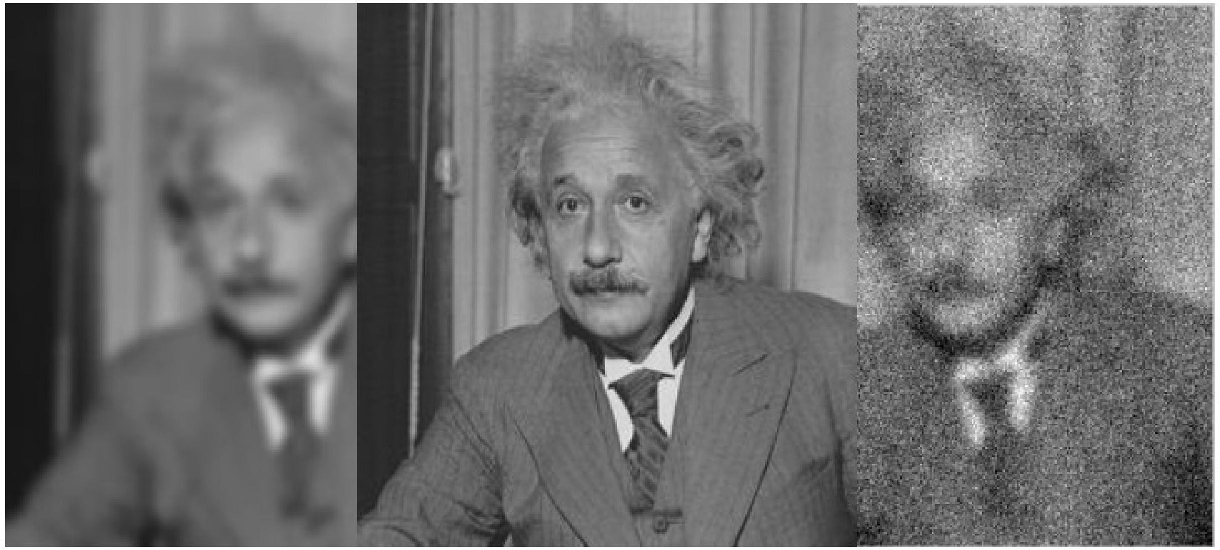
Image Super Resolution

10 Juli 2023

@mahaamesha



out-of-focus blur noise

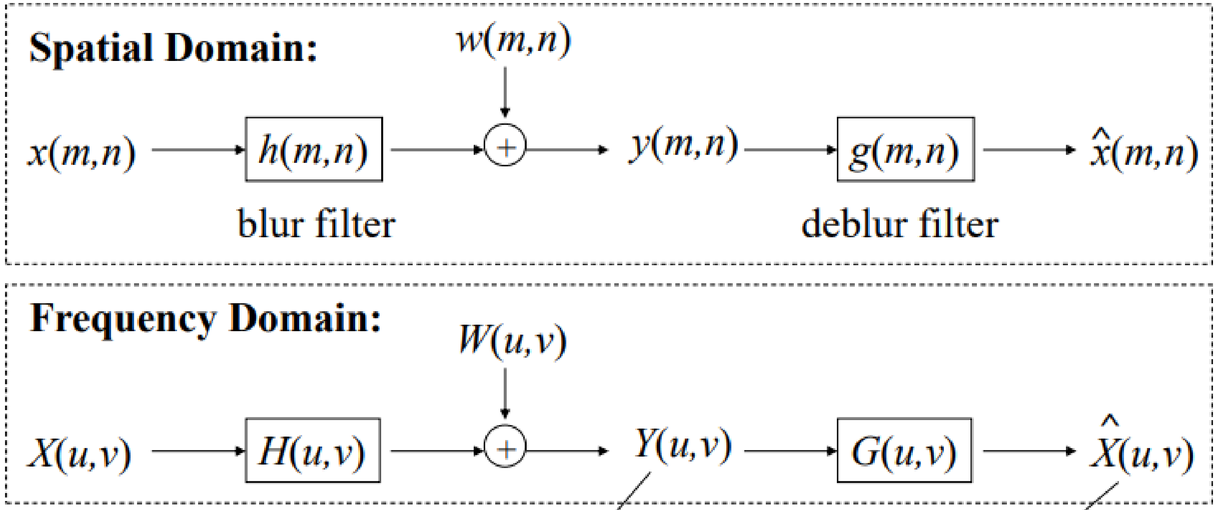
Denoising & Deblurring

Blur & Noise

Remove the noise first, then do deblurring. **Concern: noise amplification**.

To solve salt & pepper noise, use **median filter**.

The PSF $h(m, n)$ has to be known/predicted. Move to frequency domain and use **Wiener Filter**.



$$Y(u,v) = X(u,v)\,H(u,v) + W(u,v)$$

$$\boxed{\hat{X}(u,v) = Y(u,v)G(u,v) = \frac{X(u,v)H(u,v) + W(u,v)}{H(u,v)} = X(u,v) + \frac{W(u,v)}{H(u,v)}}$$

Get the inverse filter

Inverse filter: $G(u,v) = \dfrac{1}{H(u,v)}$

Pseudo-inverse filter:
$$\boxed{G(u,v) = \begin{cases} \dfrac{1}{H(u,v)} & |H(u,v)| > \delta \\ 0 & |H(u,v)| \le \delta \end{cases}}$$

Radially limited inverse filter:
$$\boxed{G(u,v) = \begin{cases} \dfrac{1}{H(u,v)} & \sqrt{u^2+v^2} \le R \\ 0 & \sqrt{u^2+v^2} > R \end{cases}}$$

Wiener filter:
$$\boxed{G(u,v) = \frac{H^*(u,v)}{|H(u,v)|^2 + K}} \quad \text{where} \quad K = \frac{\sigma_W^2}{\sigma_X^2}$$

complex conjugate

Wiener denoising filter:
$$\boxed{G(u,v) = \frac{\sigma_X^2}{\sigma_X^2 + \sigma_W^2}}$$

$$\boxed{G(u,v) = \frac{H^*(u,v)}{|H(u,v)|^2 + \dfrac{\sigma_W^2}{\sigma_X^2}}}$$

Phase: Has same phase response as Inverse Filter

$$\mathrm{Phase}[H_W(\omega_x,\omega_y)] = \mathrm{Phase}[H^*(\omega_x,\omega_y)]$$
$$= -\mathrm{Phase}[H(\omega_x,\omega_y)] = \mathrm{Phase}[\frac{1}{H(\omega_x,\omega_y)}]$$

Practicality: Need to specify σ_W^2 and σ_X^2

σ_W^2 Can be estimated from sensor characteristics

σ_X^2 Can be estimated from image

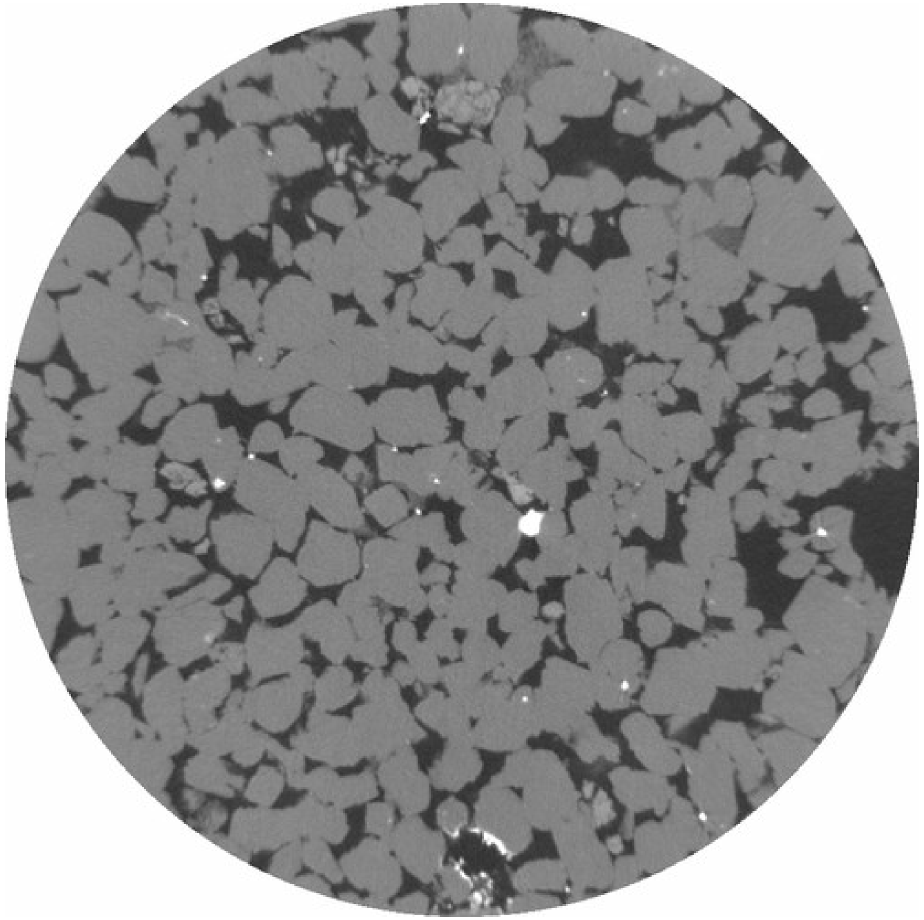
Mini-project: Resolve out-of-focus

1. Read ideal image
2. Create PSF, do gaussian blurring (ksize=7, sigma=3), add salt n pepper noise
3. Deblurring:
   1. Transform to frequency domain
   2. Get OTF, WTF, use Wiener approach
4. Get result

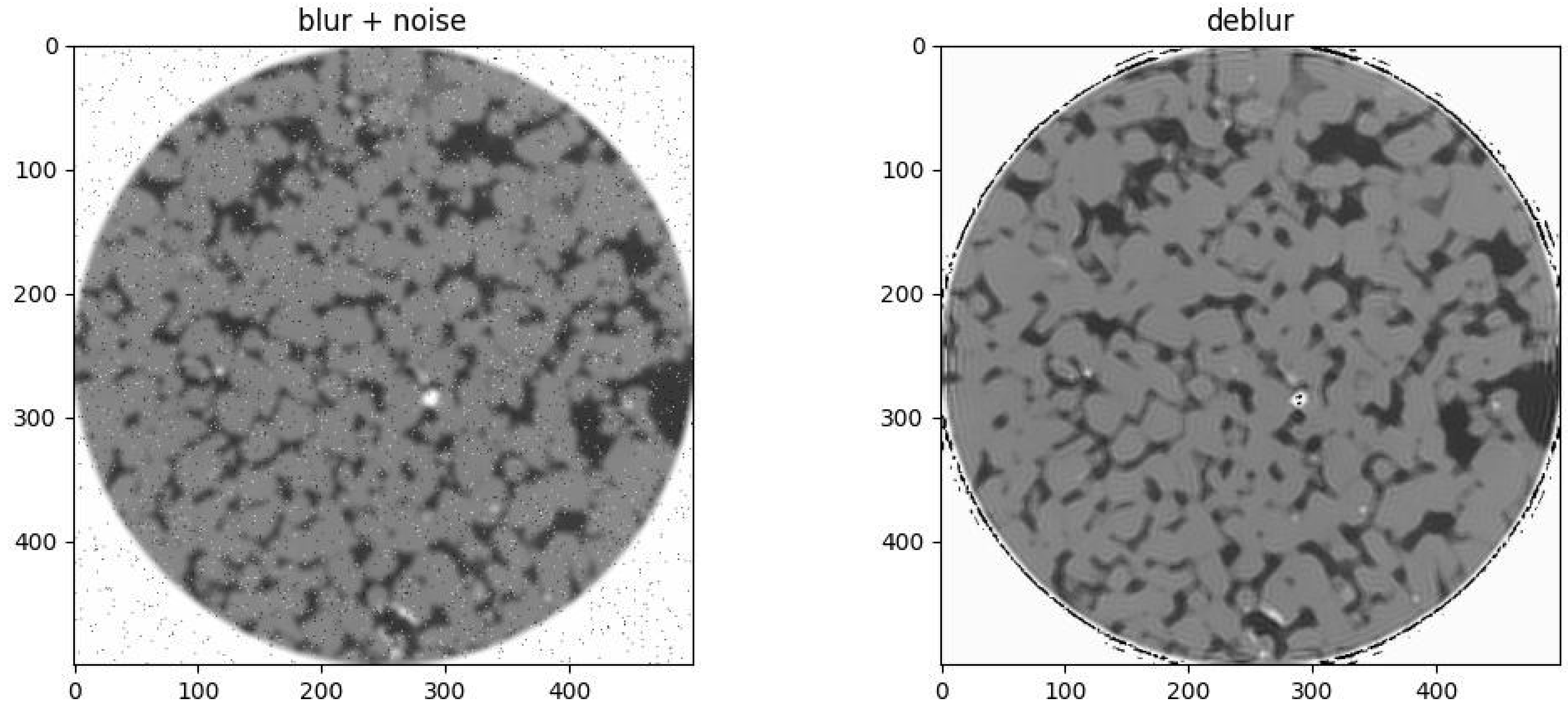
Real Case Challenge: Estimate PSF, K, solve ringing effect

Evaluation: MSE, PSNR, SSIM, histogram matching, etc

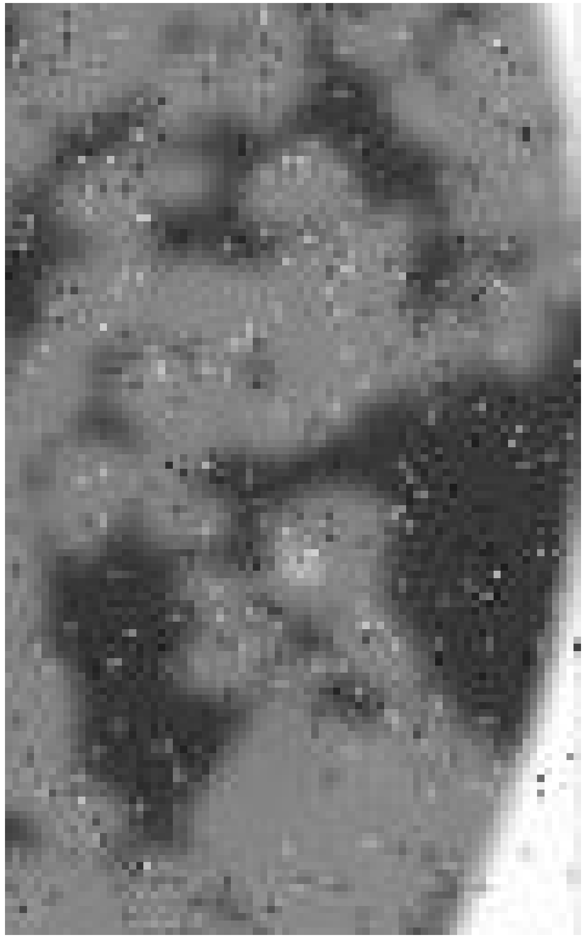
Ideal image (500 x 500)

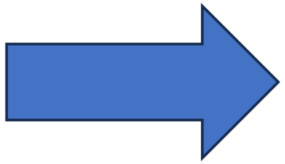


Mini-project: Resolve out-of-focus



Mini-project: Resolve out-of-focus





K=0.01
MSE=48.285

Mini-project: Resolve out-of-focus

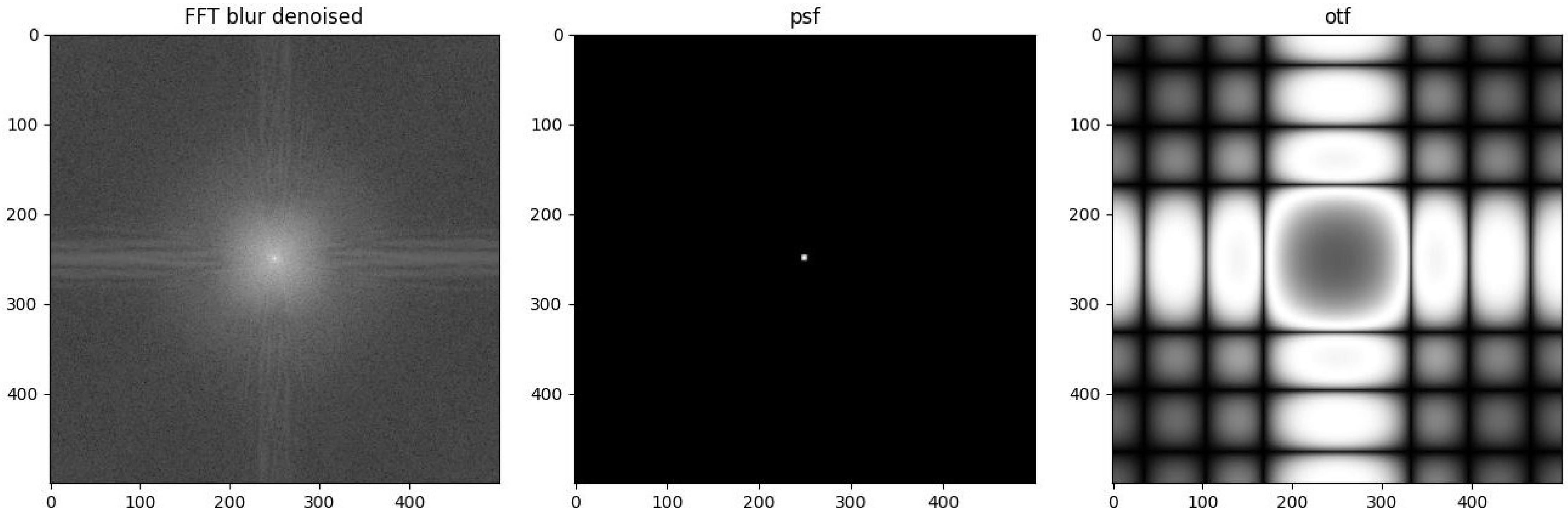


Image Pyramid

Image Pyramid

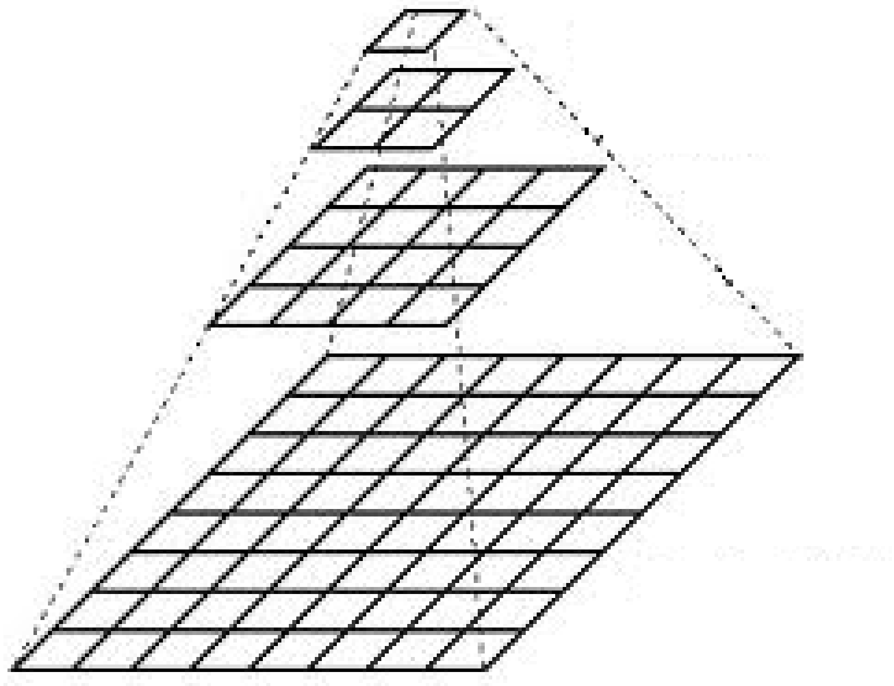
Low resolution

- No details (blurred)
- Store low frequencies

High resolution

- Details
- Low + high frequencies

Performs bilinear interpolation: Bicubic (common)



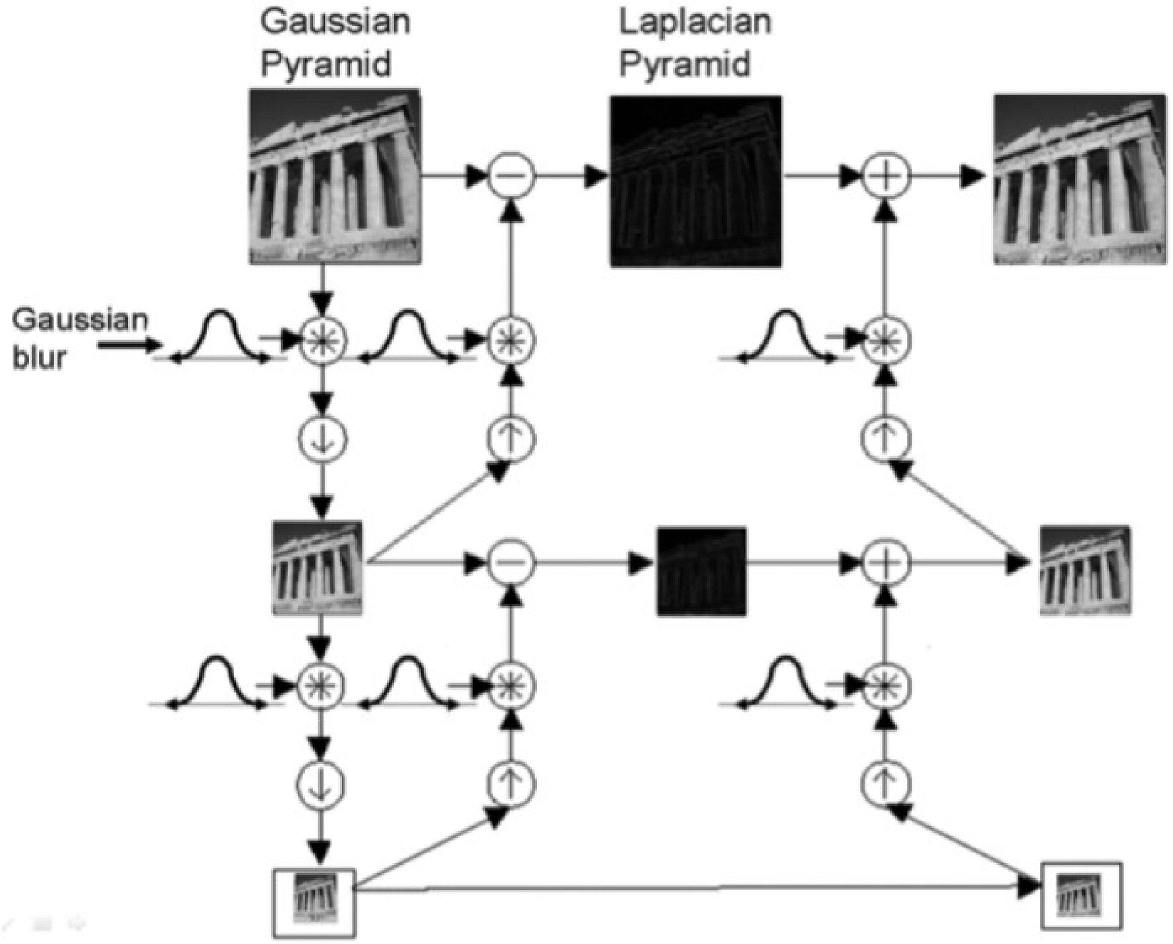
Gaussian & Laplacian Pyramid

Gaussian pyramid

- Blurring (Gaussian is good)
- Downsampling

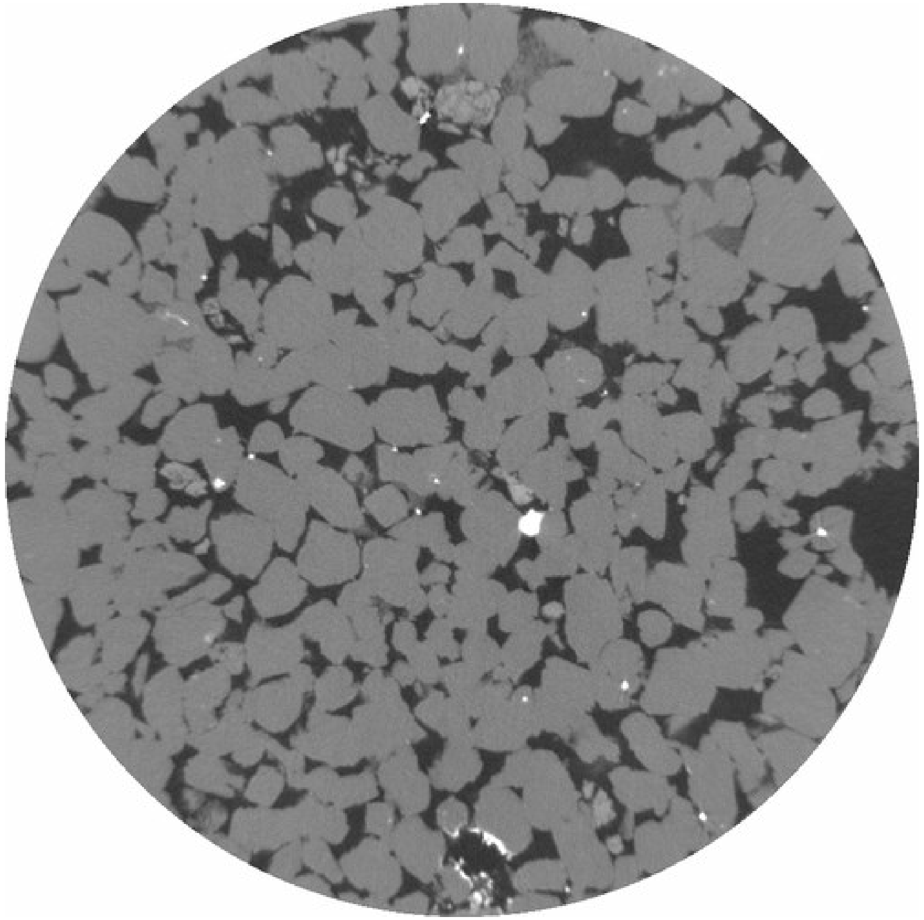
Laplacian pyramid

- Upscaling
- Interpolation (fill empty pixel)



Mini-project: Upscaling

Ideal image (500 x 500)



1. Read ideal image
2. Do pyramid upscaling
   (until level 5 for testing)
3. Result

MSE increasing caused because of blurring.

Mini-project: Upscaling

original vs im0
MSE = 0.0
PSNR = inf

original vs im1
MSE = 11.681
PSNR = 37.455

original vs im2
MSE = 16.176
PSNR = 36.042

original vs im3
MSE = 17.738
PSNR = 35.642

original vs im4
MSE = 18.338
PSNR = 35.497

original vs im5
MSE = 18.520
PSNR = 35.454

Name	Size
im_pyramid_imfsize0.jpg	164 KB
im_pyramid_imfsize1.jpg	398 KB
im_pyramid_imfsize2.jpg	1,092 KB
im_pyramid_imfsize3.jpg	3,280 KB
im_pyramid_imfsize4.jpg	9,830 KB

Mini-project: Upscaling

1000 x 1000

16000 x 16000

Thanks