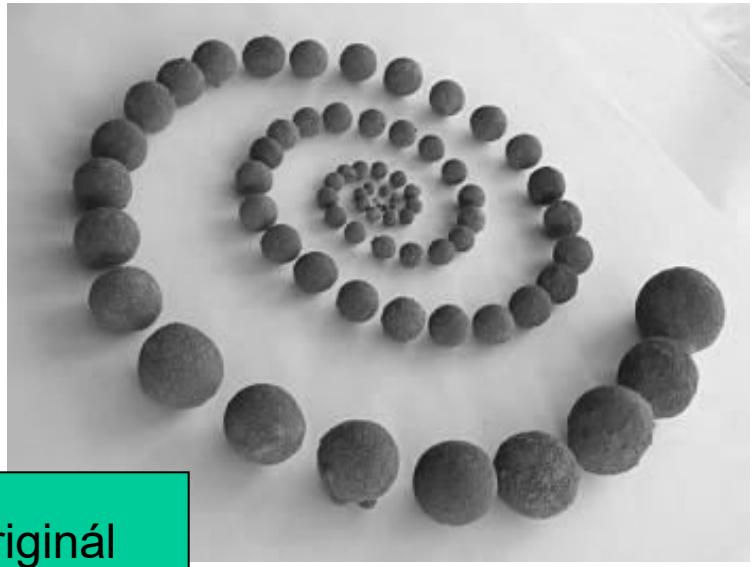
SNR 10



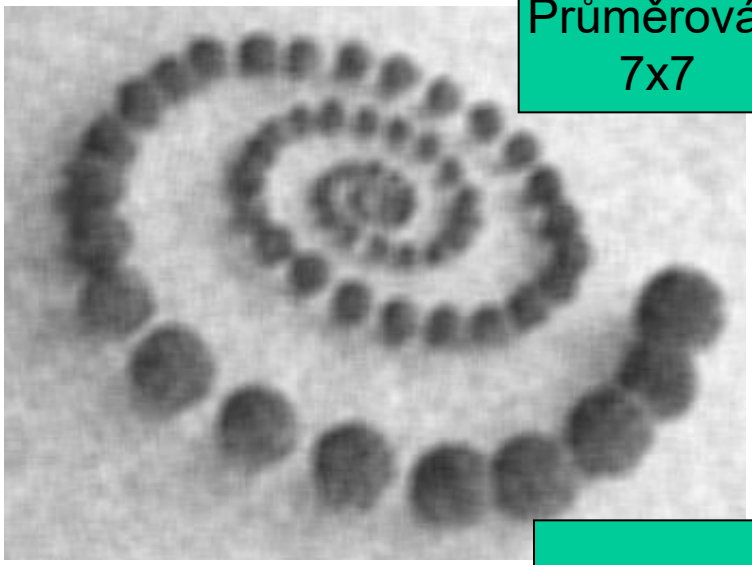
Rotující okénko



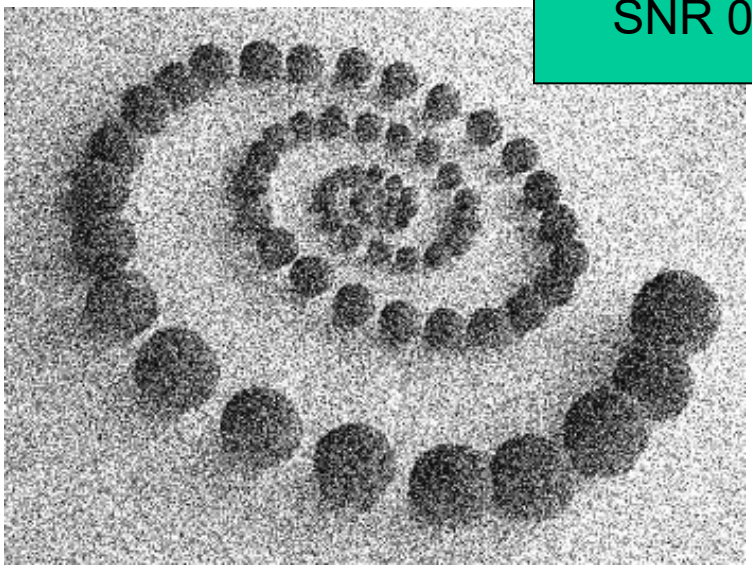
Rotující okno



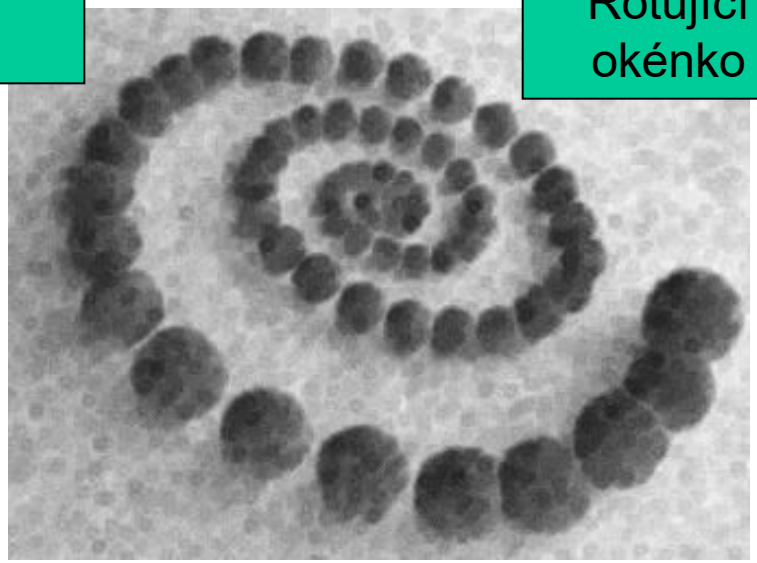
Originál



Průměrování 7x7



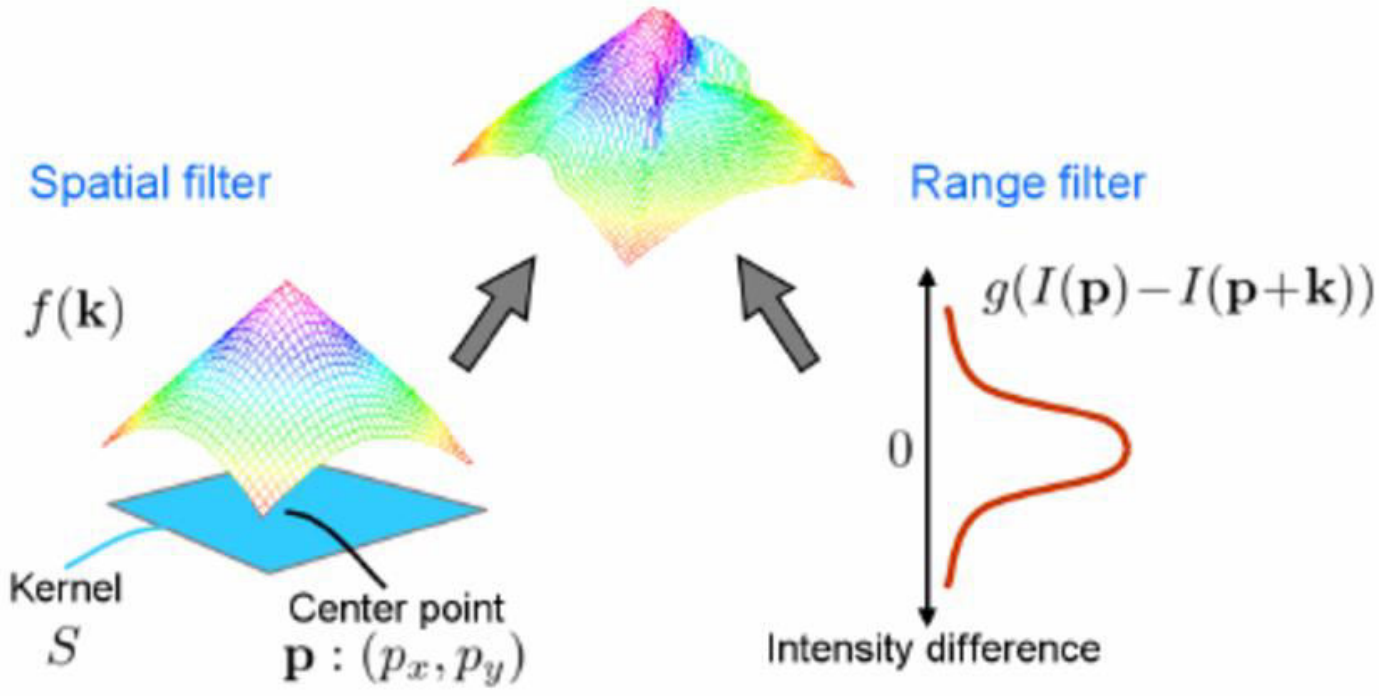
SNR 0



Rotující okénko

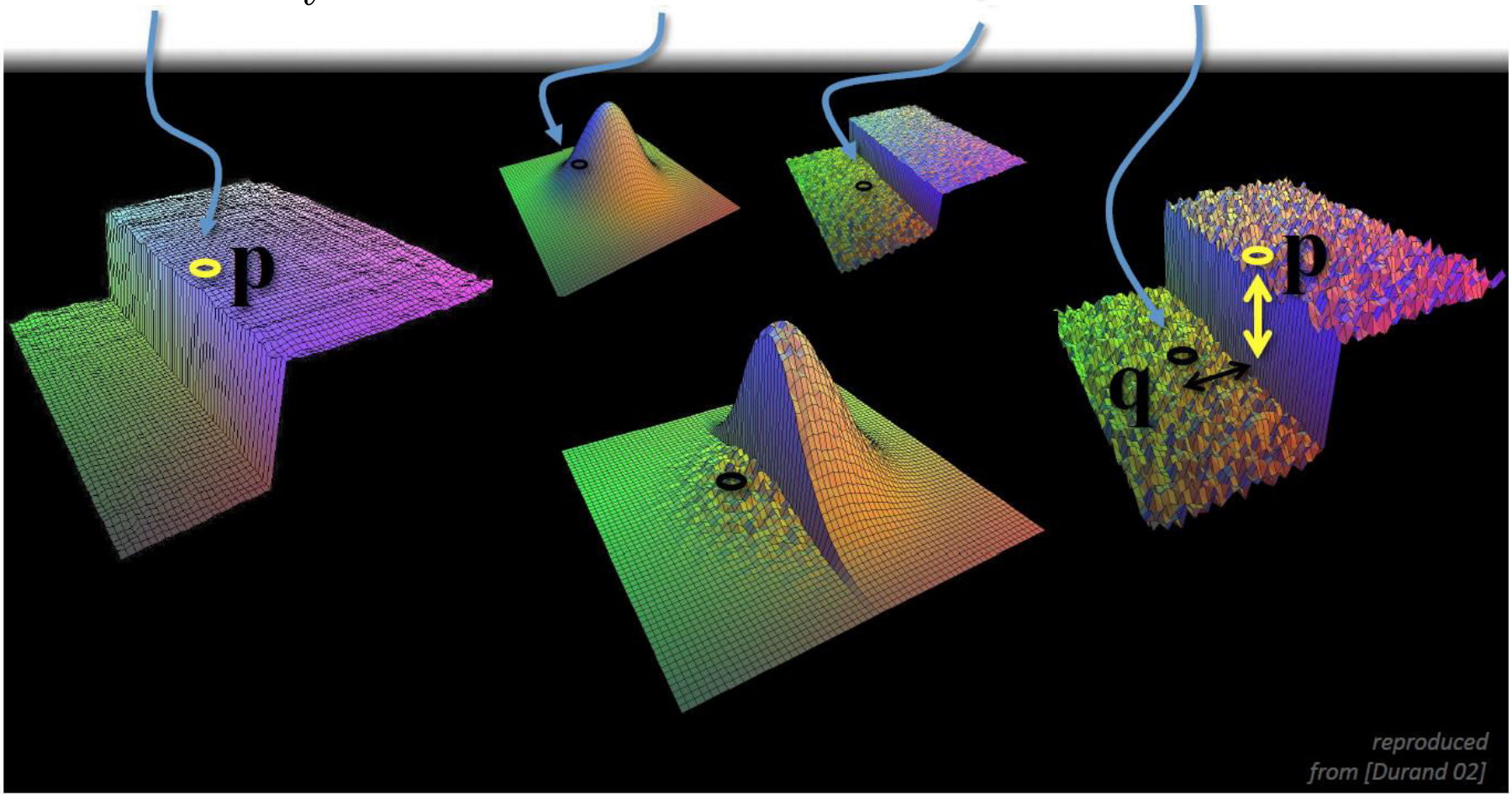
Bilaterální filtr

- Průměrování v okolí přes podobné intenzity (bilaterální filtr)



$$\hat{g}(x) = \sum_t G_{\sigma_s}(\|x-t\|) G_{\sigma_r}(\|g(x)-g(t)\|) g(t)$$

$$\hat{g}(x) = \sum_t G_{\sigma_s}(\|x - t\|) G_{\sigma_r}(\|g(x) - g(t)\|) g(t)$$



σ_r

Gaussian blur

0.1 0.25 ∞

σ_s

2

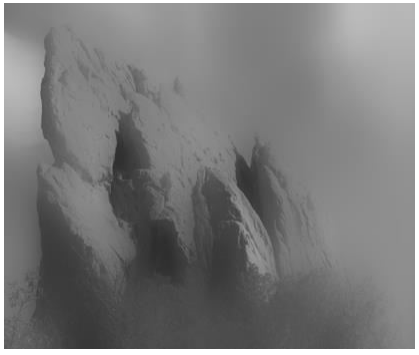
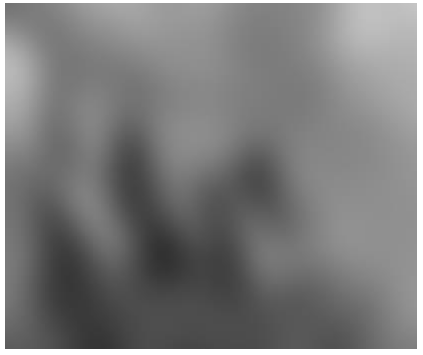
6

18







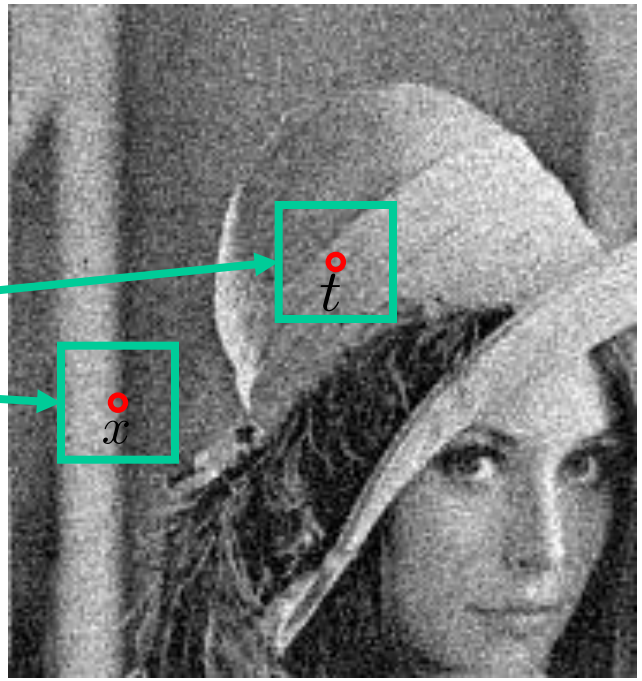




Non-local Means filtr

- Průměrování přes všechny pixely s váhou, která je dána podobností okolí

$$\|\mathcal{N}(x) - \mathcal{N}(t)\|^2$$

$$\hat{g}(x) = \sum_t \cancel{G_{\sigma_s}(\|x - t\|)} G_{\sigma_r}(\|\mathcal{N}(x) - \mathcal{N}(t)\|^2) g(t)$$



- BM3D (2007)

vstup

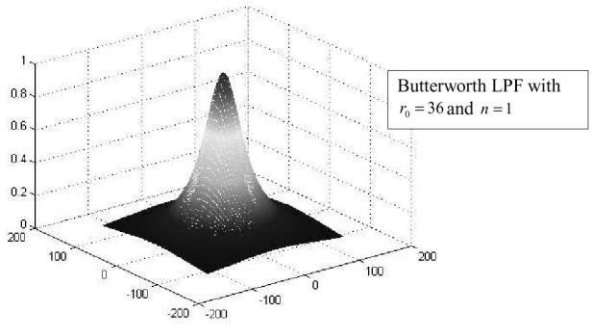
jednoduché průměrování

schody

bilaterální filtr

NL-means filtr

Hladký low-pass filtr
ve frekvenční oblasti

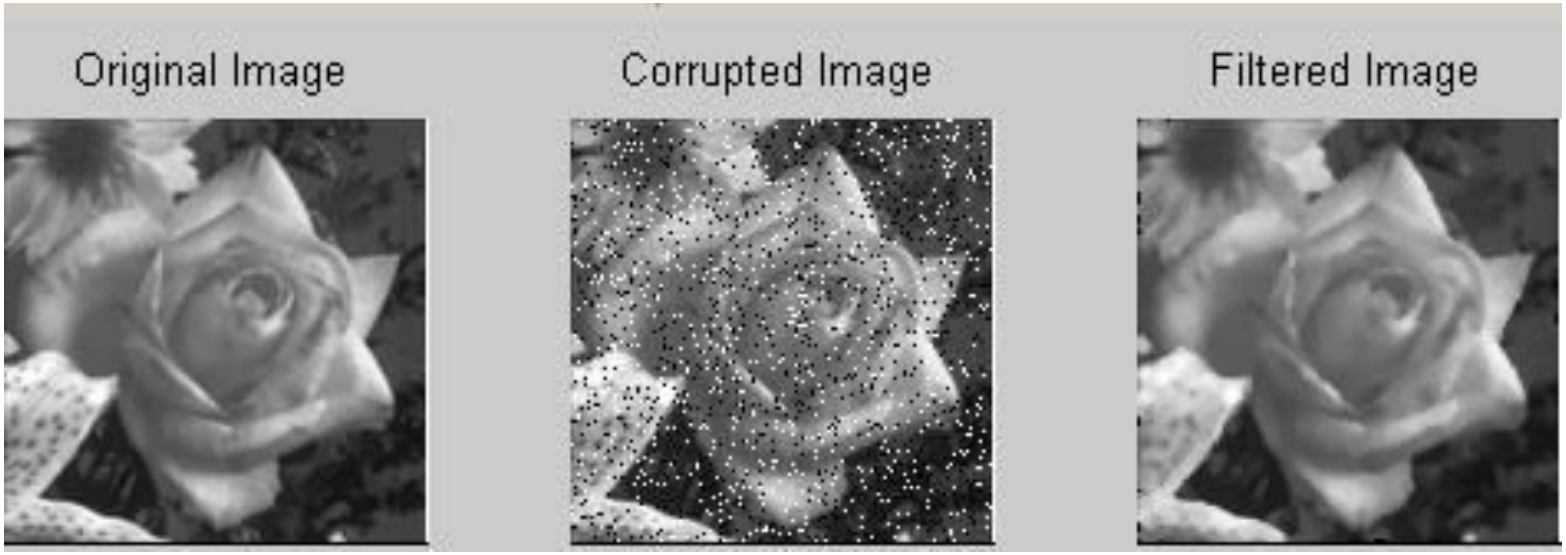


LPF image, $r_0 = 13$

LPF image, $r_0 = 10$

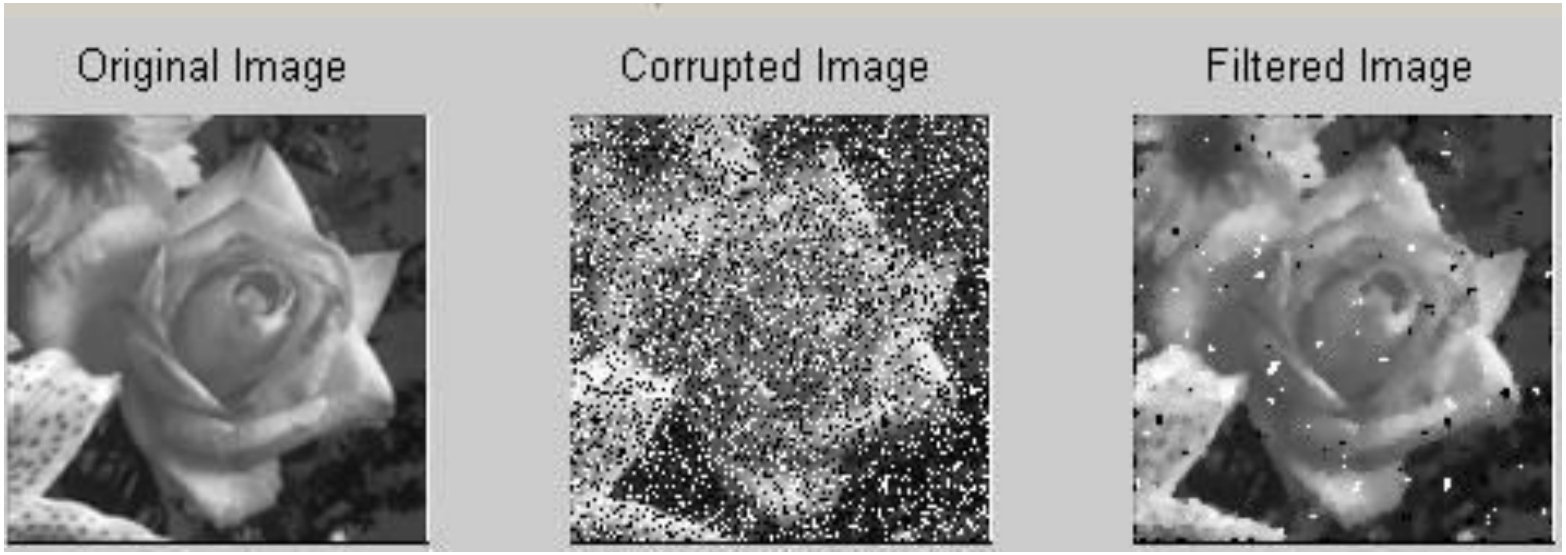
Nelineární filtry

- **Medián**

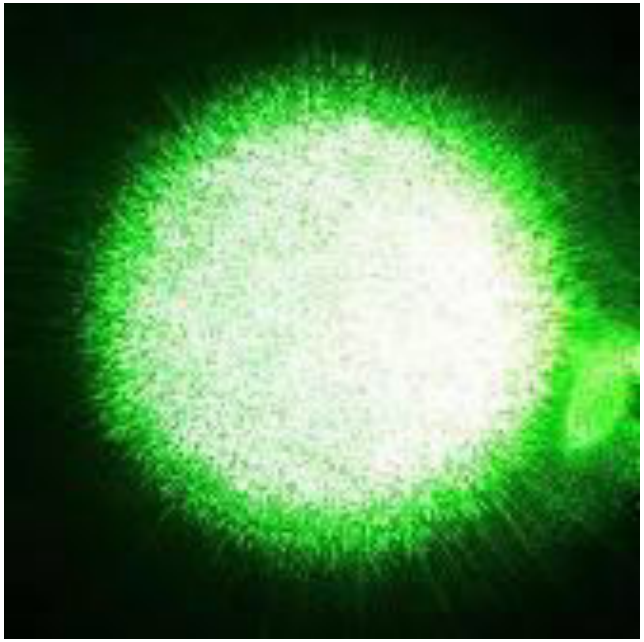


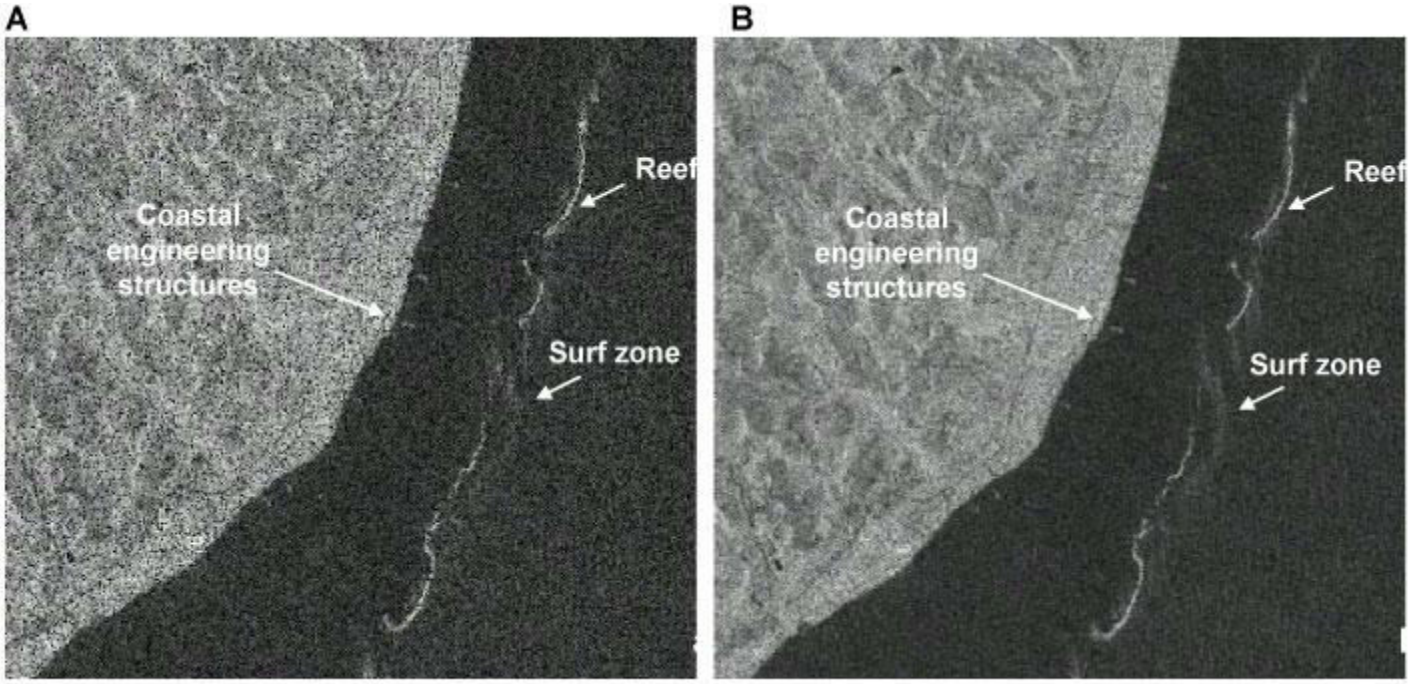
Nelineární filtry

- **Medián**



Speckle noise




A
Coastal
engineering
structures
Reef
Surf zone
B
Coastal
engineering
structures
Reef
Surf zone

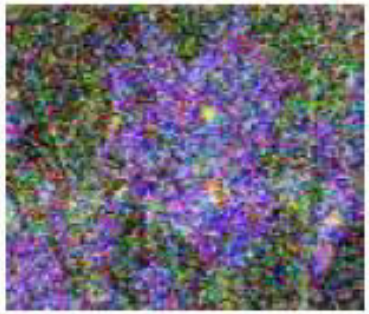
Color median filter

(a)

(b)

(c)

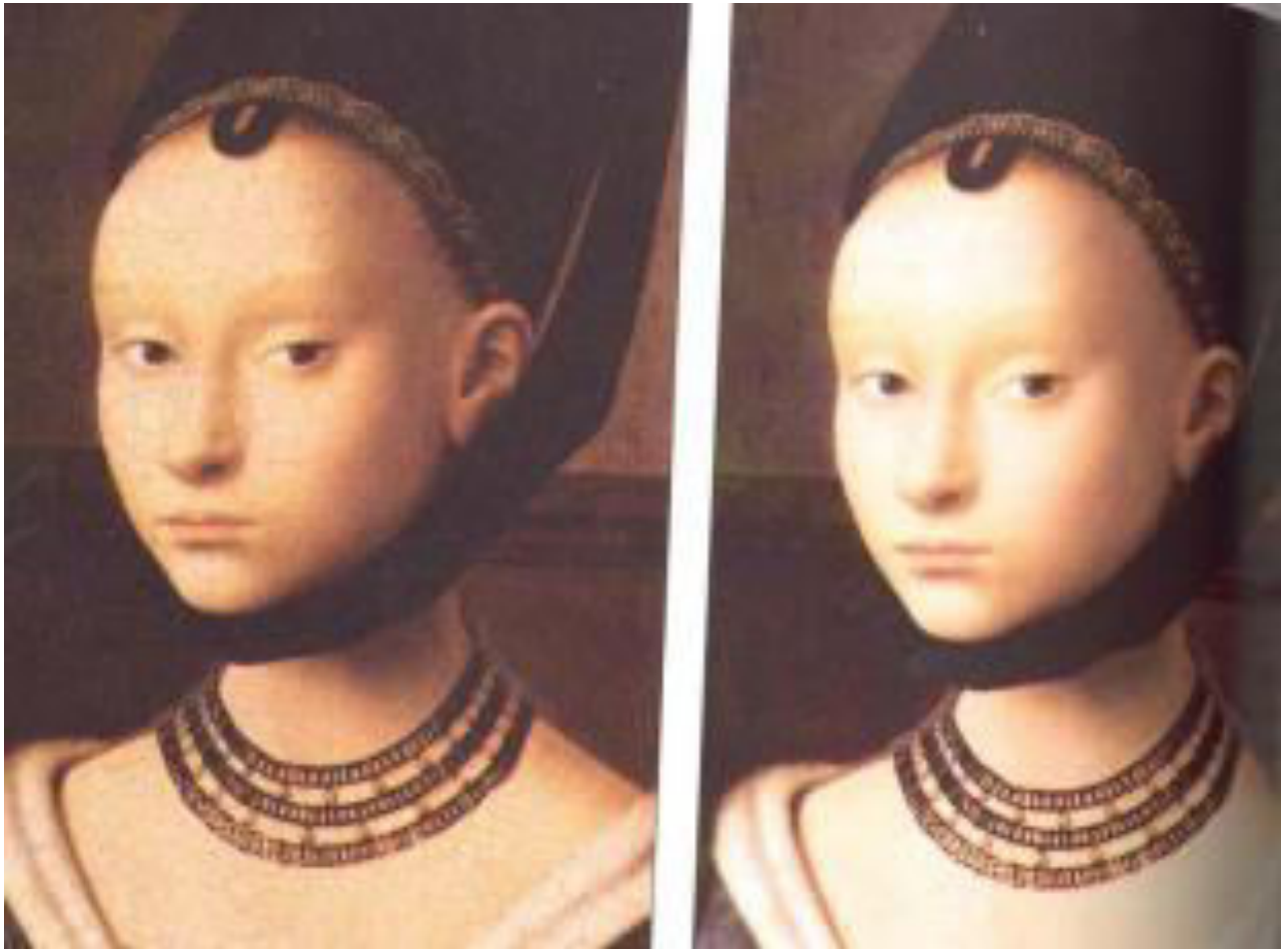
(d)



(e)

(f)

(g)



Minimalizace funkcionálu

Průměrování v obraze

šum

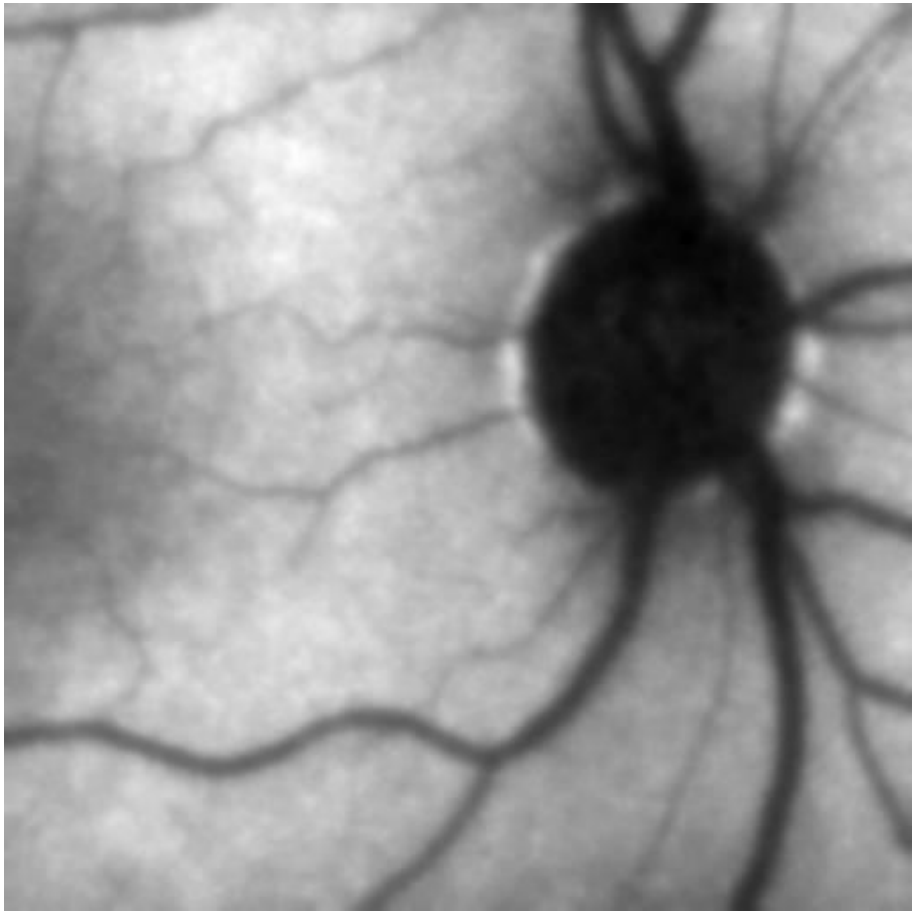
3x3

5x5

7x7

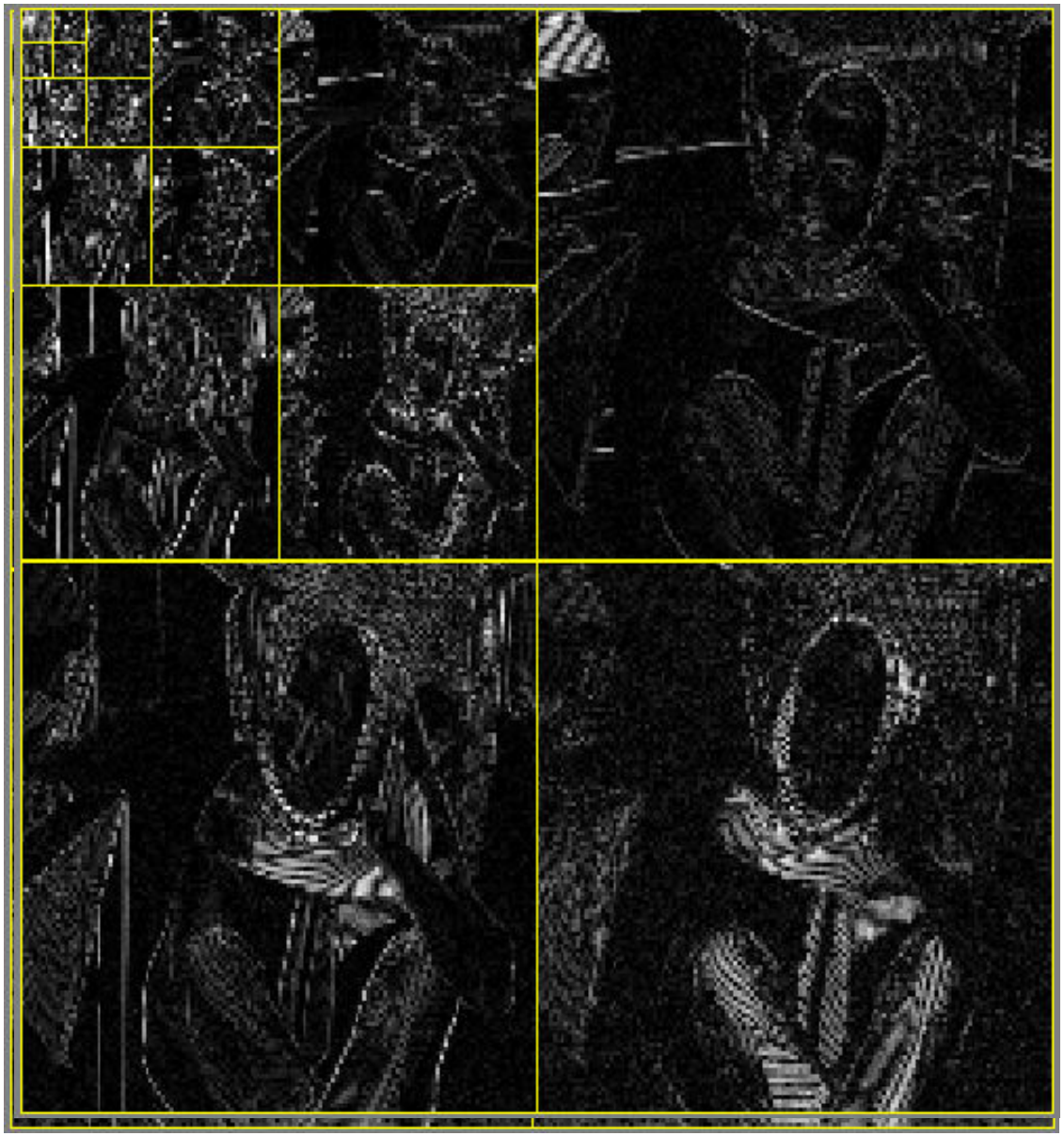
Infračervený obrázek - splajny

Autofluorescenční snímky oka

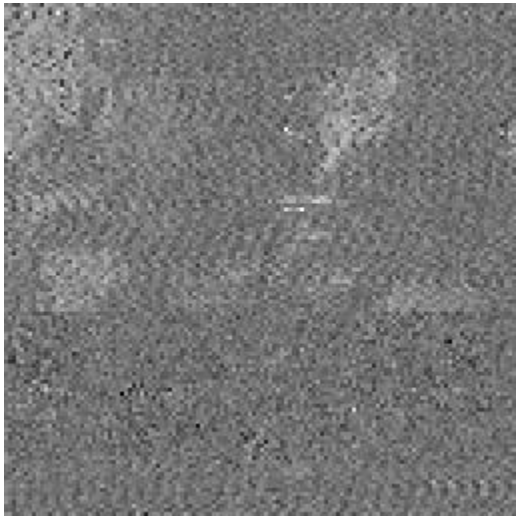


Anizotropní difuze

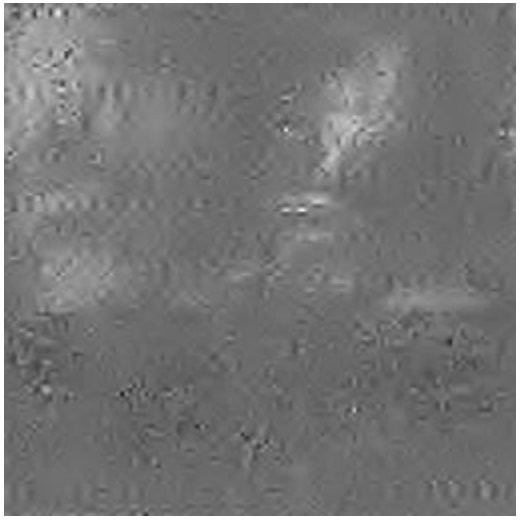
Wavelety



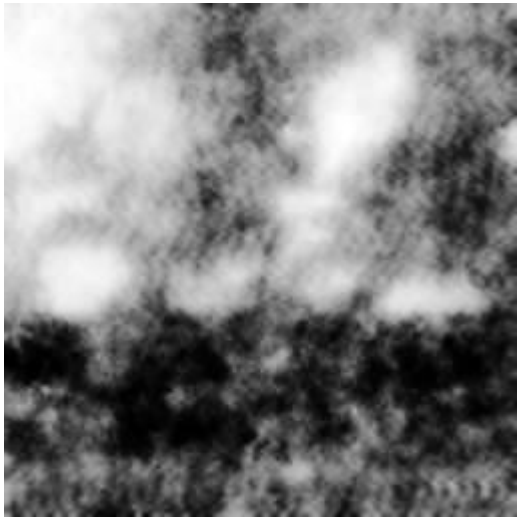
Wavelety



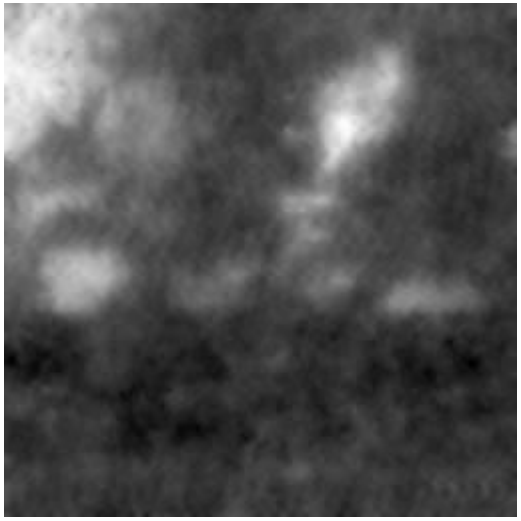
noisy BEEM image



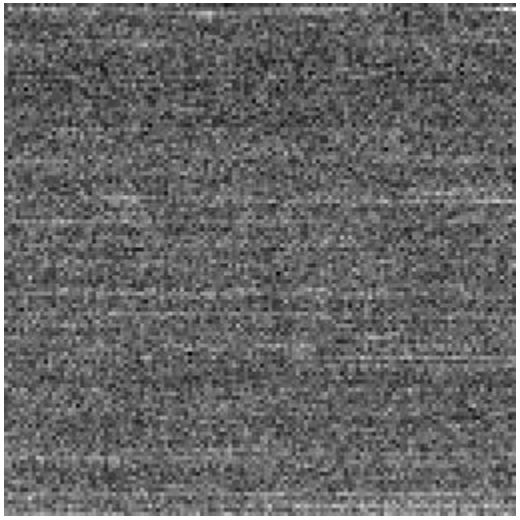
wavelet-based denoising



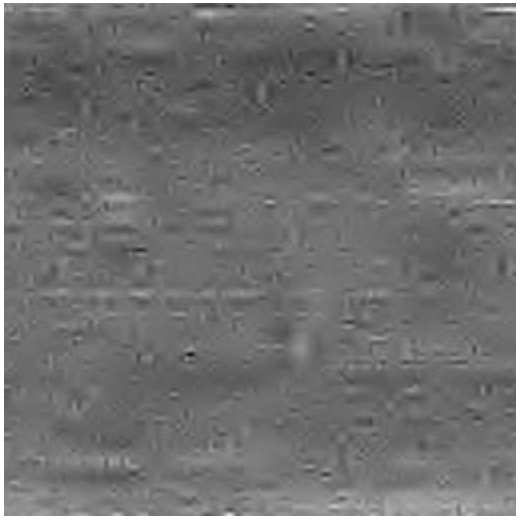
TV + histogram equalization



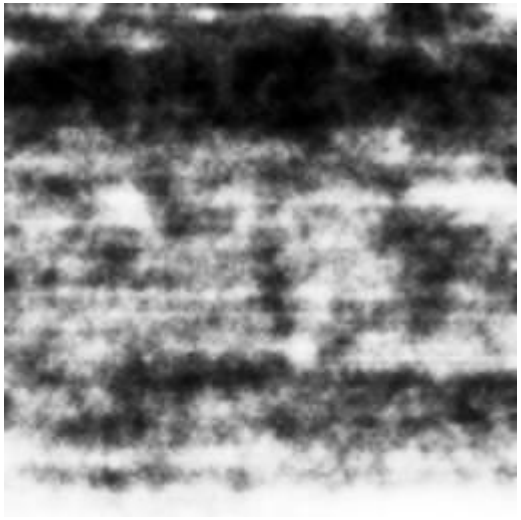
TV-based denoising



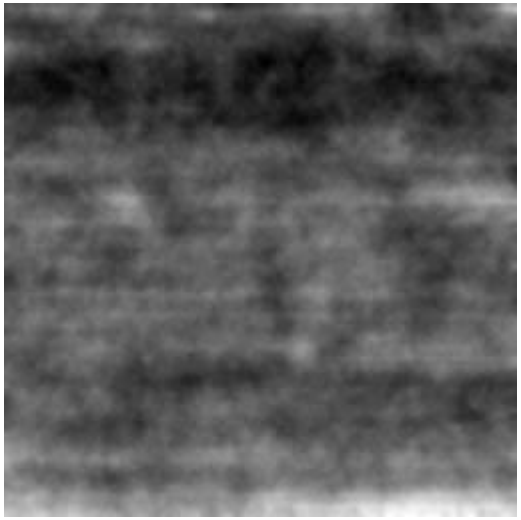
noisy BEEM image



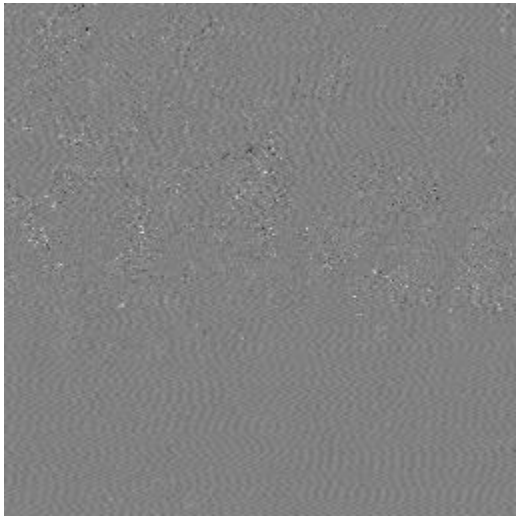
wavelet-based denoising



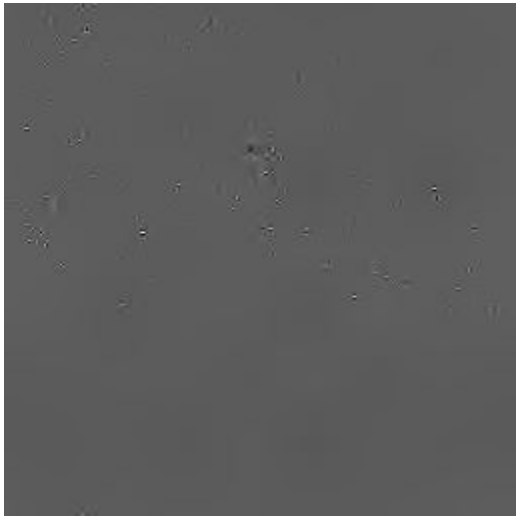
TV + histogram equalization



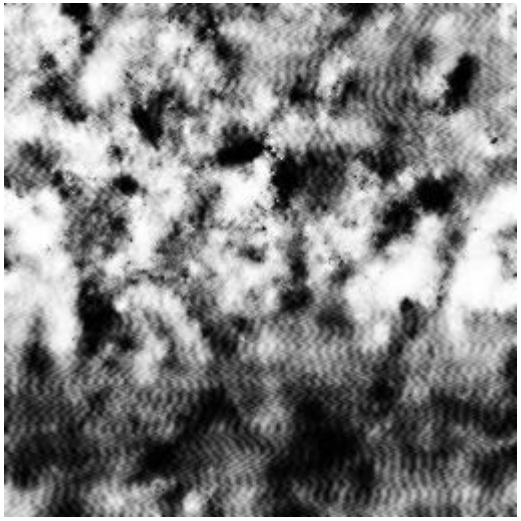
TV-based denoising



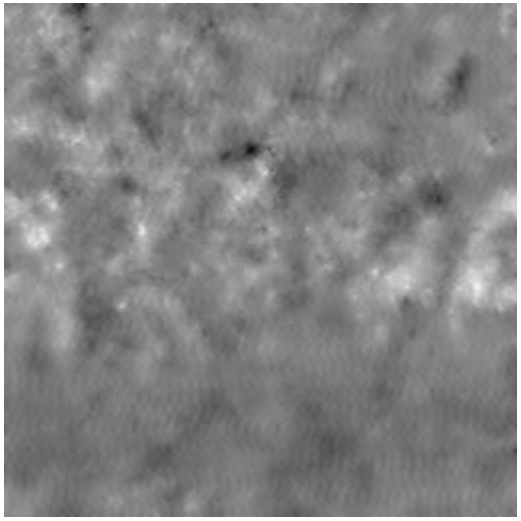
noisy BEEM image



wavelet-based denoising



TV + histogram equalization



TV-based denoising

Díky, pro dnešek

končíme se šumem!

Nějaké otázky ?