Image Processing in Spatial Domain

- Spatial domain refers to the image plane itself and image processing methods in this category are based on direct manipulation of pixels in an image.

- The spatial domain processes can be denoted by the expression.

$$g\,(x,y) = T[f(x,y)]$$

where $f(x,y)$ is the input image, $g\,(x,y)$ is the output image, and T is an operator on f defined over a neighbourhood of a point (x,y).

=

conv

-1	0	+1
-2	0	+2
-1	0	+1

Transformation function

$$g\,(x,y) = T[f\,(x,y)]$$

When T depends only on the central pixel, or the pixel of interest , we can call T as a **point operator**. If T also depends on the neighbouring pixels then we can call T as a **mask operator**.

=

conv

-1	0	+1
-2	0	+2
-1	0	+1

⟸ Mask operator

=

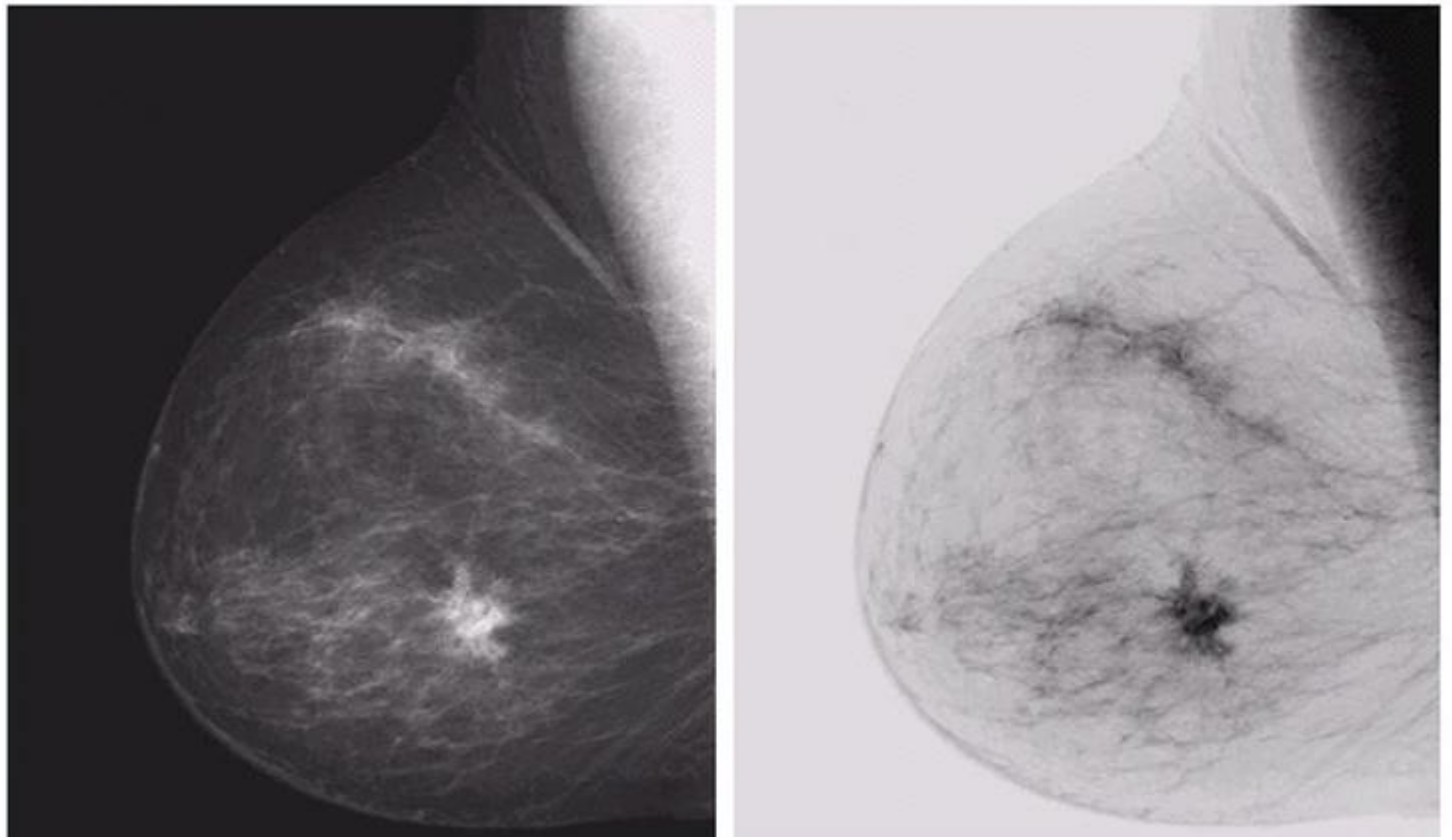
255 -

⟸ Point operator

Image Negatives

The negative of an image with intensity levels in the range $[0, L-1]$ is obtained by using the negative transformation as shown below

$$s = L - 1 - r$$



a b

FIGURE 3.4 (a) Original digital mammogram. (b) Negative image obtained using the negative transformation in Eq. (3.2-1). (Courtesy of G.E. Medical Systems.)

Image source : Gonzalez and Woods

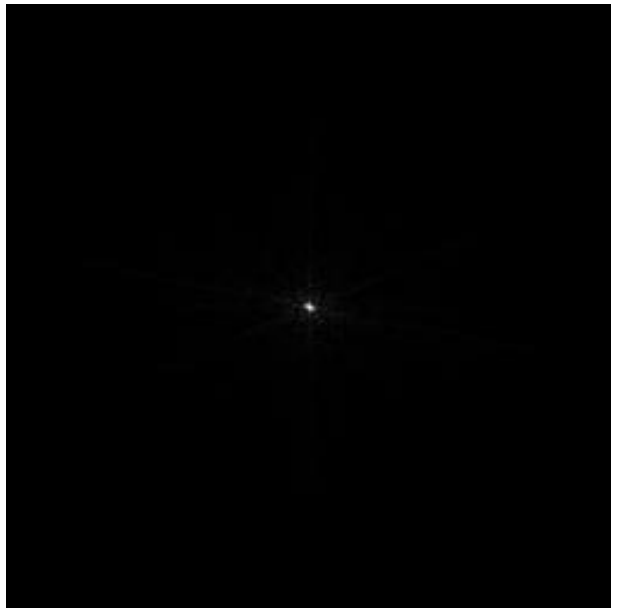
Log Transformations

The general form of log transformation is:

$$s = c \log(1 + r)$$

Where c is a constant and it is assumed that $r \geq 0$.

Log transformation maps a narrow range of low intensity values in the input into a wider range of output levels.



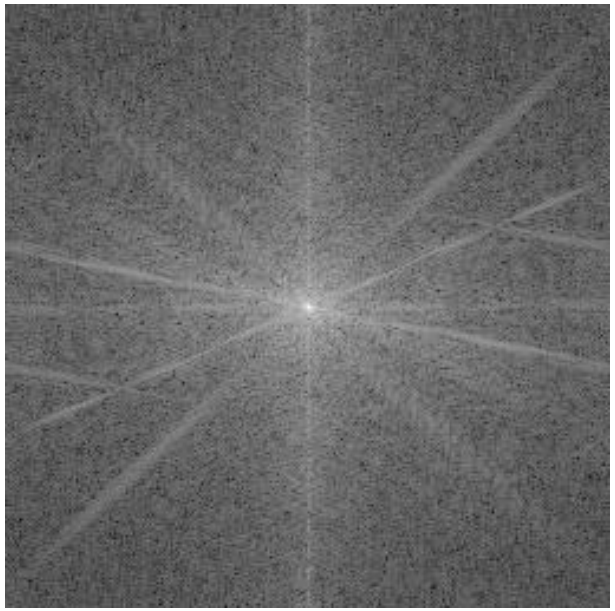
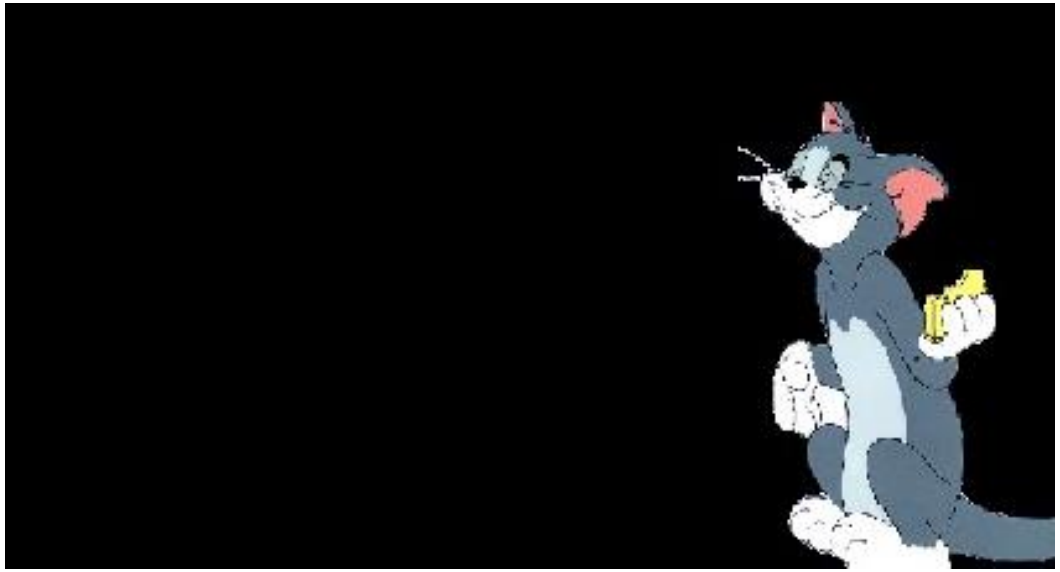


Image Addition



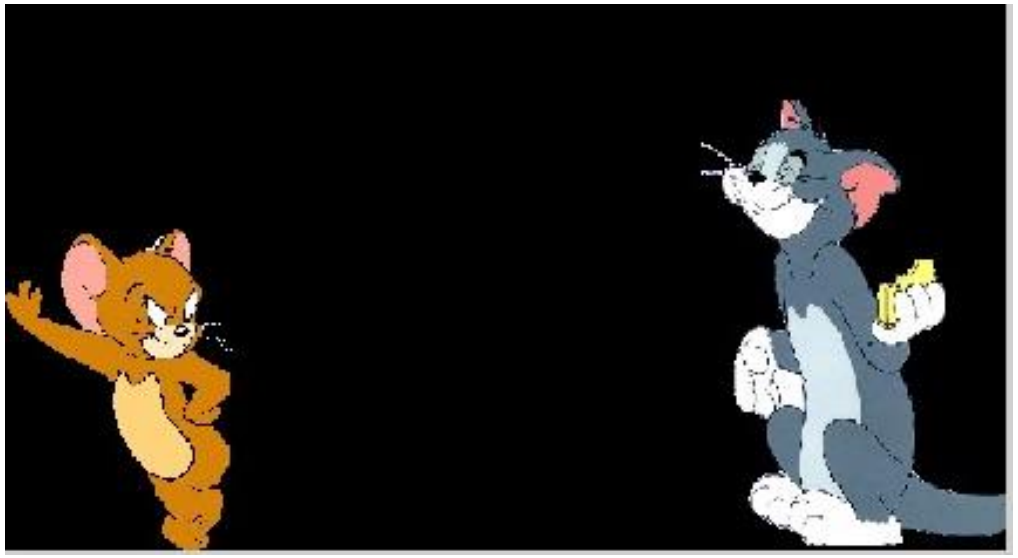
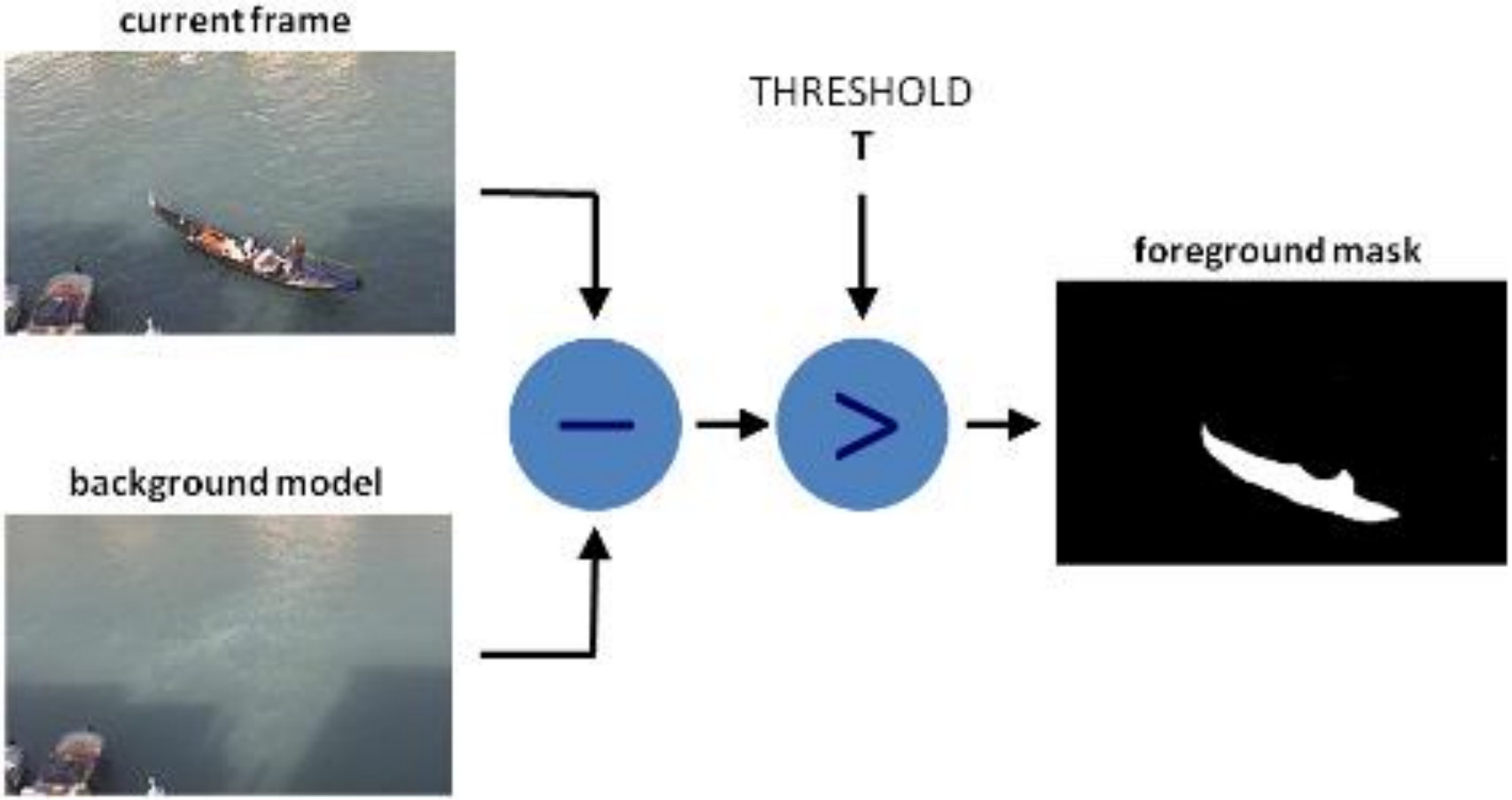


Image Subtraction



https://docs.opencv.org/master/d1/dc5/tutorial_background_subtraction.html

Thresholding

- Input values below **threshold** a_{th} set to a_0
- Input values above **threshold** a_{th} set to a_1

$$f_{\text{threshold}}(a) = \begin{cases} a_0 & \text{for } a < a_{\text{th}} \\ a_1 & \text{for } a \geq a_{\text{th}} \end{cases}$$

- Converts grayscale image to binary image (binarization) if
  - $a_0 = 0$
  - $a_1 = 1$

Thresholding Example

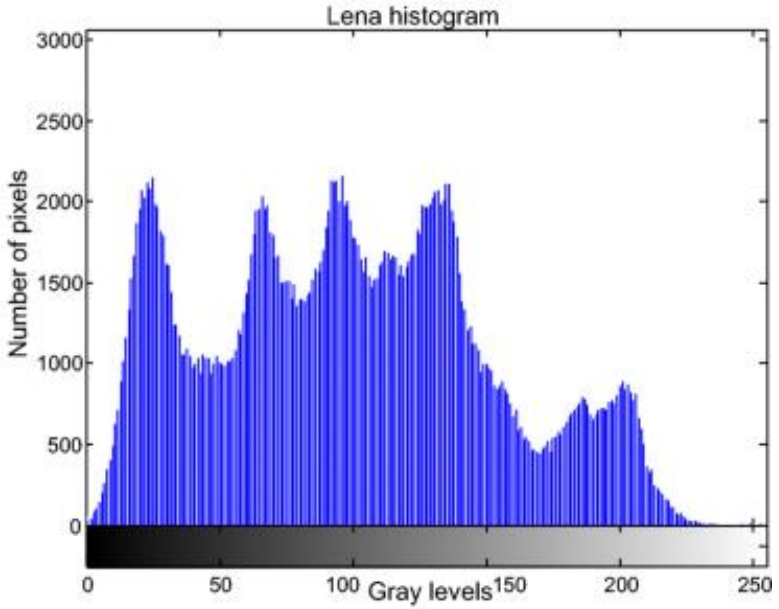
Original Image

Thresholded Image

Image Histogram

Image histogram plots how many times (frequency) each intensity values occur in the image.

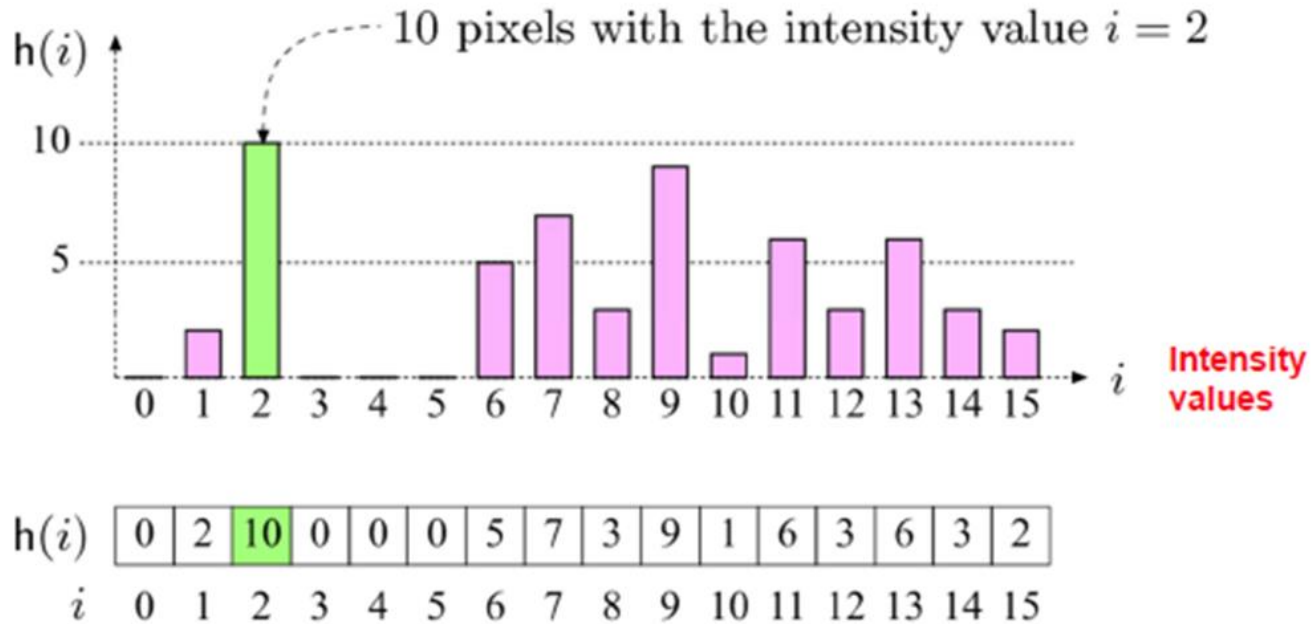
(a)



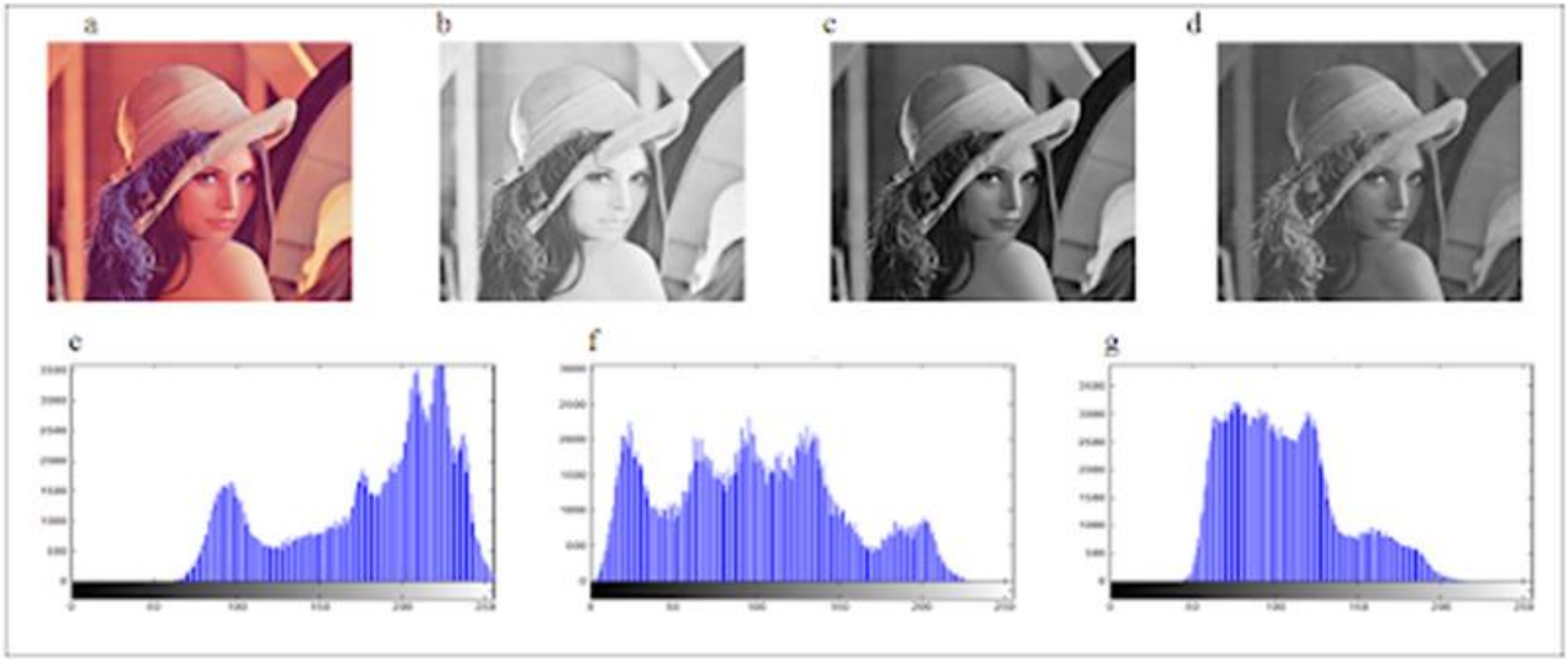
(b)

```
[m n] = size(A)
H[0:255] =0;
for i = 1:m
    for j = 1:n
        x = A(i,j)
        H(x) = H(x)+1;
    end
end
```

Histograms



- E.g. K = 16, 10 pixels have intensity value = 2
- Histograms: only statistical information
- No indication of **location** of pixels


a
b
c
d
e
f
g

Histograms

- Different images can have **same** histogram
- 3 images below have same histogram

- Half of pixels are gray, half are white
  - Same histogram = same statisics
  - Distribution of intensities could be different
- Can we reconstruct image from histogram? No!

Histograms

- Histograms help detect image acquisition issues
- Problems with image can be identified on histogram
  - Over and under exposure
  - Brightness
  - Contrast
  - Dynamic Range
- Point operations can be used to alter histogram. E.g
  - Addition
  - Multiplication
  - Exp and Log
  - Intensity Windowing (Contrast Modification)