EE 604
Digital Image Processing

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Announcement

- More problems posted in assignment#1

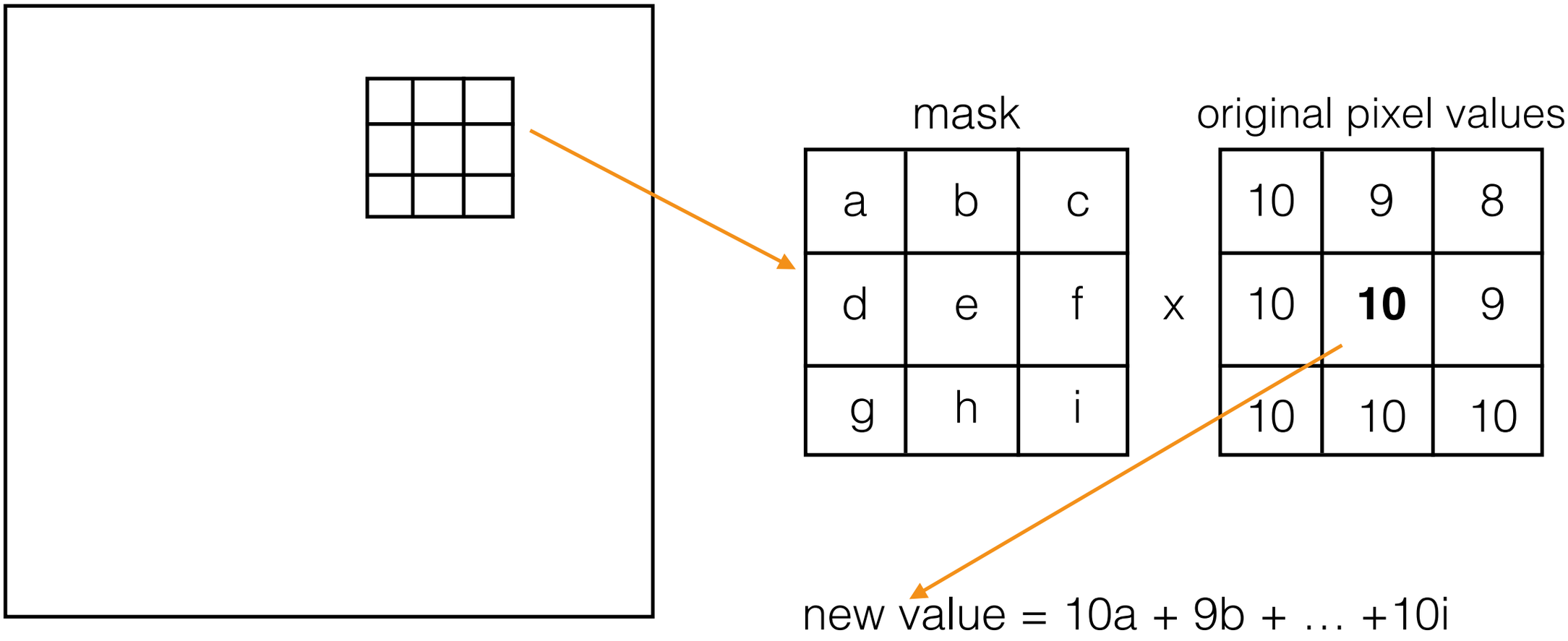
Lecture outline

- Image enhancement in spatial domain
    - wrapping up
- Image enhancement in frequency domain
    - Fourier transform of images
    - Frequency domain filtering

Enhancement in spatial domain

- **Point operations**
    - transformation of a pixel depends only on the intensity of that pixel.
- **Histogram processing**
    - transformation depends on global image characteristics
    - unaware of location, neighborhood
- **Spatial filters**
    - transformation depends on the local neighborhood of a pixel
    - smoothing, sharpening, other operations

Spatial filters



Spatial filters

$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$
$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$
$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$

averaging mask

$\frac{1}{273}$

1	4	7	4	1
4	16	26	16	4
7	26	41	26	7
4	16	26	16	4
1	4	7	4	1

Gaussian (weighted averaging) mask

Spatial filters

0	1	0	1	1	1
1	−4	1	1	−8	1
0	1	0	1	1	1

0	−1	0	−1	−1	−1
−1	4	−1	−1	8	−1
0	−1	0	−1	−1	−1

Laplacian mask

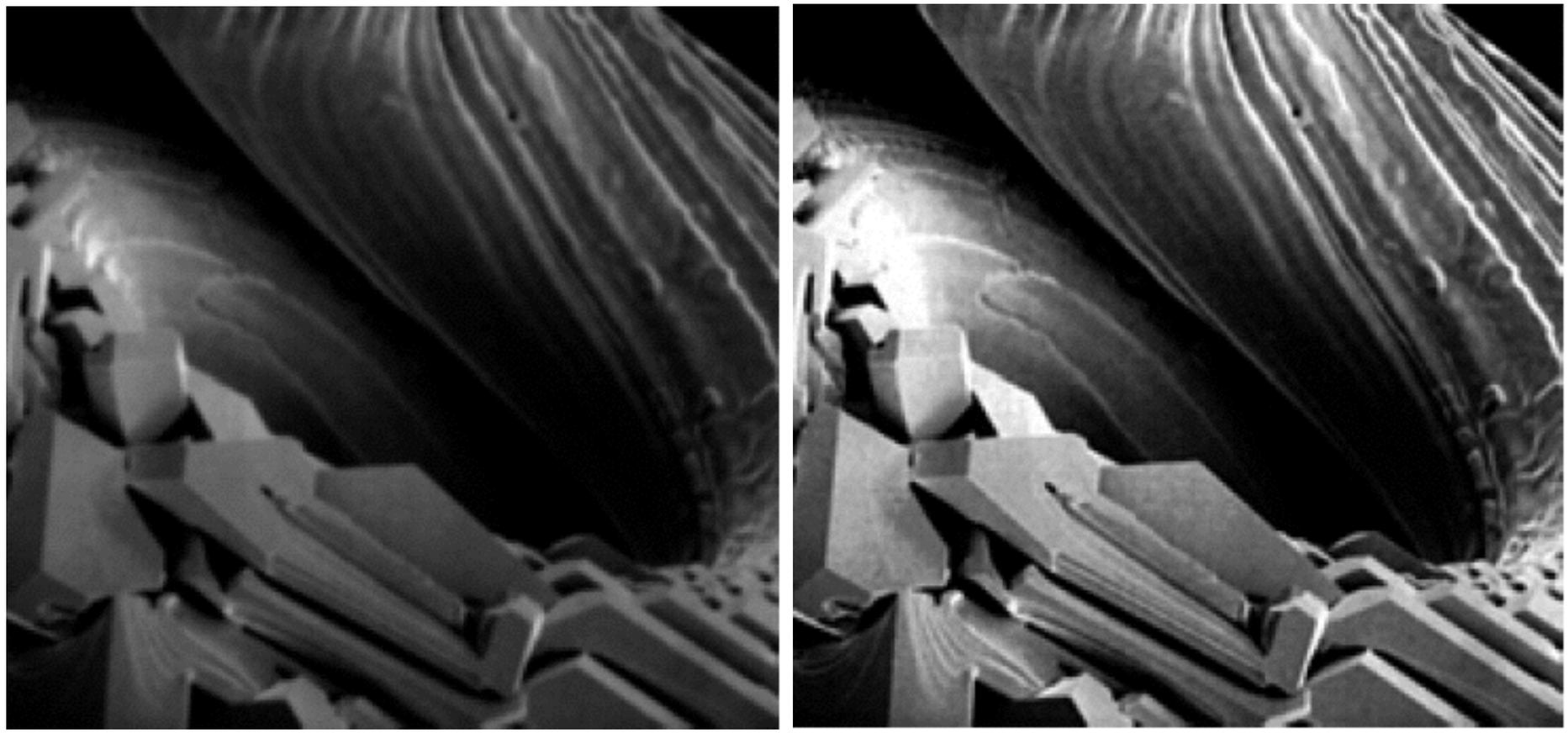
Spatial filters

–1	–2	–1
0	0	0
1	2	1

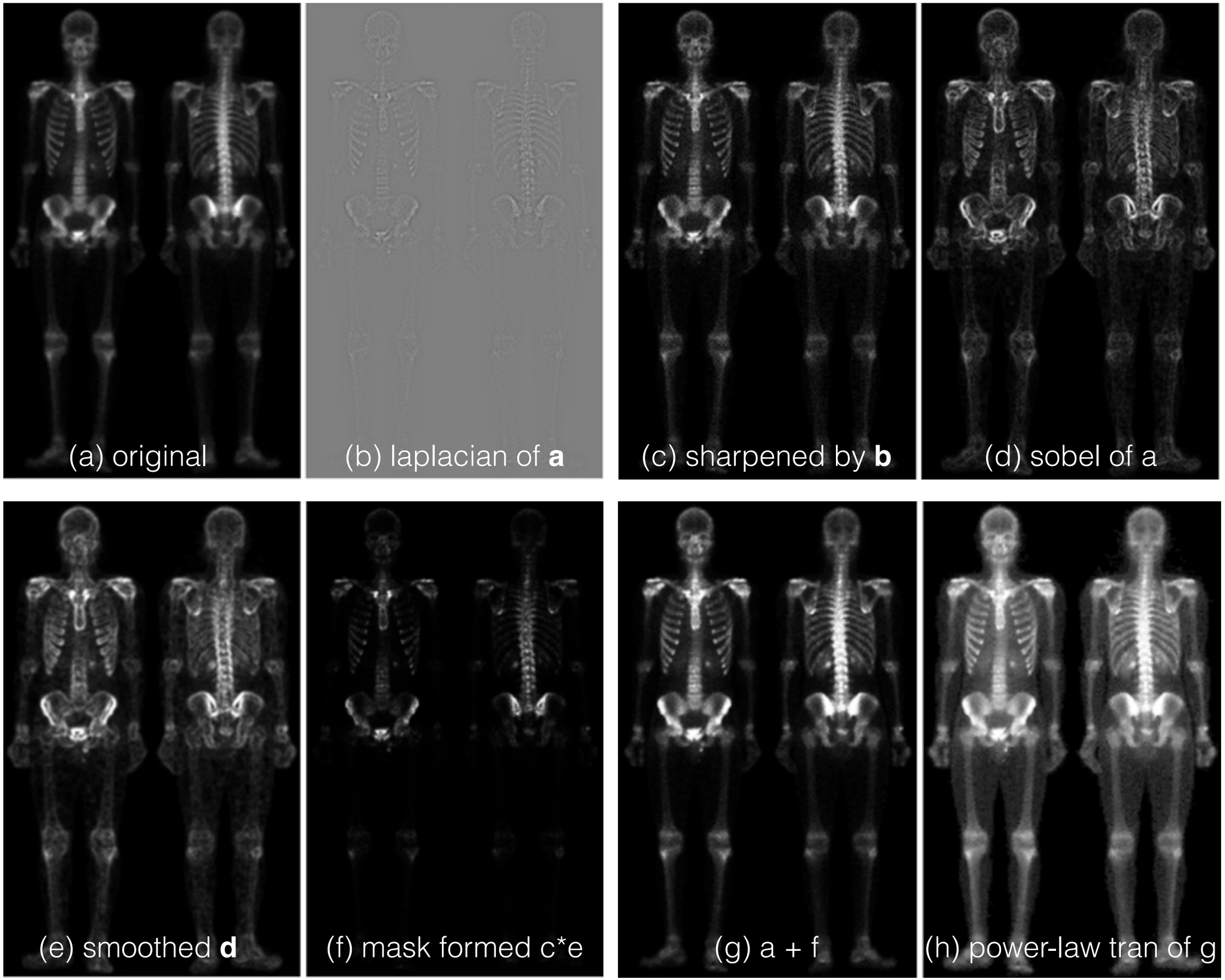
–1	0	1
–2	0	2
–1	0	1

Sobel mask

Spatial filters



after high-boost filtering



Lecture outline

- Image enhancement in spatial domain
    - wrapping up
- Image enhancement in frequency domain
    - Fourier transform of images
    - Frequency domain filtering

Fourier transform

- Decomposes a signal in terms of sinusoids
- DFT pairs

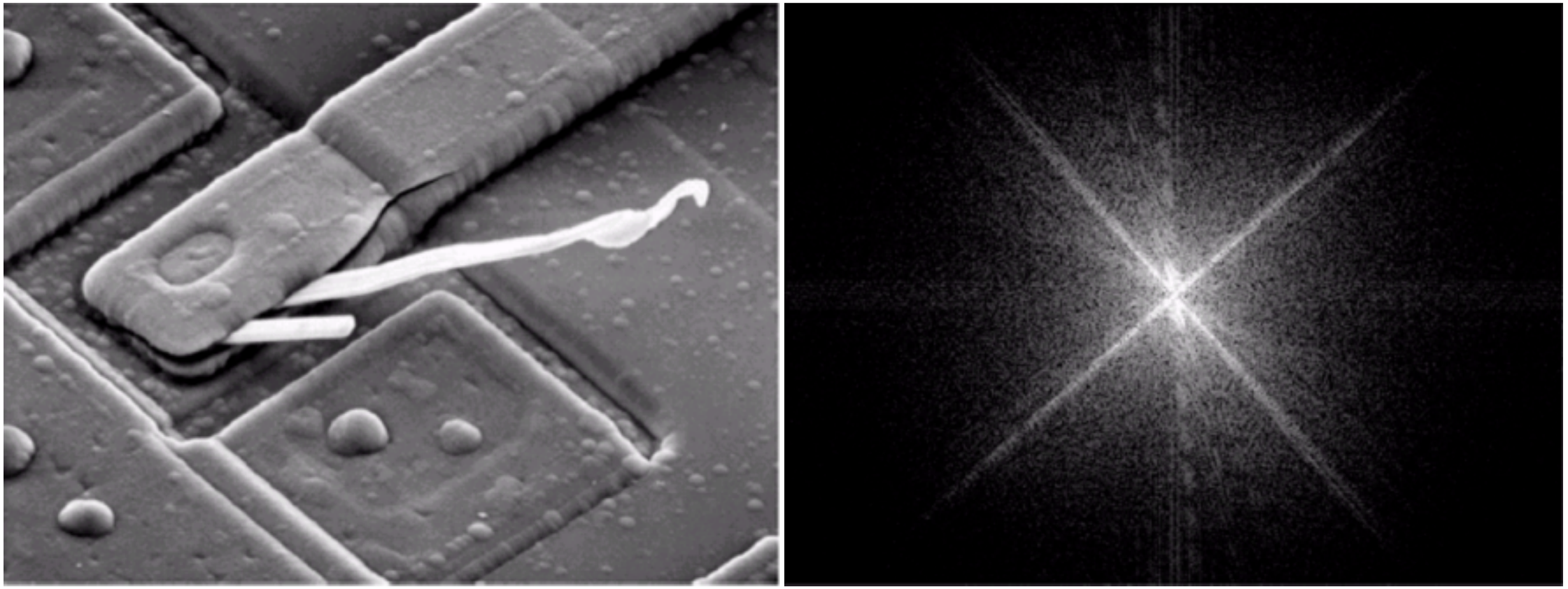
$$F(u) = \frac{1}{M} \sum_{x=0}^{M-1} f(x) e^{\frac{-j2\pi ux}{M}}$$

$$f(x) = \sum_{u=0}^{M-1} F(u) e^{\frac{j2\pi ux}{M}}$$

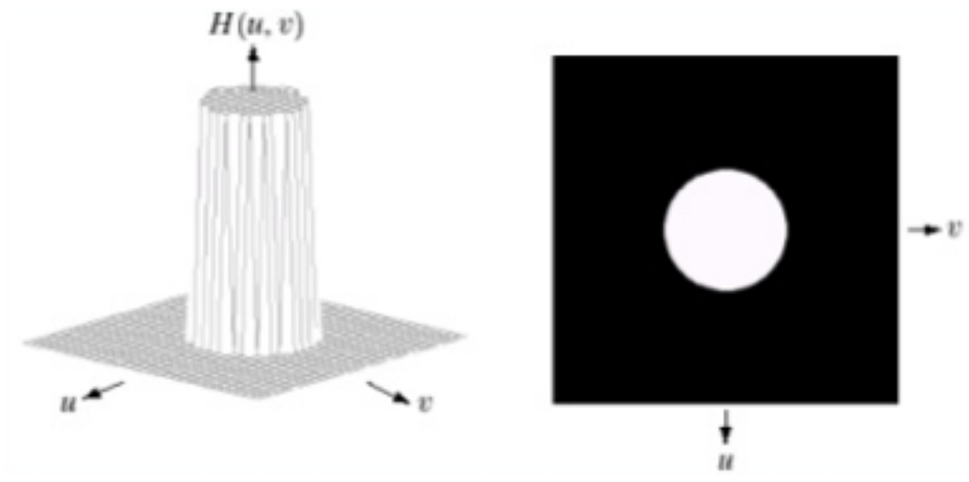
Fourier transform of an image

$$F(u,v) = \frac{1}{M}\frac{1}{N}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)e^{-j2\pi(\frac{ux}{M}+\frac{vy}{N})}$$

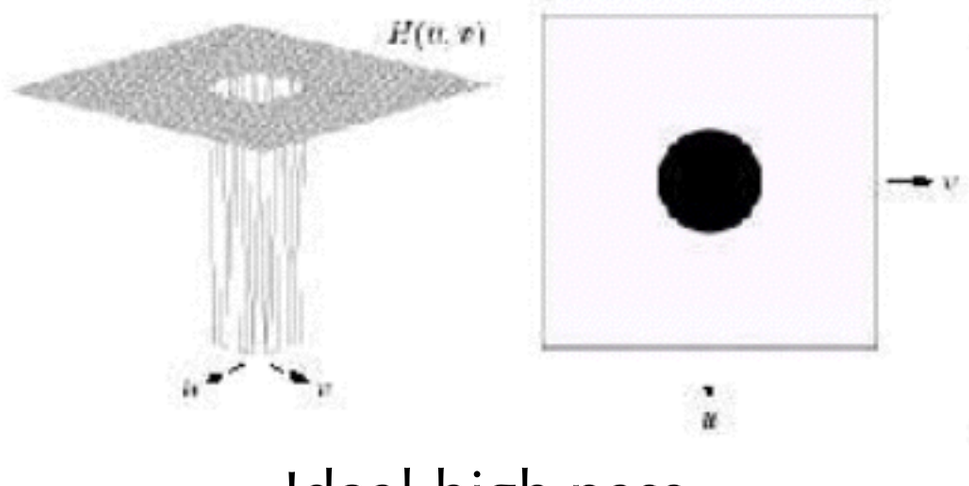
$$f(x,y) = \sum_{u=0}^{M-1}\sum_{v=0}^{N-1} F(u,v)e^{j2\pi(\frac{ux}{M}+\frac{vy}{N})}$$



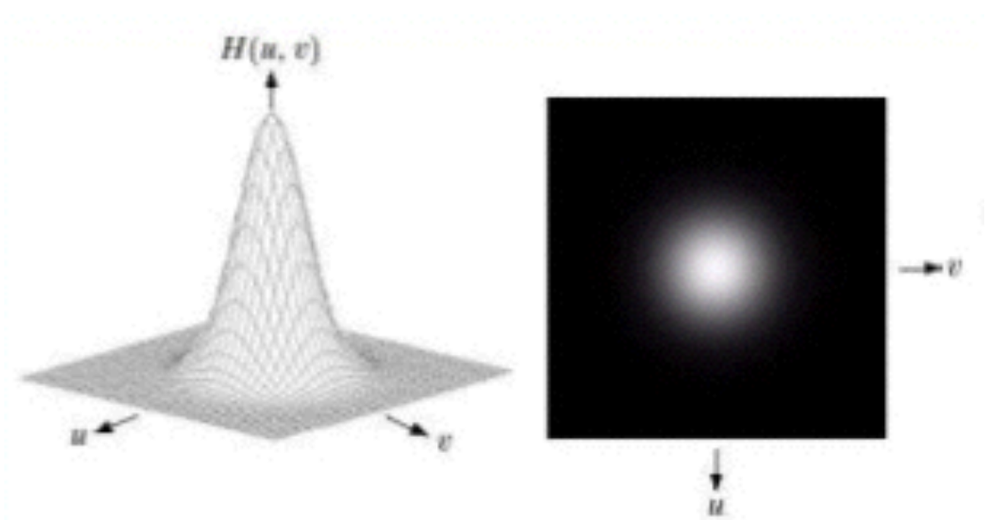
Frequency domain filters



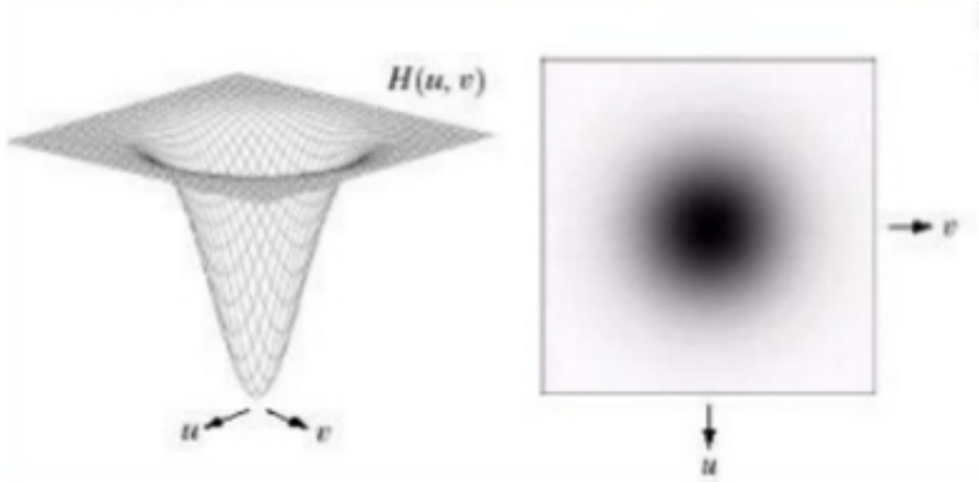
Ideal low pass



Ideal high pass

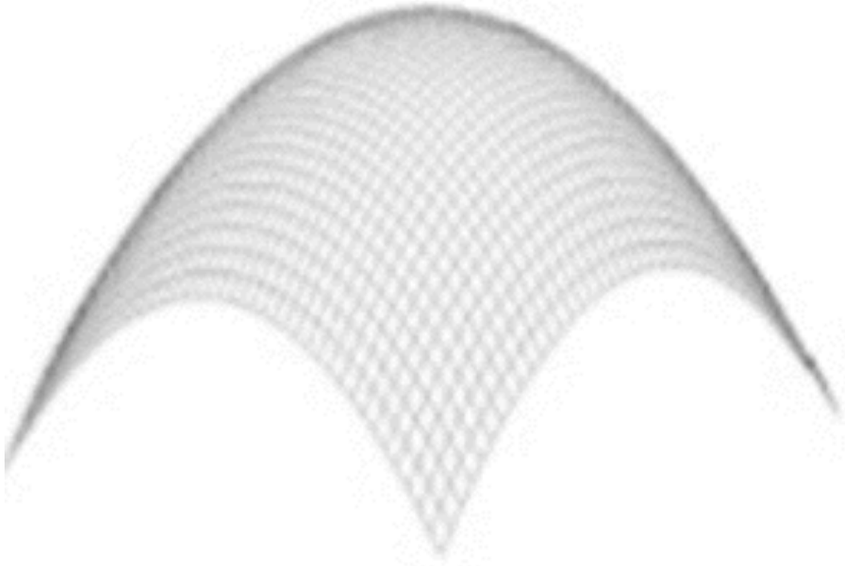


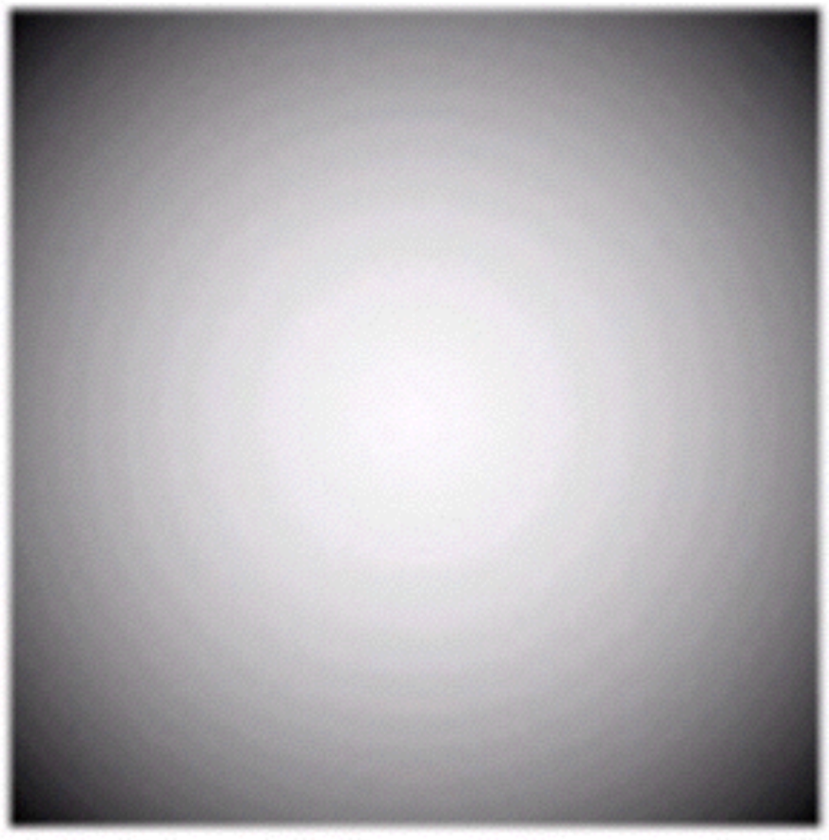
Gaussian low pass



Gaussian high pass

Laplacian in frequency domain





Homomorphic filtering