Computer Vision and Image Processing (CSEL-393)

Lecture 4

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Image

- **Zooming**: Process of looking at the details of the image by enlarging the image.
- **Pixel**: Stores the value proportional to the light intensity at that particular location
- **Pixel Resolution (Total Pixel):** Number of rows x Number of columns
- Increase in pixel resolution results in more clear image (mage is more near to the real image i.e. analog image) when we zoom an image. Its drawback is computation is expensive

Image properties

- **Pixel Resolution**: total number of pixels in an image i.e. ***Number of rows (M) x Number of Columns (N)*** also denoted as ***Height x width***
- Mega Pixels :

Number of rows (M) x Number of Columns (N) /10 Lac

- Example:
- If an Image has dimensions 2500*3192
  - ***Number of rows (M)=2500***
  - ***Number of Columns (N)=3192***
- Pixels Resolution= ***Number of rows (M) x Number of Columns (N)***
  7982350 bytes
- Dividing it by 1 million = 7.9= 8 mega pixels (approx)
- Size of an image is defined as : M x N x bpp (bits per pixels)
- Bpp: how many bits are required to represent a pixel. High bbp-> quality is improved

Aspect Ratio

- Relationship between height and width of an image
- Example
  - Aspect ratio of an image= 6:2
    = 6(for width):2 (height)
  - Pixel resolution of an image= 480000
  - Bpp: 8
  - Question: calculate dimension of an image
  - Question: calculate size of an image

Aspect Ratio

Calculating dimension of an Image

Eq-1: c:r=6:2 → c=6 * r /2

Eq-2: c= 480000/r

Comparing Eq-1 and Eq-2

6 * r/2= 480000 /r

r^2= (480000 *2)/6

r=sqrt((480000 *2)/6)

r=400

Putting r value in eq-2

c=1200

Hence dimension= 400x1200

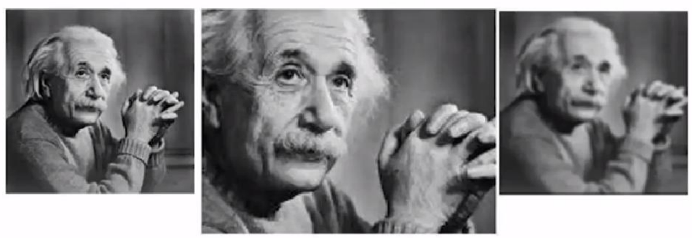
Calculating size of an Image

Size of an image= rows x col x bpp=400*1200*8=3840000 bit

Size of an image in bytes = 480000 bytes= 48 KB

Spatial Resolution

- Pixel resolution= rows * cols
- Clarity of an image cannot be determined by the pixel resolution.
- Spatial Resolution: Smallest visible detail in an image. i.e., number of independent pixels values per inch.



Spatial Resolution

- Spatial Resolution: Smallest visible detail in an image. i.e., number of independent pixels values per inch. It is determined by how sampling was carried out
- Types of Spatial resolution:
  - **Pixel size:** computer vision
  - **Dots per inch or DPI** (usually used in monitor): Graphics Designers
  - **Lines per inch or LPI :** Laser printers as these draw lines while printing
  - **Pixel per inch or PPI** : smart devises as tablets, Mobile phones etc.

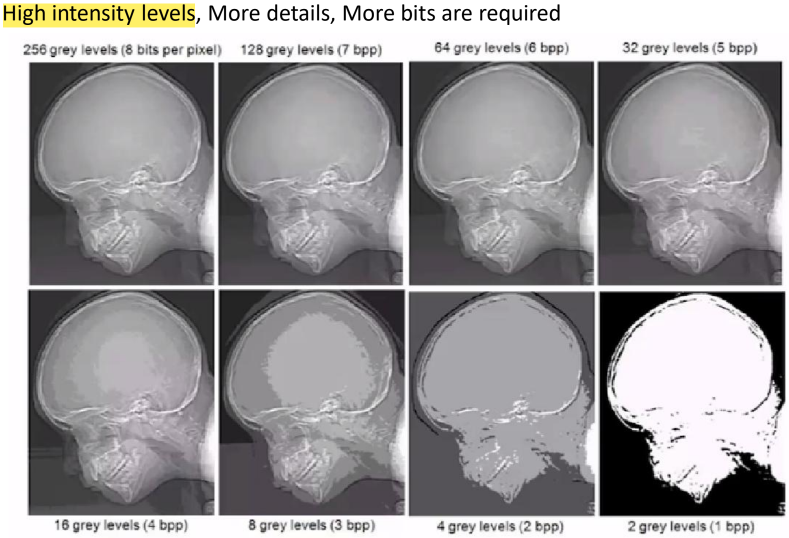
Intensity Level Resolution

- Intensity level resolution refers to the number of intensity levels used to represent the image. Finer level of details are obtained if we use more intensity levels.
- Intensity level resolution is usually given in terms of the number of bits used to store each intensity level . More bits used more intensity levels would require more computation

Bits	Intensity Levels	Example
1	2	0,1
2	4	00, 01, 10, 11
4	16	0000, 0001, 0101, 1111, …
8	256	00110011, 01010101, …
16	65536	1010101010101010, …

Intensity Level Resolution

Low Intensity Level: Low details, less bits are required
High intensity levels, More details, More bits are required



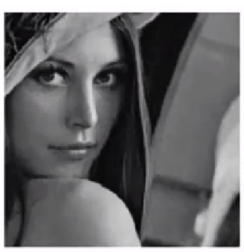
How much Resolution is ENOUGH

- What is average image quality acceptable to develop the applications
- Does the image look aesthetically pleasing? Can you see what you need to see within the image?.
- Depends on the scope of the problem which we are solving

Recognize Number plate

Count Vehicles

How much Resolution is ENOUGH



Low Detail

Medium Detail

High Detail

Image Enhancement

- Process of improving the quality of an image so that we can understand images, extract features features from the images
- Reasons :
  - Highlights interesting detail in images: sharpen the boundaries of an objects so that these can be differentiated
  - Removing noise from images: remove unwanted information
  - Making images more visually appealing
  - Categories of image enhancement techniques
    - Spatial domain techniques: Direct manipulation of image pixels
    - Frequency domain techniques: Manipulation of Fourier transform or wavelet transform of an image

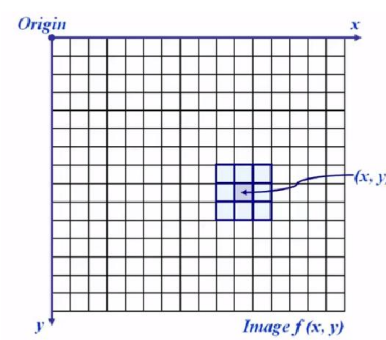
Image Enhancement in Spatial Domain

- In spatial domain an operation (linear or non-linear) is performed on the pixels in the neighborhood of coordinate (x,y) in the input image F(x,y), giving enhanced image g(x,y).
- Image is defined as two variable x and y as F(x,y)
- Image is defined as F(X,Y)
  - X--> Spatial coordinates x,y
  - Y→ Color
- Small box is Filter
- Neighborhood can be any shape but generally it is rectangular (3x3, 5x5, 9x9 etc)

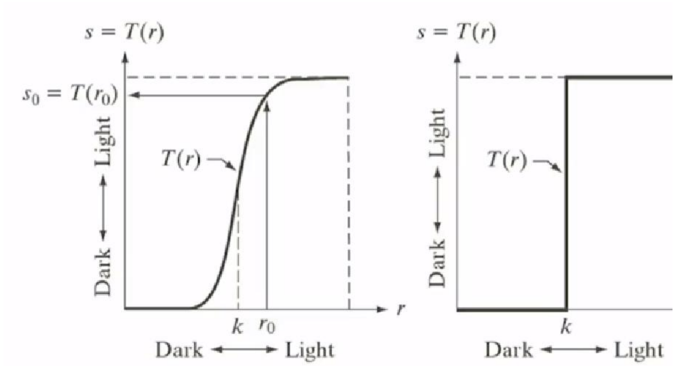
g(x,y) = T[f(x,y)]

We are given an image f(x,y) and we want to apply a transformation i.e. T to improve the quality of an image. The resultant image will received as g(x,y)

. Hence g(x,y) is the enhanced image or transformed image



Intensity Transformation



Grey Scale Manipulation

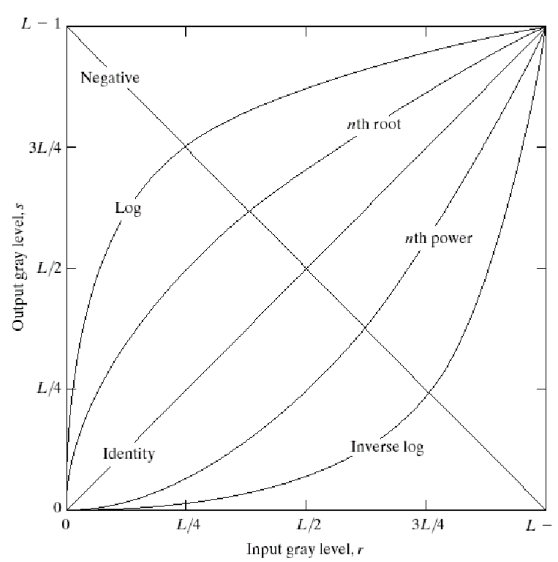
- Simplest form of window (1x1)
- Assume input gray scale values (r) are in range [0, L-1] (in 8 bit images L = 256)

Intensity Transformation

- Types of Transformation: for gray scale images there are three transformations
  - Linear Transformation
  - Log Transformation
  - Power Law Transformation

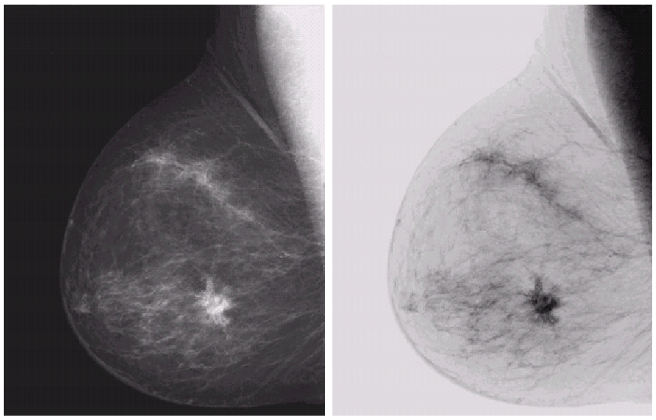
Grey Scale Manipulation

FIGURE 3.3 Some basic gray-level transformation functions used for image enhancement.



- Linear: Negative, Identity
- Logarithmic: Log, Inverse Log
- Power-Law: *n*th power, *n*th root

Image Negative



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 Negative: $s = L - 1 - r$

Log Transformation

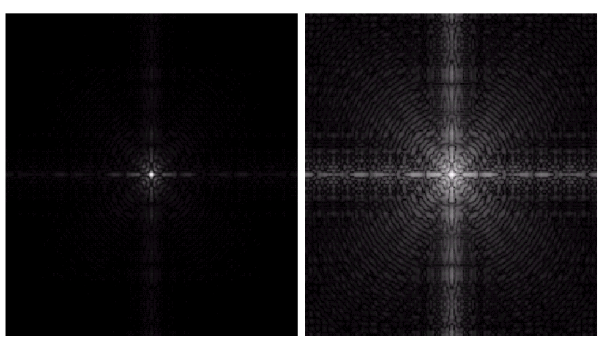
$$s = c \log(1+r)$$

c: constant

- Compresses the dynamic range of images with large variations in pixel values
- Useful when the input gray level values may have extremely large range of values

a b

FIGURE 3.5 (a) Fourier spectrum. (b) Result of applying the log transformation given in Eq. (3.2-2) with $c = 1$.



Power Law Transformation

- $s = cr^{\gamma}$
- C, γ : positive constants
- Gamma correction
- Maps a narrow range of dark input values into a wider range of output values or vice versa

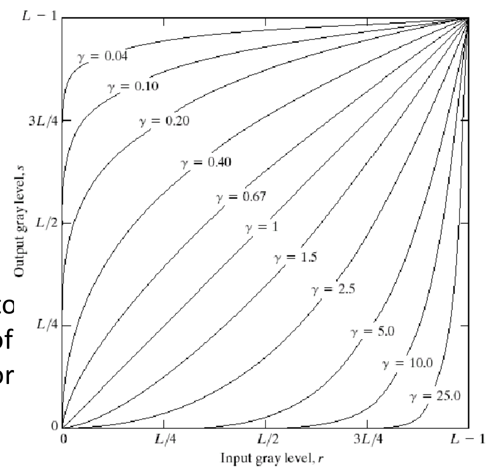
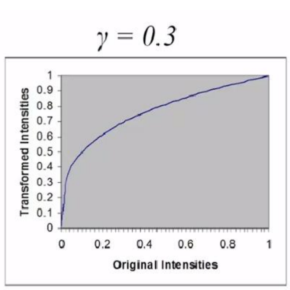


FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases).

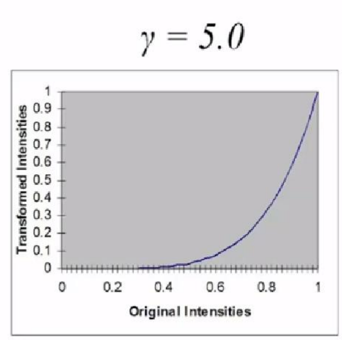
Example of Power Law Transformation

Maps a narrow range of dark input values into a wider range of output values or vice versa



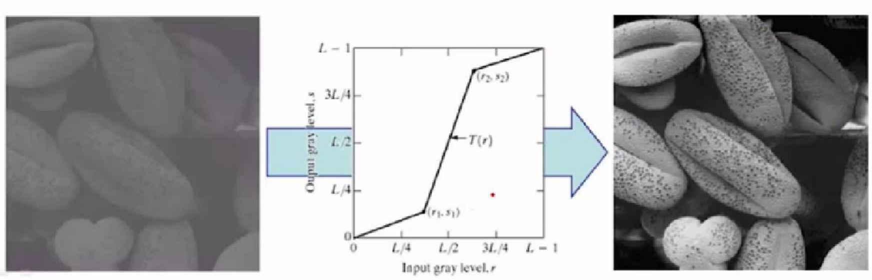
Example of Power Law Transformation

Maps a narrow range of dark input values into a wider range of output values or vice versa



Piecewise Linear Transformation

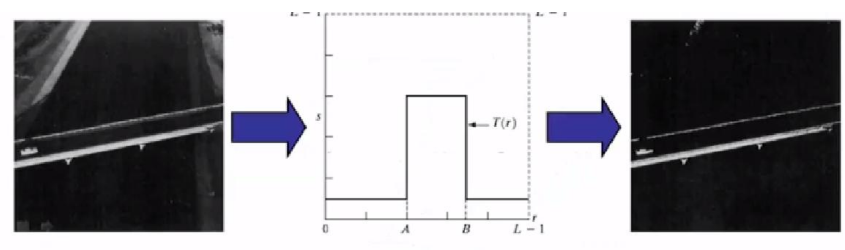
- Instead of applying a well defined mathematical formula on complete image, we arbitrary user defined transform.



Above example show contrast stretching linear transform to add contrast to a poor quality image

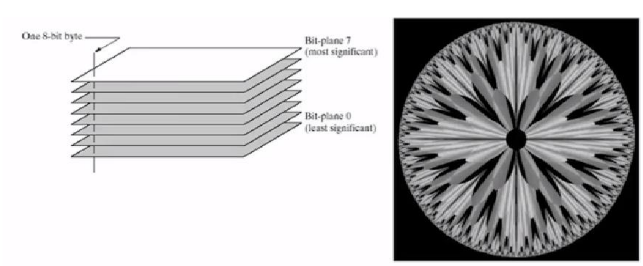
Piecewise Linear Transformation

- Highlights a specific range of grey level
- Similar to thresholding
- Other levels can be suppressed or maintained
- Useful for highlighting features in an image



Bit Plan Slicing

- We can highlight interesting aspects of image by isolating particular bits of the pixel values in an image.
  - Higher-order bits usually contain most of the significant visual information (e.g. 00000001, 10000001)
  - Lower-order bits contain slight details



Bit Plan Slicing

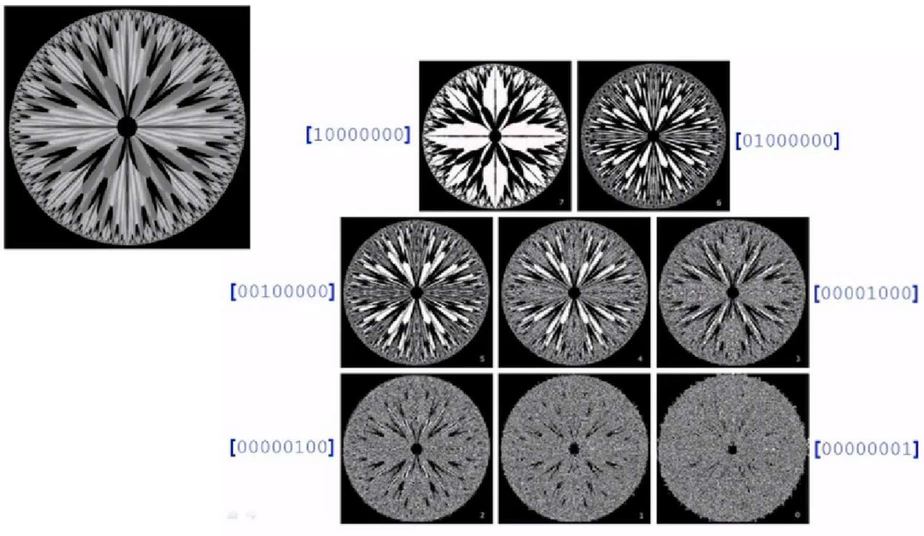


Image Histogram

- The histogram of an image shows us the distribution of grey levels in the image
- Useful in image processing, especially in Segmentation

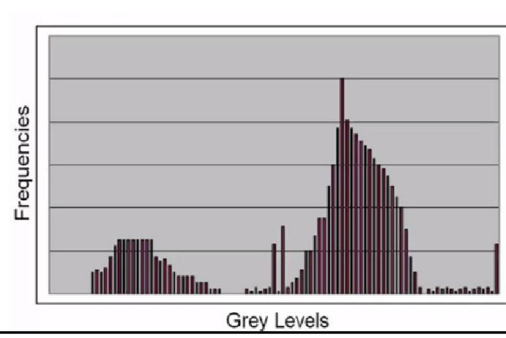
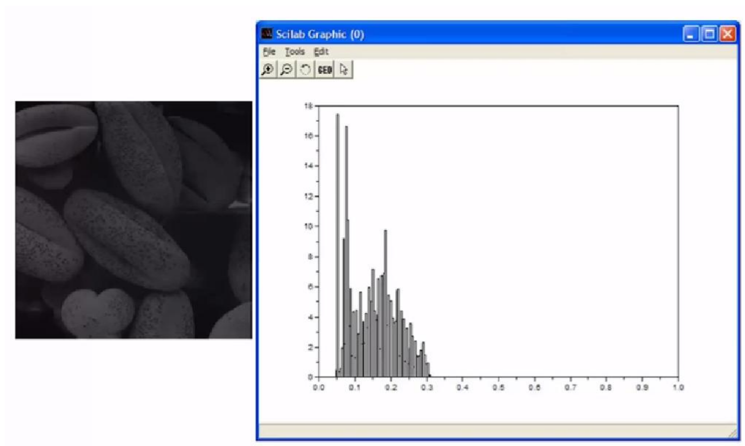


Image Histogram

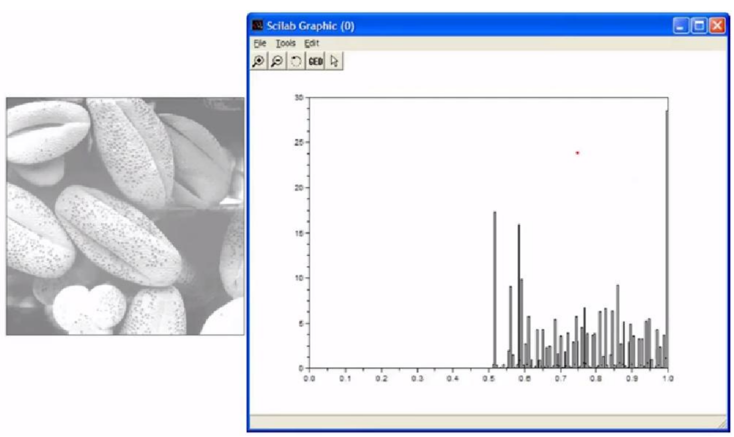
Majority of the intensity values are towards 0 that means black



Intensity Values ranges from 0 to 1.
0.5 means middle of t=intensity range having gray color

Image Histogram

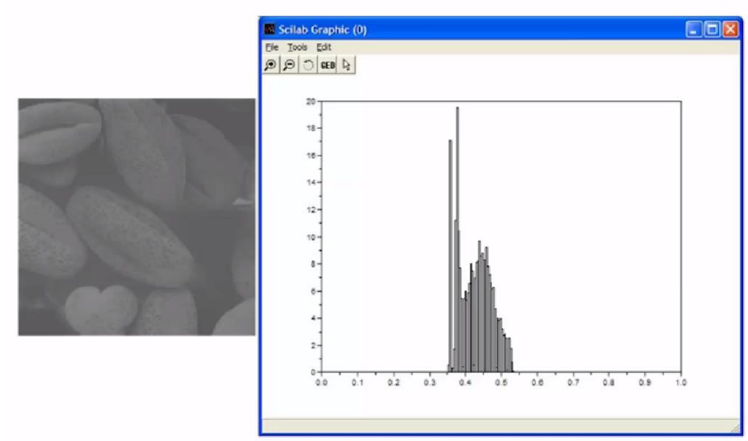
Majority of the intensity values are towards 1 that means white



Intensity Values ranges from 0 to 1.
0.5 means middle of t=intensity range having gray color

Image Histogram

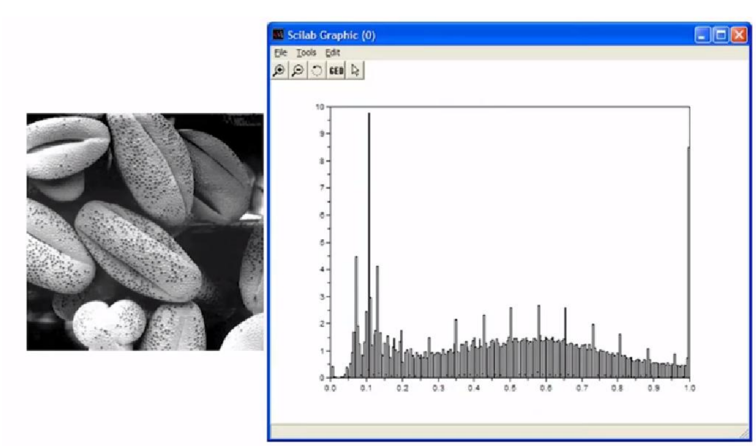
Majority of the intensity values are towards middle of 0 and 1 that means gray scale



Intensity Values ranges from 0 to 1.
0.5 means middle of t=intensity range having gray color

Image Histogram Equalization

Equalize intensities



Intensity Values ranges from 0 to 1.
0.5 means middle of t=intensity range having gray color

Histogram Equalization

- Contrast Stretching
- We can fix images that have poor contrast by applying a pretty simple contrast specification
- The interesting part is how do we decide on this transformation function?
  - Histogram equalization

Histogram Equalization Example

Gray Levels (Rk)	F
0	8
1	10
2	10
3	2
4	12
5	16
6	4
7	2
N	64

Histogram Equalization Example

Gray Levels (Rk)	F	P=F/N
0	8	0.125
1	10	0.15625
2	10	0.15625
3	2	0.03125
4	12	0.1875
5	16	0.25
6	4	0.0625
7	2	0.03125
N	64	

Histogram Equalization Example

Gray Levels (Rk)	F	P=F/N	Cm= Current + Sum of all previous intensities P
0	8	0.125	0.125
1	10	0.15625	0.28125
2	10	0.15625	0.4375
3	2	0.03125	0.46875
4	12	0.1875	0.65625
5	16	0.25	0.90625
6	4	0.0625	0.96875
7	2	0.03125	1
N	64		

Histogram Equalization Example

Gray Levels (Rk)	F	P=F/N	Cm= Current + Sum of all previous intensities P	New Gray Level L^= L-1 (7 in this example) x CM
0	8	0.125	0.125	0.875
1	10	0.15625	0.28125	1.96875
2	10	0.15625	0.4375	3.0625
3	2	0.03125	0.46875	3.28125
4	12	0.1875	0.65625	4.59375
5	16	0.25	0.90625	6.34375
6	4	0.0625	0.96875	6.78125
7	2	0.03125	1	7
N	64			

Histogram Equalization Example

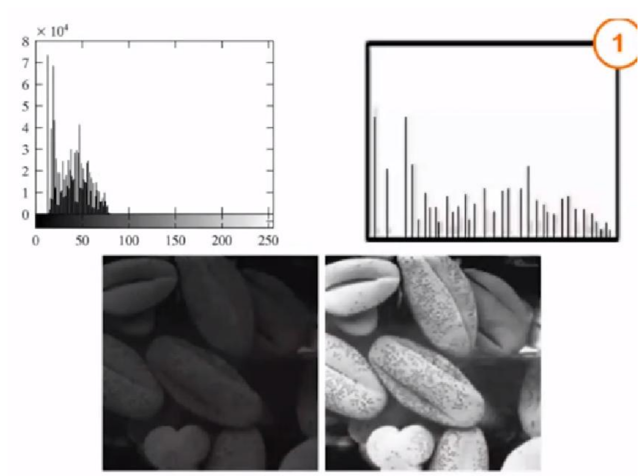
Gray Levels (Rk)	F	P=F/N	Cm= Current + Sum of all previous intensities P	New Gray Level L^= L-1 (7 in this example) x CM	New Gray Level Round Off
0	8	0.125	0.125	0.875	1
1	10	0.15625	0.28125	1.96875	2
2	10	0.15625	0.4375	3.0625	3
3	2	0.03125	0.46875	3.28125	3
4	12	0.1875	0.65625	4.59375	5
5	16	0.25	0.90625	6.34375	6
6	4	0.0625	0.96875	6.78125	7
7	2	0.03125	1	7	7
N	64				

Histogram Equalization Example

Gray Levels (Rk)	F	P=F/N	Cm= Current + Sum of all previous intensities P	New Gray Level L^= L-1 (7 in this example) x CM	New Gray Level Round Off	OLD Gray Levels	Number of Pixels
0	8	0.125	0.125	0.875	1	0	8
1	10	0.15625	0.28125	1.96875	2	1	10
2	10	0.15625	0.4375	3.0625	3	2	10
3	2	0.03125	0.46875	3.28125	3	3	2
4	12	0.1875	0.65625	4.59375	5	4	12
5	16	0.25	0.90625	6.34375	6	5	16
6	4	0.0625	0.96875	6.78125	7	6	4
7	2	0.03125	1	7	7	7	2
N	64						

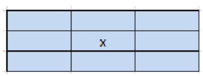
Draw frequency graph of both with and without Histogram equalization

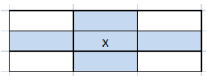
Histogram Equalization Example

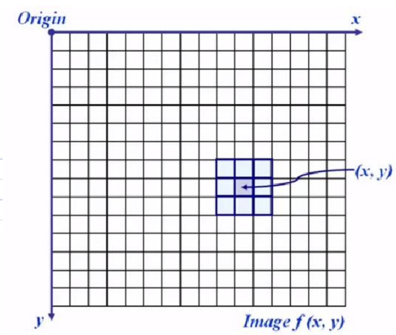


Spatial Filtering

- Neighborhood operations simply operate on a larger neighborhood of pixels than point operations
- Neighborhoods are mostly a rectangle around a central pixel
- Any size rectangle and any shape filter are possible. Usually symmetric i.e. odd window size i.e. 3x3, 5x5, 9x9
- 4 connectivity
- 8 Connectivity







Spatial Filtering

- Image enhancement operations can also 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.
- The **subimage** is called a **filter mask**, **kernel**, **template**, or **window**.
- The values in a filter subimage are referred to as **coefficients**, rather than pixels.
- The process consists simply of moving the filter mask from point to point in an image.
- For linear spatial filtering, the response is given by a sum of products of the filter coefficients and the corresponding image pixels in the area spanned by the filter mask

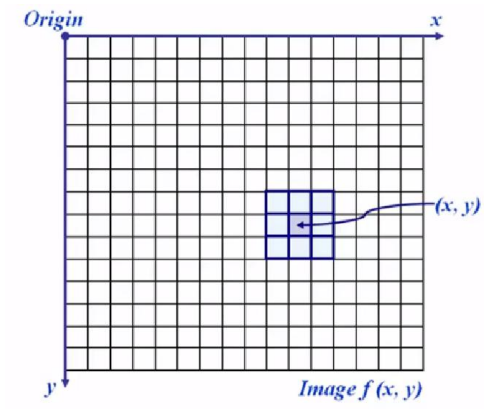
Neighbourhood operations

- Some simple neighbourhood operations include:
- **Min**: Set the pixel value to the minimum in the neighbourhood
- **Max**: Set the pixel value to the maximum in the neighbourhood
- **Median**: The median value of a set of numbers is the midpoint value in that set

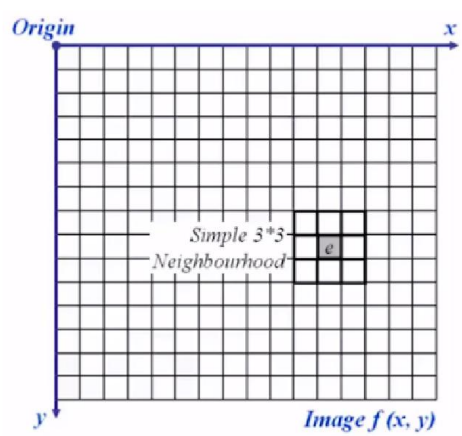
Neighbourhood operations

- Some simple neighbourhood operations include:
- **Min**: Set the pixel value to the minimum in the neighbourhood: when image intensities values are towards blackish
- **Max**: Set the pixel value to the maximum in the neighbourhood: when image intensities values are towards whitish
- **Median**: The median value of a set of numbers is the midpoint value in that set : when image intensities values are towards middle range
- Other filters: Average filter i.e. mean filter, Gaussian etc.

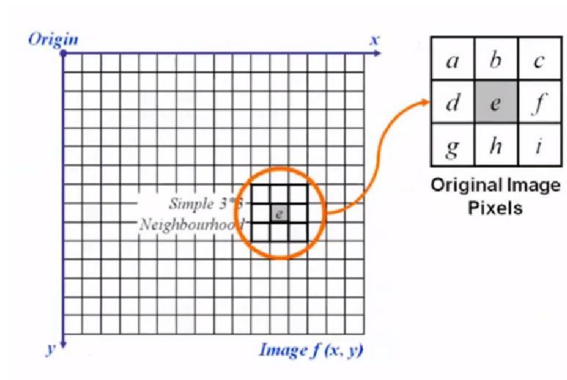
Spatial Filter Process



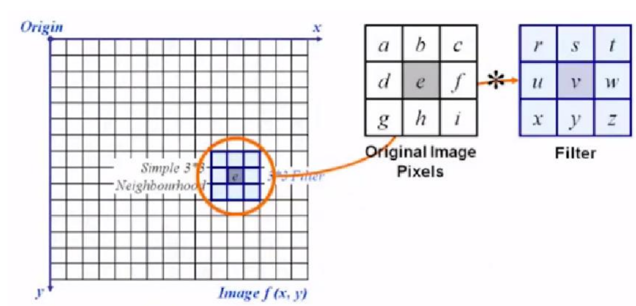
Spatial Filter Process



Spatial Filter Process

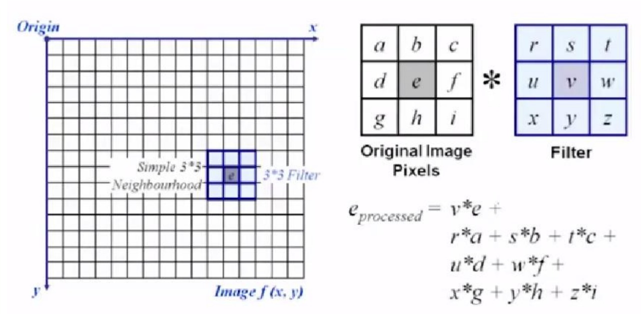


Spatial Filter Process

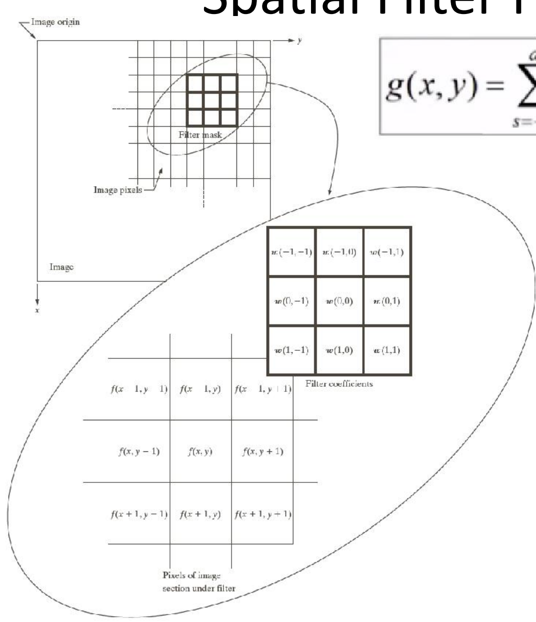


Spatial Filter Process

Sum of Product Operations (SoP)



Spatial Filter Process



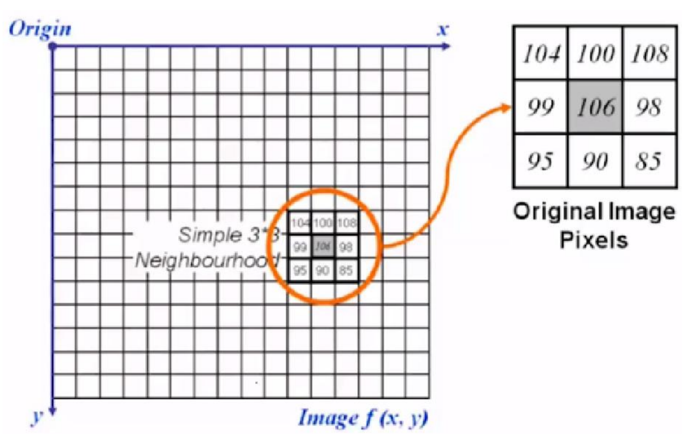
$$g(x, y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t) f(x+s, y+t)$$

Smoothing Spatial Filter

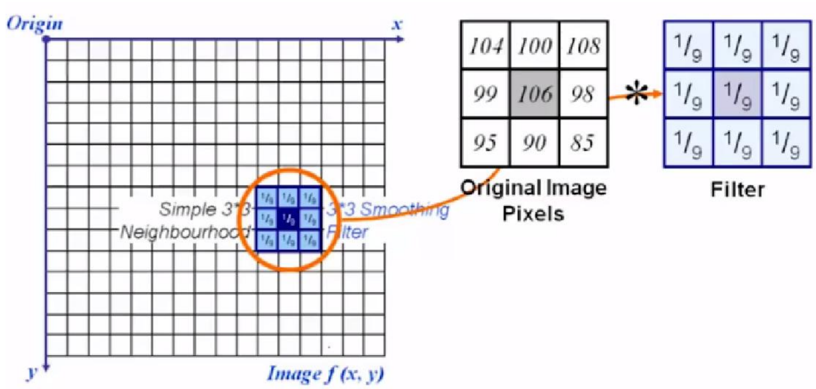
$^1/_9$	$^1/_9$	$^1/_9$
$^1/_9$	$^1/_9$	$^1/_9$
$^1/_9$	$^1/_9$	$^1/_9$

- One of the simplest spatial filtering operations we can perform is a smoothing operation
  - Simply average all of the pixels in a neighbourhood around a central value
  - Especially useful in removing noise from images
  - Also useful for highlighting overall details of image

Smoothing Spatial Filter



Smoothing Spatial Filter



Smoothing Spatial Filter