Lecture 2:

Image Enhancement

Image Sensing and Acquisition

- The types of images in which we are interested are generated by the combination of an "*illumination*" source and the ***reflection*** or ***absorption*** of energy from that source by the elements of the "scene" being imaged.

Why Enhancement?

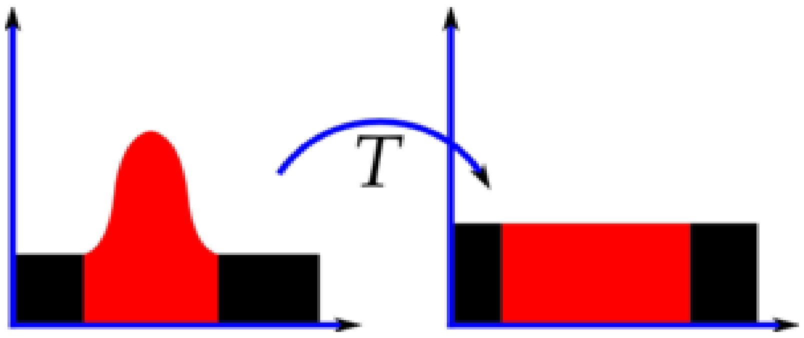
- Images may suffer from the following degradations:
  - **Poor contrast** due to poor illumination or finite sensitivity of the imaging device
  - Electronic **sensor noise** or atmospheric disturbances leading to broadband noise
  - Aliasing effects due to **inadequate sampling**
  - Finite aperture effects or motion leading to spatial

Cont..

- There are various and simple algorithms for image enhancement based on lookup tables
  - ***Contrast enhancement***
- Other algorithms also work with simple linear filtering methods
  - ***Noise removal***

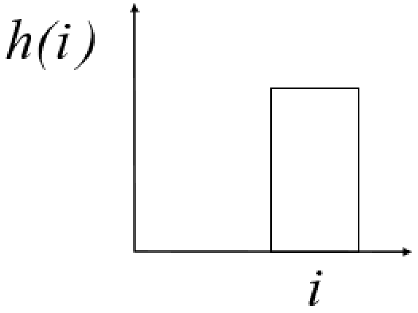
Histogram equalisation

- Equalization increases the global **contrast** of many images, especially when the usable **data** of the image is represented by close contrast values.
- Through this adjustment, the **intensities** can be better distributed on the histogram.This allows for areas of lower local contrast to gain a higher contrast.
- Histogram equalization accomplishes this by effectively ***spreading out the most frequent intensity values***.
  - ✓ The method is useful in images with backgrounds and foregrounds that are both bright or both dark. In particular, the method can lead to better views of **bone** structure in **x- ray** images

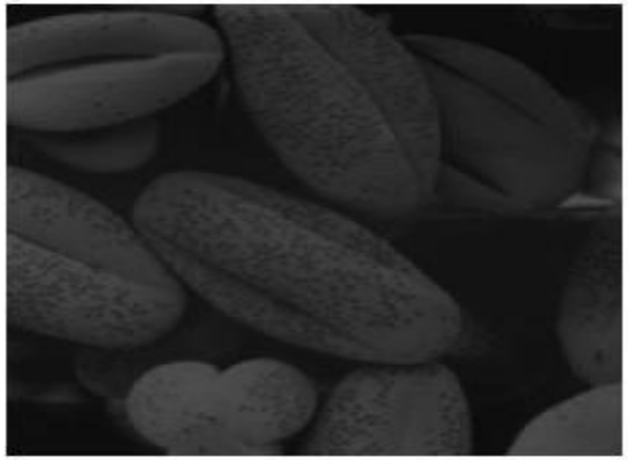


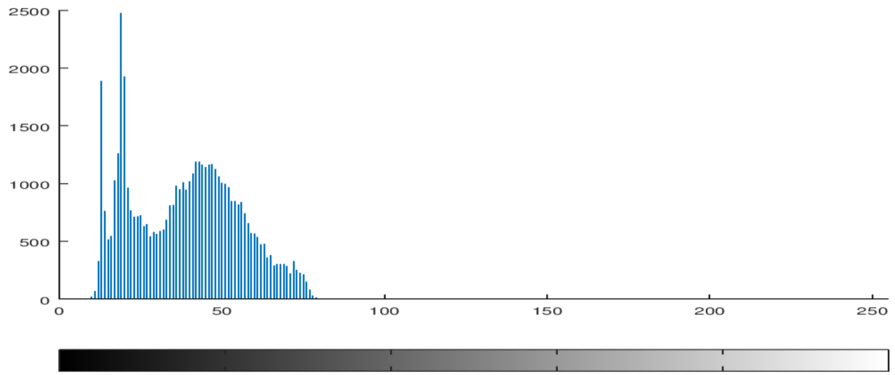
Histogram equalisation

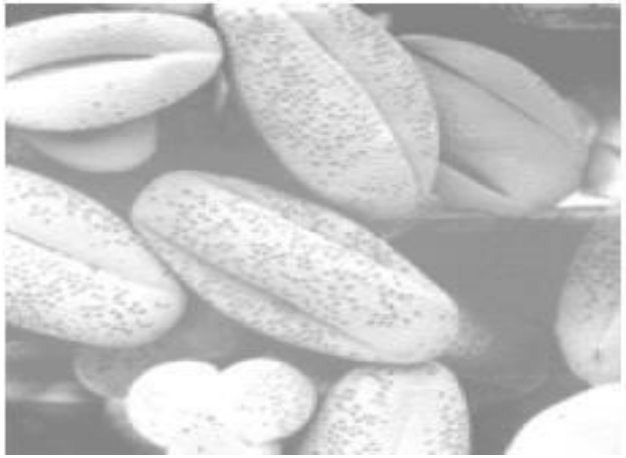
- In an image of low contrast, the image has grey levels concentrated in a narrow band
  - *The grey-levels are not too dark or too bright but in the middle. And it covers only few grey-level intensity range*
- Define the grey-level histogram of an image $h(i)$ where :
  - $h(i)$=number of pixels with grey level = i
- Graphically, the histogram for a specific grey-level will be:

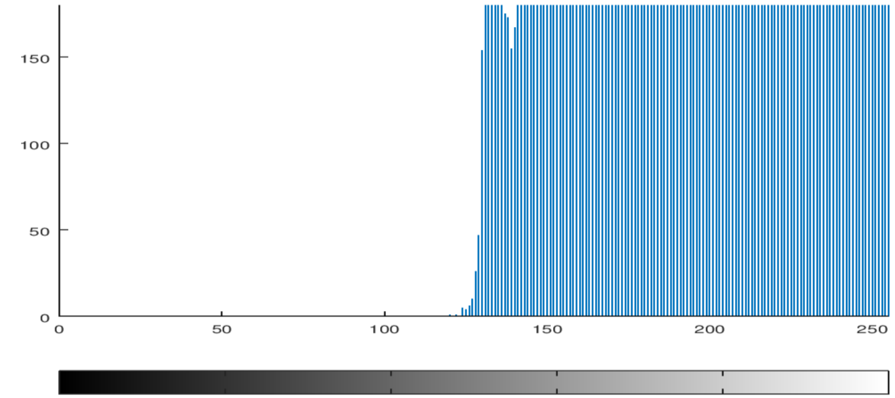


Darker vs Bright Image

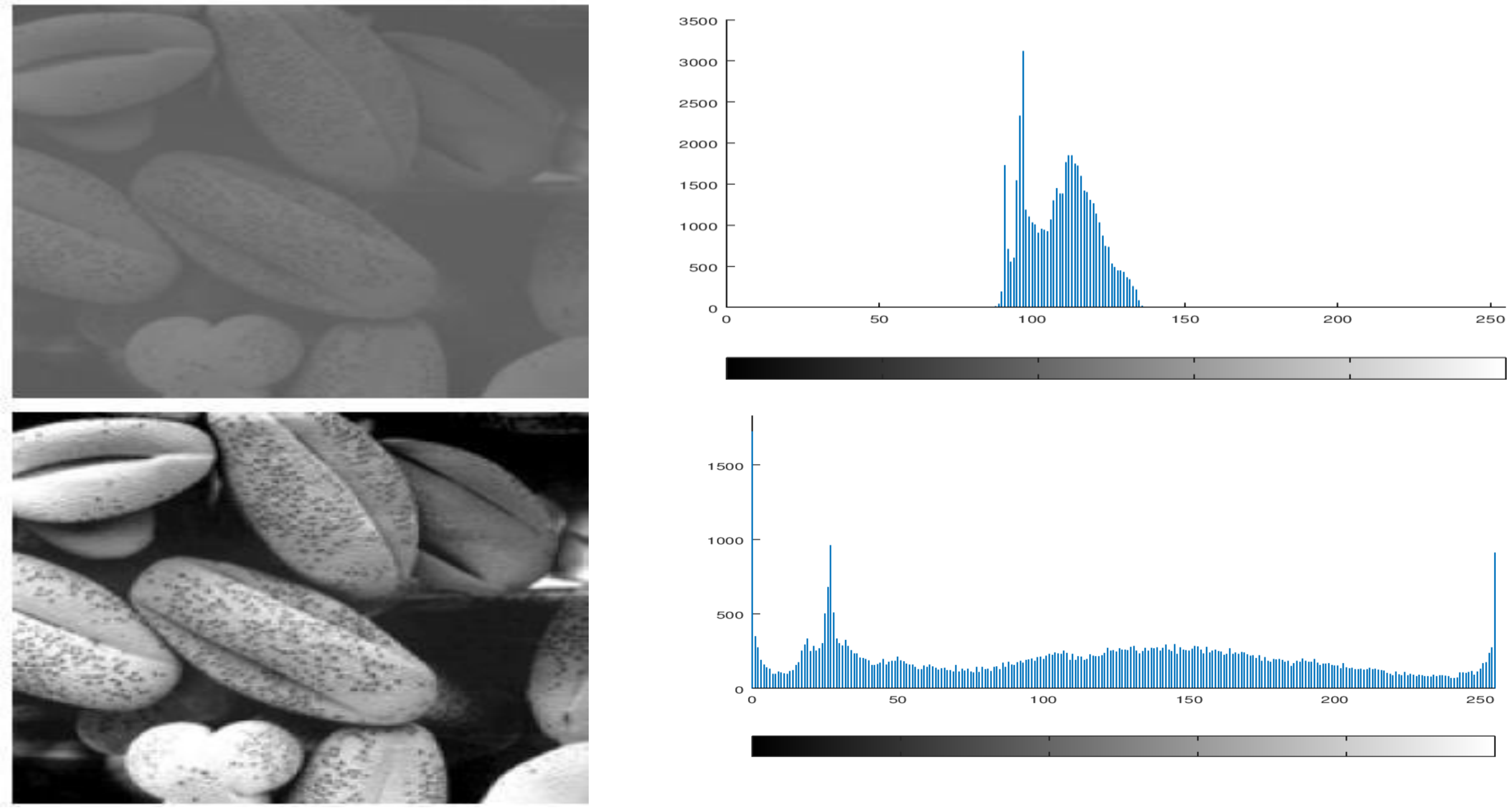








Low vs High Contrast Image



Histogram equalisation

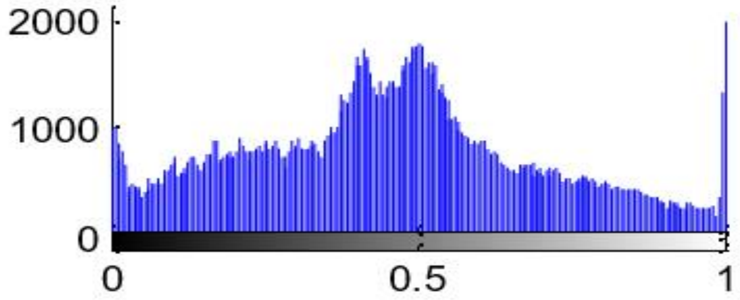
Original

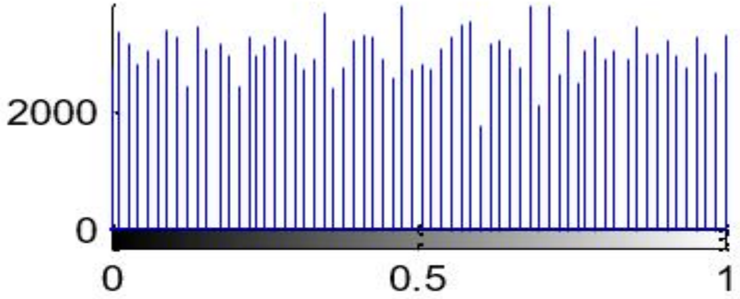
Black/White

Grey Level

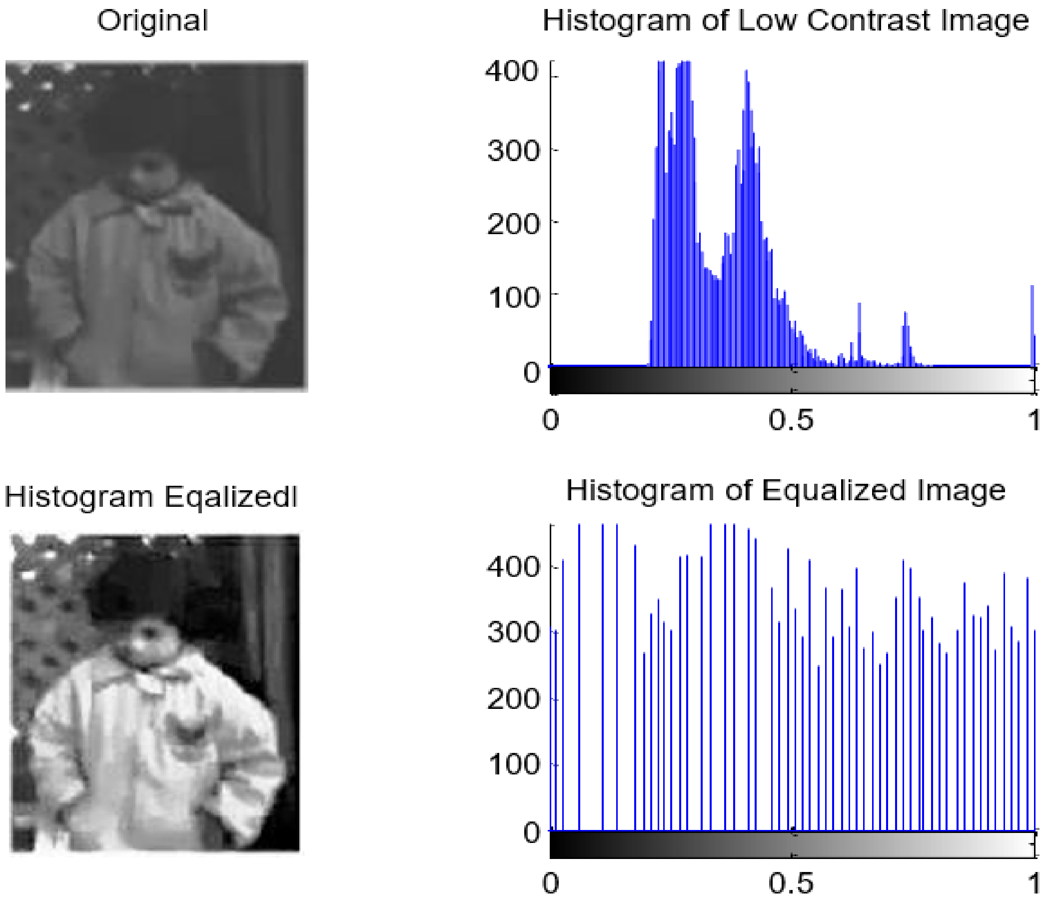
Histogram Equalized

Histogram Equalized Image

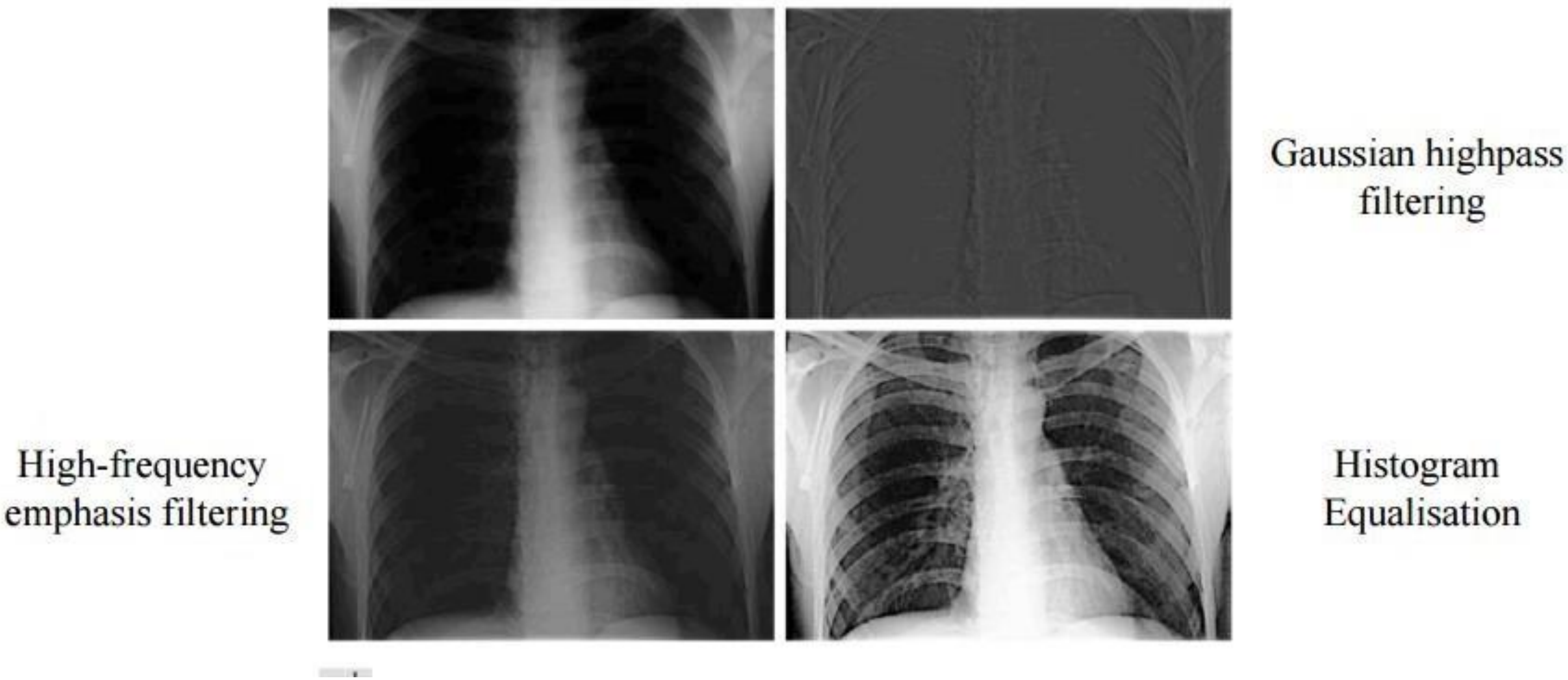




Improving a Low Contrast Image



Histogram equalisation



Grey level transformation

- There are three basic grey level transformation.
  - Linear
  - Logarithmic
  - Power – law
- Linear transformation includes simple ***identity*** and ***negative*** transformation.
  - In Identity transformation, each value of the input image is directly mapped to each other value of output image.That results in the same input image and output image.
  - In negative transformation, each value of the input image is subtracted from the L-1 and mapped onto the output image.

Image Filtering

- Simple image operators can be classified as:
  - **'pointwise'** which changes a pixel independent of the others;
  - **'neighbourhood'** (filtering) which changes the pixel value by consulting some or all of its neighbours
- ***Histogram equalisation is a pointwise operation***
- More general filtering operations use neighbourhoods of pixels

Spatial domain filtering

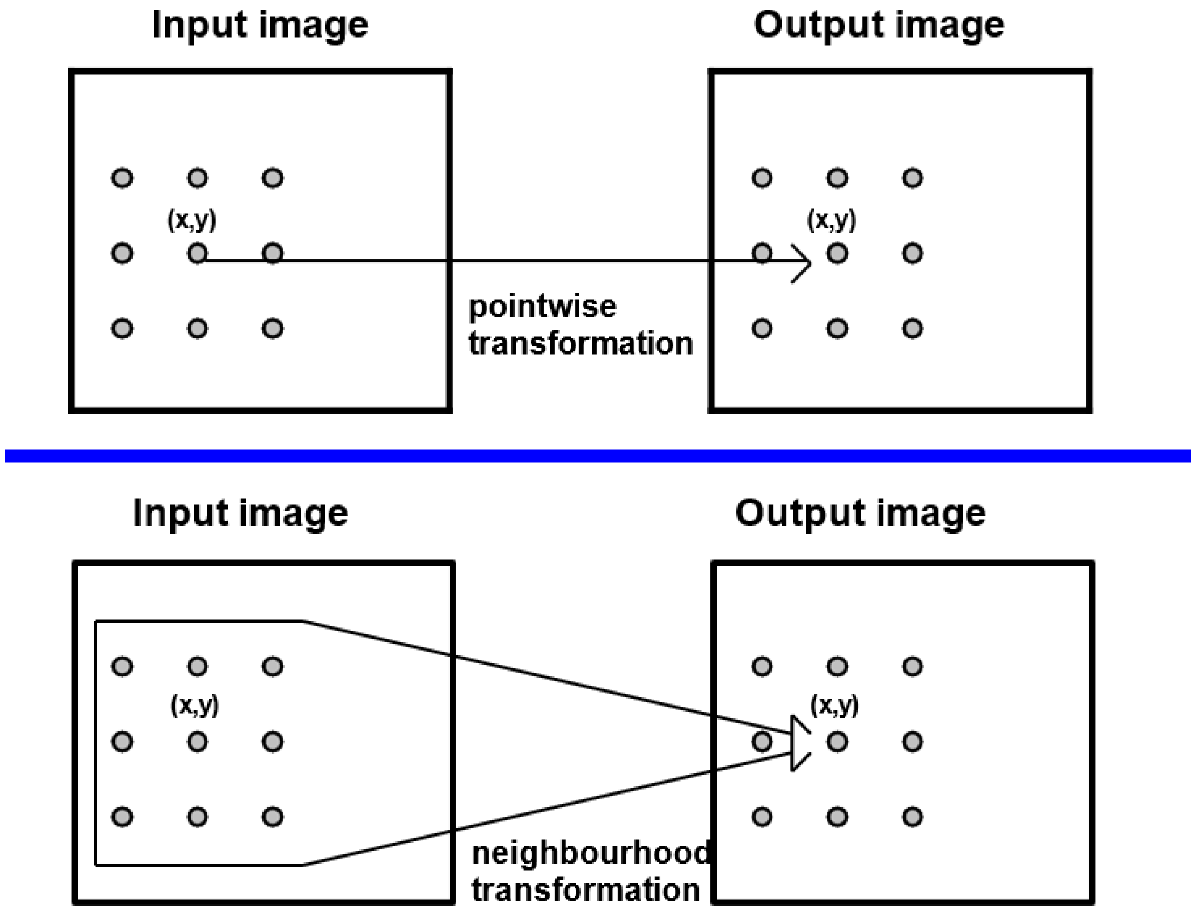
- Some **neighborhood** operations work with
  - the values of the image pixels in the neighborhood, and
  - the corresponding values of a subimage that has the same dimensions as the neighborhood window.
- The subimage is called a **filter** (or mask, kernel, template, window).
- The values in a filter subimage are referred to as **coefficients**, rather than pixels.

Spatial domain filtering

- **Operation**:
  - modify the pixels in an image based on some function of the pixels in their neighborhood.
- **Simplest**:
  - **linear filtering** (replace each pixel by a linear combination of its neighbors).

Linear spatial filtering is often referred to as "convolving an image with a filter".

Image Filtering



Linear filtering and convolution

- Convolution involves:
  1. **overlap**
  2. **multiply**
  3. **add**' with 'convolution mask'

$$H = \begin{pmatrix} \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \\ \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \\ \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \end{pmatrix}$$

Spatial domain filtering

3	3	3
3	3	3
3	3	3

- ❑ What is the value of the center pixel?

3	4	3
2	3	3
3	4	2

- ❑ What assumptions are you making to infer the center value?

Spatial domain filtering

- ❑ Be careful about indices, image borders and padding during implementation.

zero | fixed/clamp | periodic/wrap | reflected/mirror

Border padding examples.

Smoothing spatial filters

- Often, an image is composed of
  - some underlying ideal structure, which we want to detect and describe,
  - together with some random noise or artifact, which we would like to remove.
- Smoothing filters are used for **blurring** and for **noise reduction**.
- Linear smoothing filters are also called **averaging filters**.

Smoothing spatial filters

I

10	11	10	0	0	1
9	10	11	1	0	1
10	9	10	0	2	1
11	10	9	10	9	11
9	10	11	9	99	11
10	9	9	11	10	10

O

X	X	X	X	X	X
X	10				X
X					X
X					X
X					X
X	X	X	X	X	X

F

1/9

1	1	1
1	1	1
1	1	1

1/9.(10x1 + 11x1 + 10x1 + 9x1 + 10x1 + 11x1 + 10x1 + 9x1 + 10x1) =
1/9.(90) = 10

Smoothing spatial filters

I

10	11	10	0	0	1
9	10	11	1	0	1
10	9	10	0	2	1
11	10	9	10	9	11
9	10	11	9	99	11
10	9	9	11	10	10

O

X	X	X	X	X	X
X					X
X					X
X					X
X				20	X
X	X	X	X	X	X

F

1/9

1	1	1
1	1	1
1	1	1

1/9.(10x1 + 9x1 + 11x1 + 9x1 + 99x1 + 11x1 + 11x1 + 10x1 + 10x1) =
1/9.(180) = 20

Order-statistic filters

I

10	11	10	0	0	1
9	$\boxed{10}$	11	1	0	1
10	9	10	0	2	1
11	10	9	10	9	11
9	10	11	9	99	11
10	9	9	11	10	10

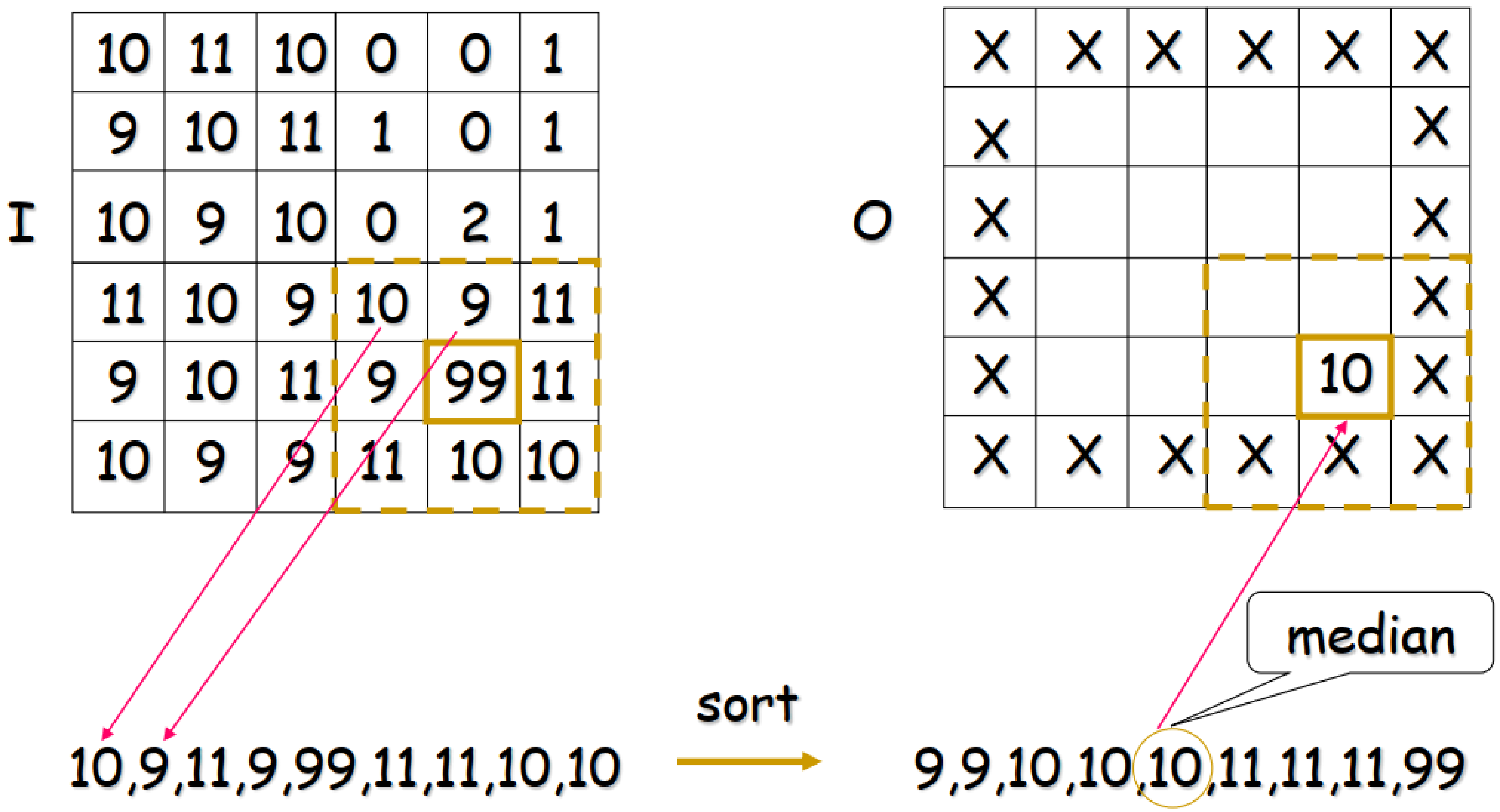
O

X	X	X	X	X	X
X	$\boxed{10}$				X
X					X
X					X
X					X
X	X	X	X	X	X

median

10,11,10,9,10,11,10,9,10 $\xrightarrow{\text{sort}}$ 9,9,10,10,10,10,10,11,11

Order-statistic filters



Common 3x3 Filters

- Low/High pass filter

$$\frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

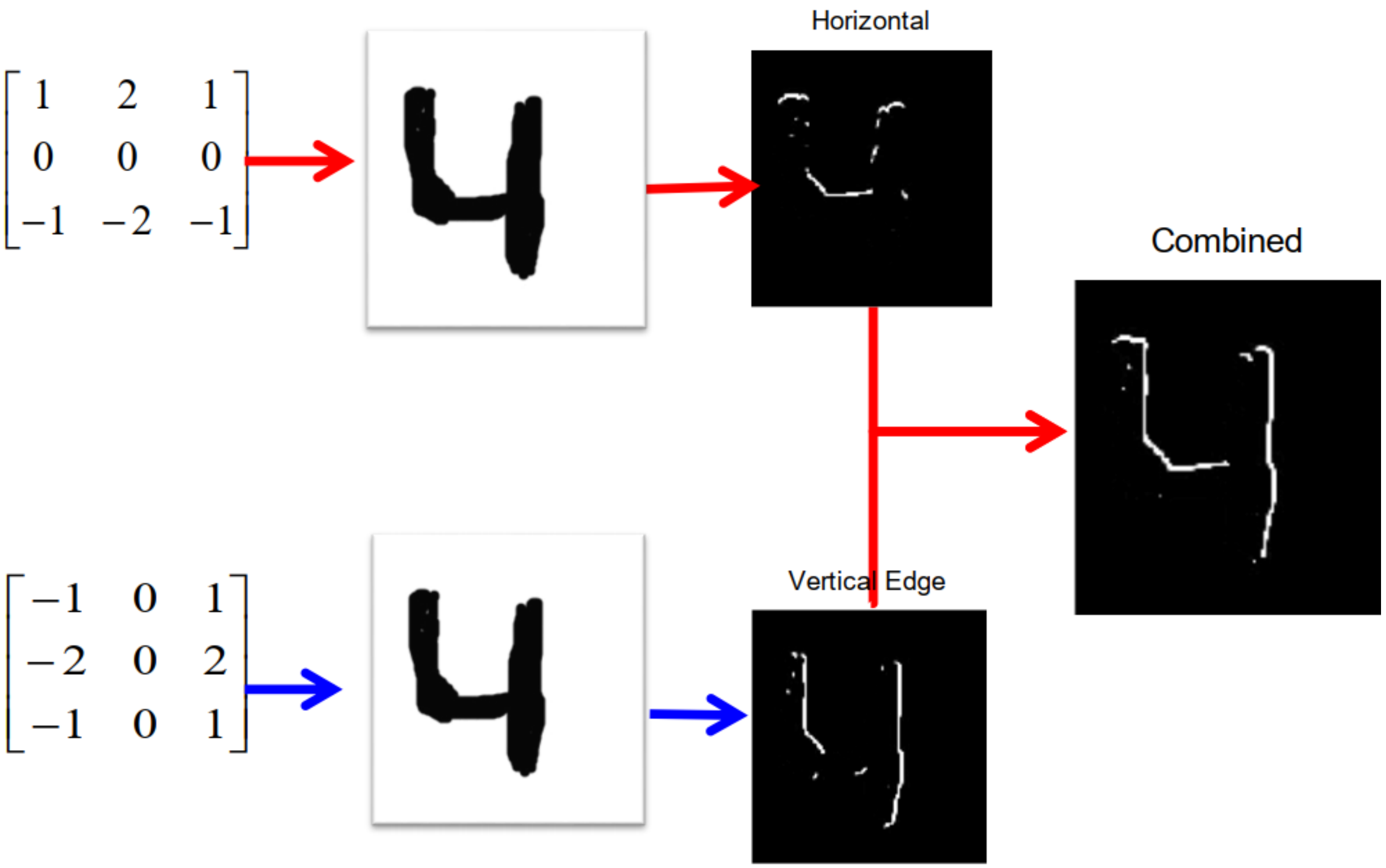
- Blur operator

$$\frac{1}{13}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 1 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

- H/V Edge detector

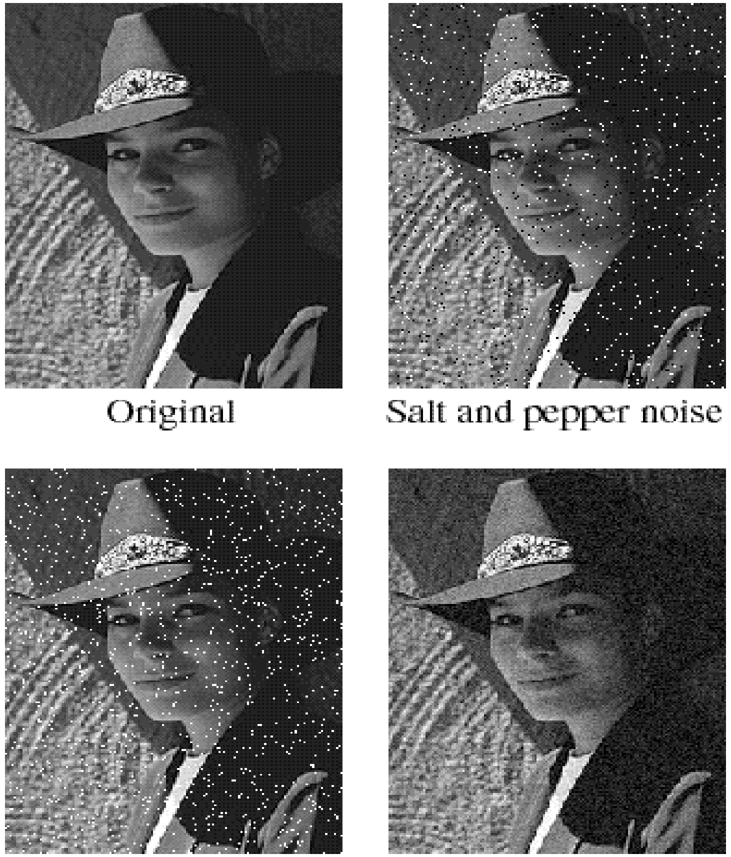
$$\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

Edge Detection



Smoothing spatial filters

- Common types of noise:
  - Salt-and-pepper noise: contains random occurrences of black and white pixels.
  - Impulse noise: contains random occurrences of white pixels.
  - Gaussian noise: variations in intensity drawn from a Gaussian normal distribution.



Original | Salt and pepper noise | Impulse noise | Gaussian noise

Linear filtering and convolution

Original

Noisy

Filtered

σ=1.5

Filtered

σ=3.0

Conclusion

- We have looked at basic (low level) image processing operations
  - Enhancement
  - Filtering
- These are usually important pre-processing steps carried out in computer vision systems

The End