DIGITAL IMAGE PROCESSING

Monsoon 2018 - CSE 478/ ECE 478

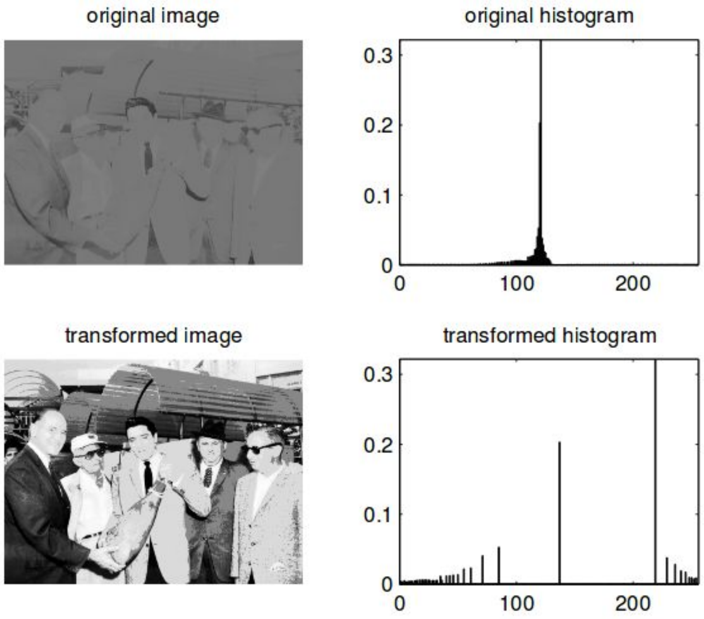
Tutorial - 18/08/2018

Agenda

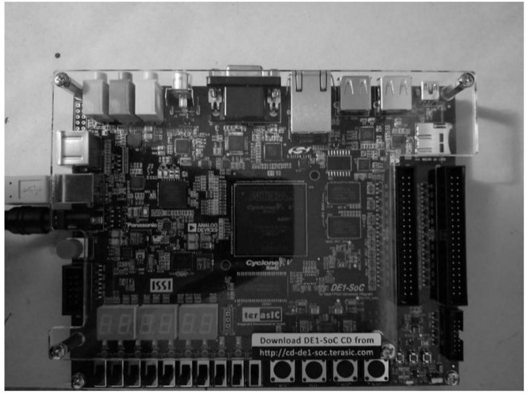
1. Histogram Equalization
2. Histogram Matching
3. Spatial Correlation and Convolution
4. Spatial Filters
5. Contrast Stretching
6. High Dynamic Ranging
7. Quantization
8. Linearity - Principle of Superposition
9. Linear Algebra - Vector Space, Null-Space, Linear Independence, Basis

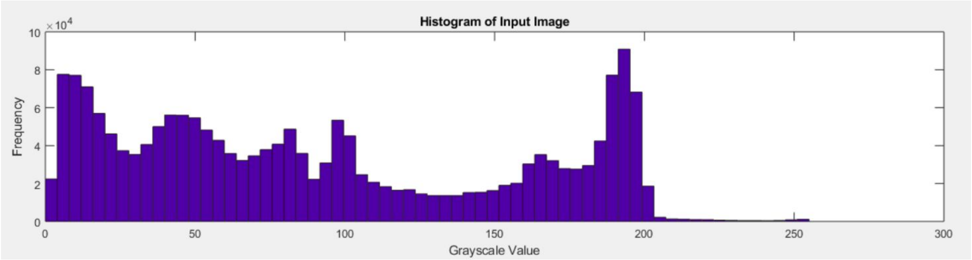
Histogram Equalization

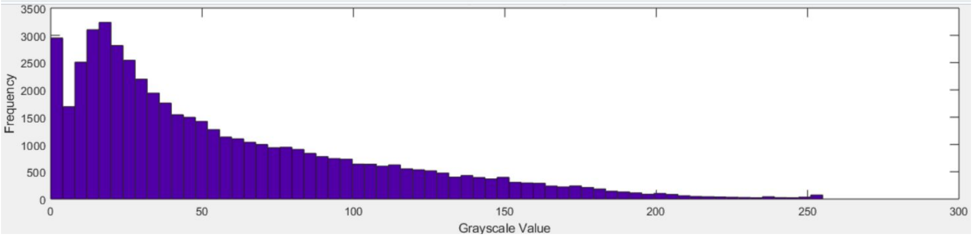
Histogram equalization is a technique for adjusting image intensities to enhance contrast.



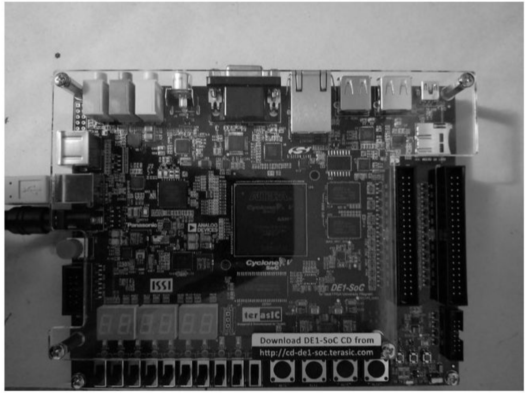
Histogram Matching

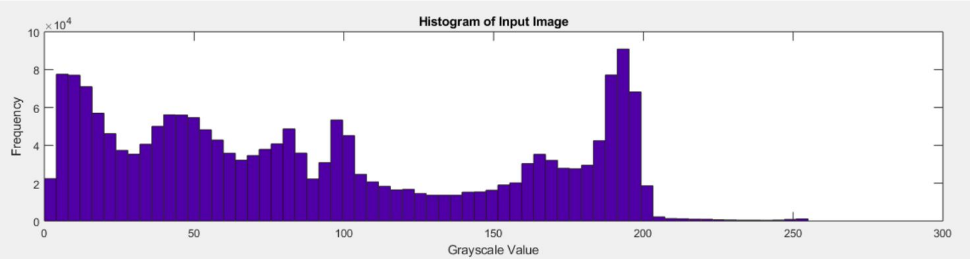


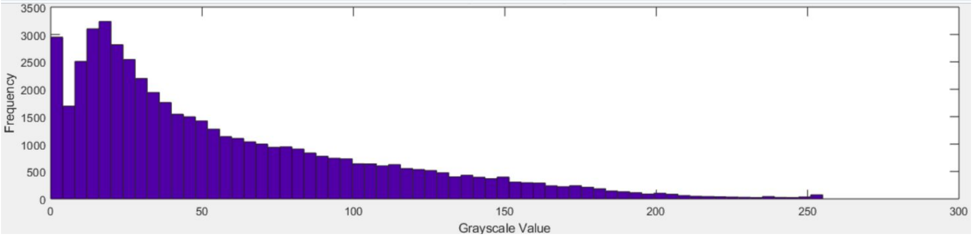


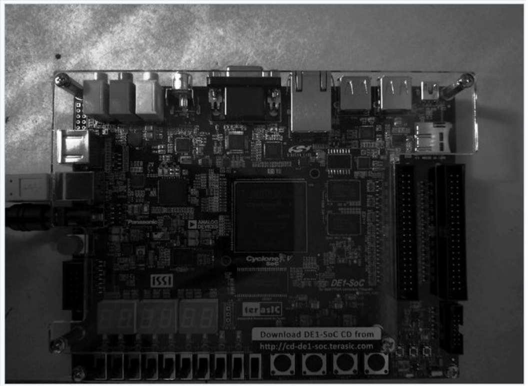


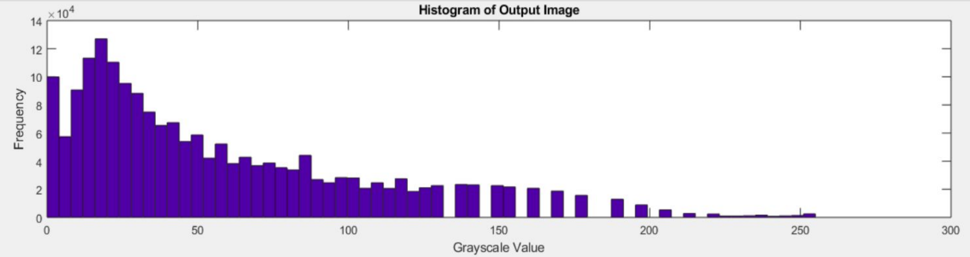
Histogram Matching











Spatial Correlation and Convolution

$$F \circ I(x) = \sum_{i=-N}^{N} F(i) I(x+i)$$

1-D Correlation

$$F * I(x) = \sum_{i=-N}^{N} F(i) I(x-i)$$

1-D Convolution

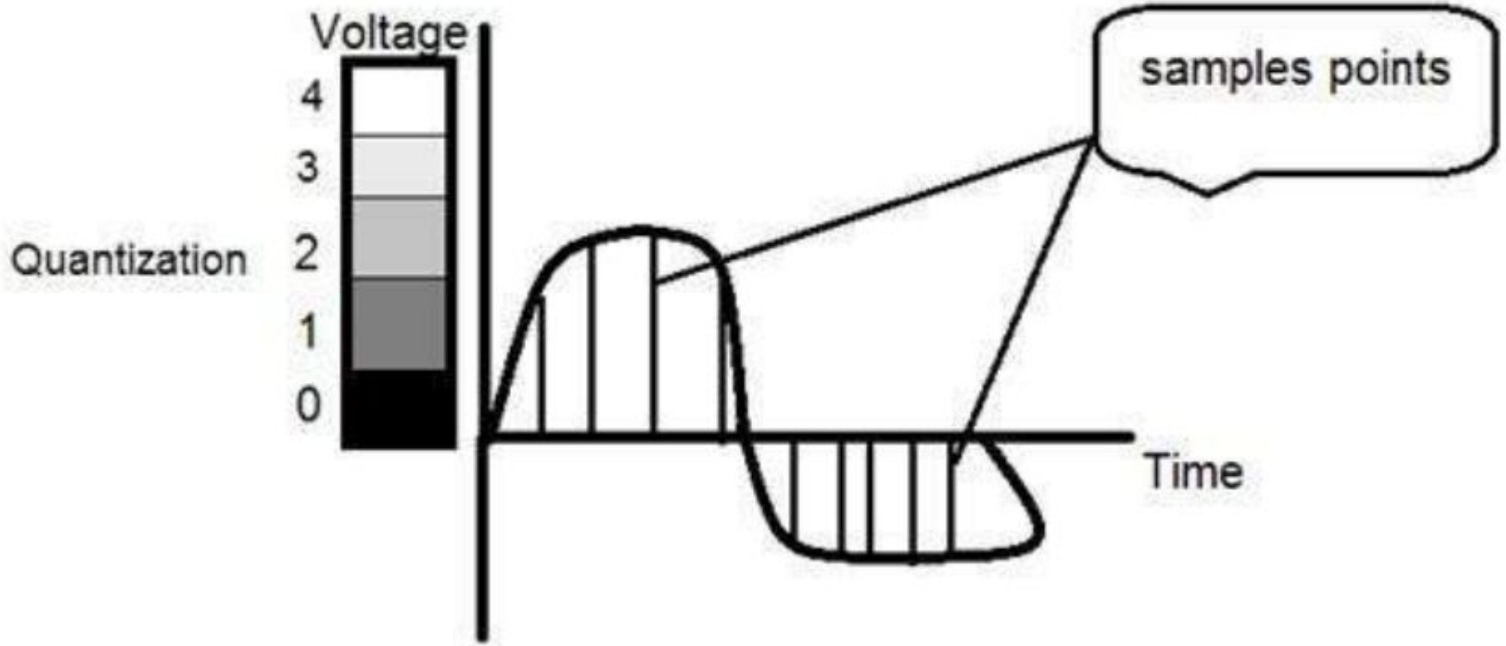
$$F \circ I(x,y) = \sum_{j=-N}^{N} \sum_{i=-N}^{N} F(i,j) I(x+i, y+j)$$

2-D Correlation

$$F * I(x,y) = \sum_{j=-N}^{N} \sum_{i=-N}^{N} F(i,j) I(x-i, y-j)$$

2-D Convolution

Quantization



Quantization

Linearity

A system is linear if it obeys the principle of Superposition.

2 conditions for a system to be linear -

1. Homogeneity
2. Additivity

Note - System linearity is independent of time scaling.

Vector Space, Null-Space, Linear Independence, Basis

L - is a linear map

- f(x+y) = f(x) + f(y)
- f(a*x) = a*f(x)

Linear independence if V is a V.S. over a Field F, such that a1,a2,...,an Ɛ F and v1,v2,v3,...,vn Ɛ V, then a1.v1 + a2.v2 + … + an.vn = 0 => a1=a2=...=an=0

Kernel or Null space of V -> L(v) -> W

Ker(L) = {v Ɛ V | L(v) = 0)

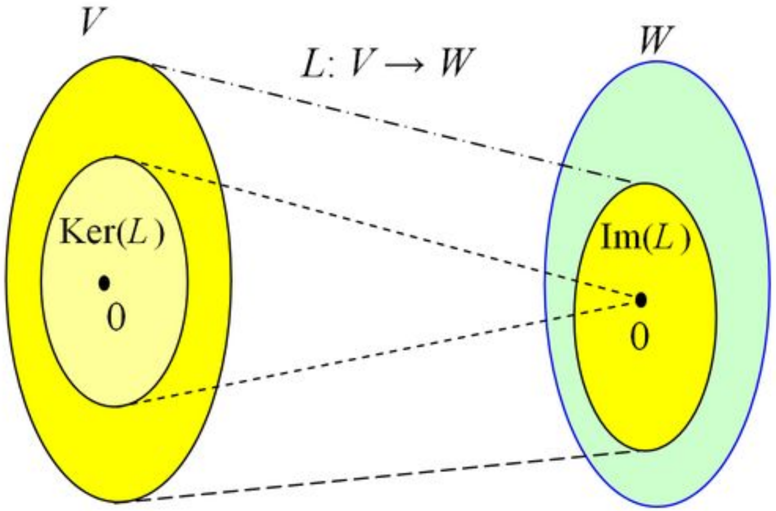
Vector Space, Null-Space, Linear Independence, Basis

Kernel or Null space of V -> L(v) -> W

- Ker(L) = {v Ɛ V | L(v) = 0)

Rank Nullity Theorem -

- dim(Ker(L)) + dim(im(L)) = dim(V)



Vector Space, Null-Space, Linear Independence, Basis

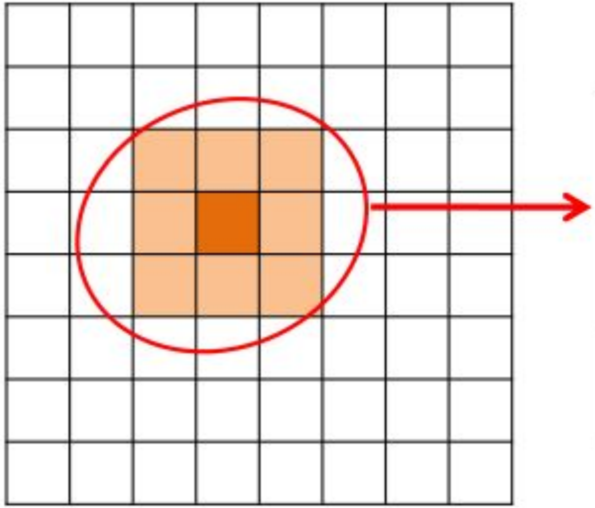
- Basis - Set of vectors in a V.S. V is called a basis if vectors are Linearly Independent and every vector in the V.S. is a linear combination of this set
- For a set to be a Basis it should -
  - Be linearly Independent
  - Span the vector space
- Linear Independence
  - Linear independence if V is a V.S. over a Field F, such that $a_1, a_2, ..., a_n \in F$ and $v_1, v_2, v_3, ..., v_n \in V$, then $a_1.v_1 + a_2.v_2 + \ldots + a_n.v_n = 0 \Rightarrow a_1 = a_2 = ... = a_n = 0$

- Spanning

  - For all $x \in V$, $x = a_1.v_1 + a_2.v_2 + \ldots + a_n.v_n$

Spatial Filtering

Spatial Filtering



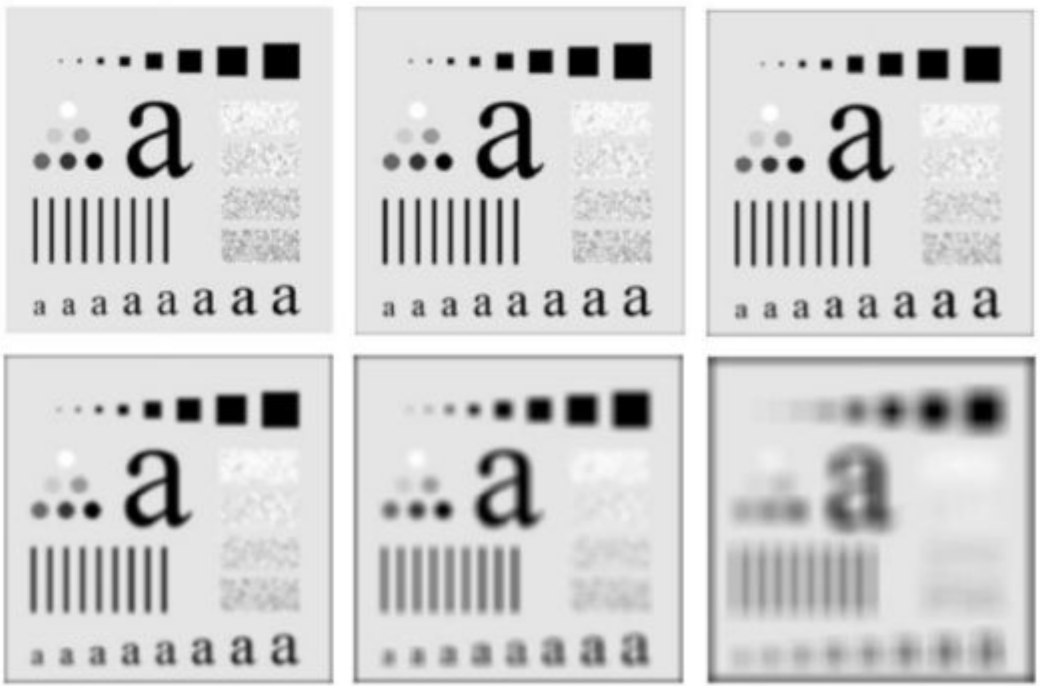
f(x-1,y-1)	f(x-1,y)	f(x-1,y+1)
f(x,y-1)	f(x,y)	f(x,y+1)
f(x+1,y-1)	f(x+1,y)	f(x+1,y+1)

3 × 3 mask

w(-1,-1)	w(-1,0)	w(-1,1)
w(0,-1)	w(0,0)	w(0,1)
w(1,-1)	w(1,0)	w(1,1)

$$g(x.y) = w(-1,-1)f(x-1,y-1) + w(-1,0)f(x-1,y)... \\ + w(0,0)f(x,y) + ... + w(1,1)f(x+1,y+1)$$

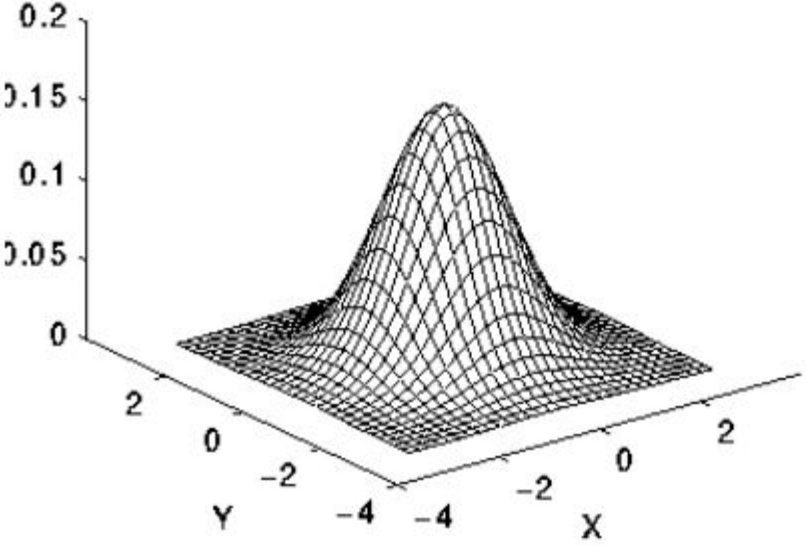
Smoothing Linear Filters



$$\frac{1}{9}\begin{array}{|c|c|c|}\hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline\end{array}$$

Square averaging filter mask size: 3,5,9,15,35

Smoothing Gaussian Filters



$\frac{1}{265}$

1	4	6	4	1
4	16	26	16	4
6	26	43	26	6
4	16	26	16	4
1	4	6	4	1

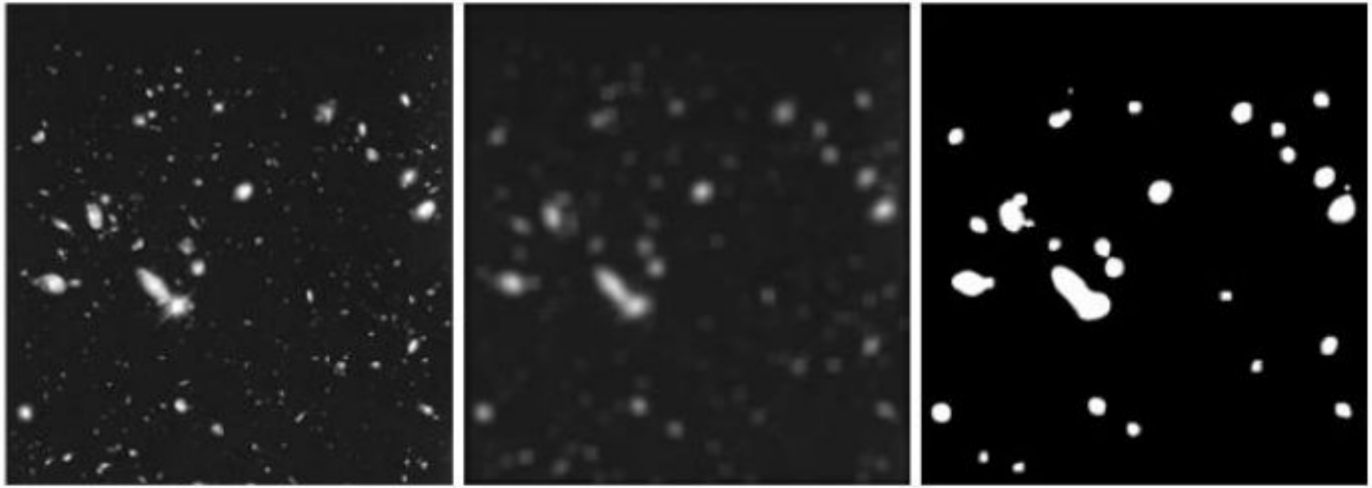
5×5 Gaussian filter, $\sigma=1$

Smoothing Gaussian Filters

5×5 Gaussian filter, σ=1

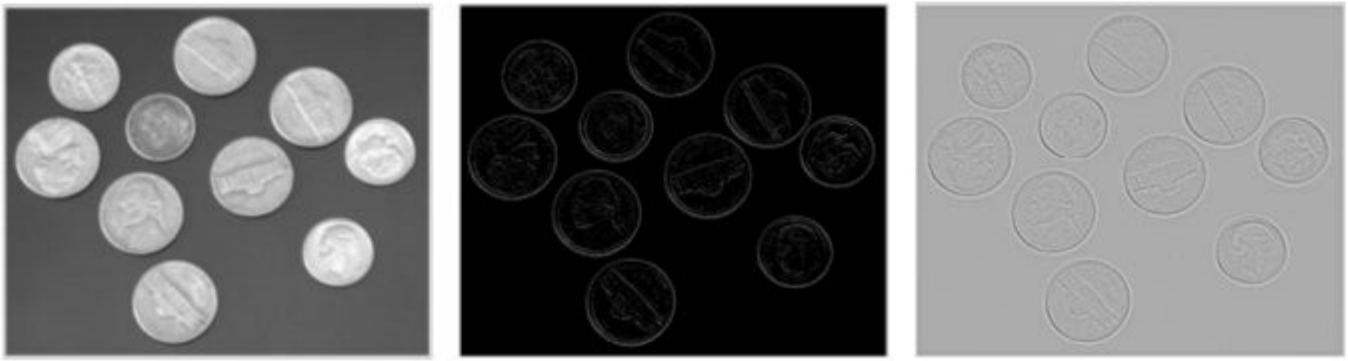
5×5 Gaussian filter, σ=3

Smoothing Linear Filters



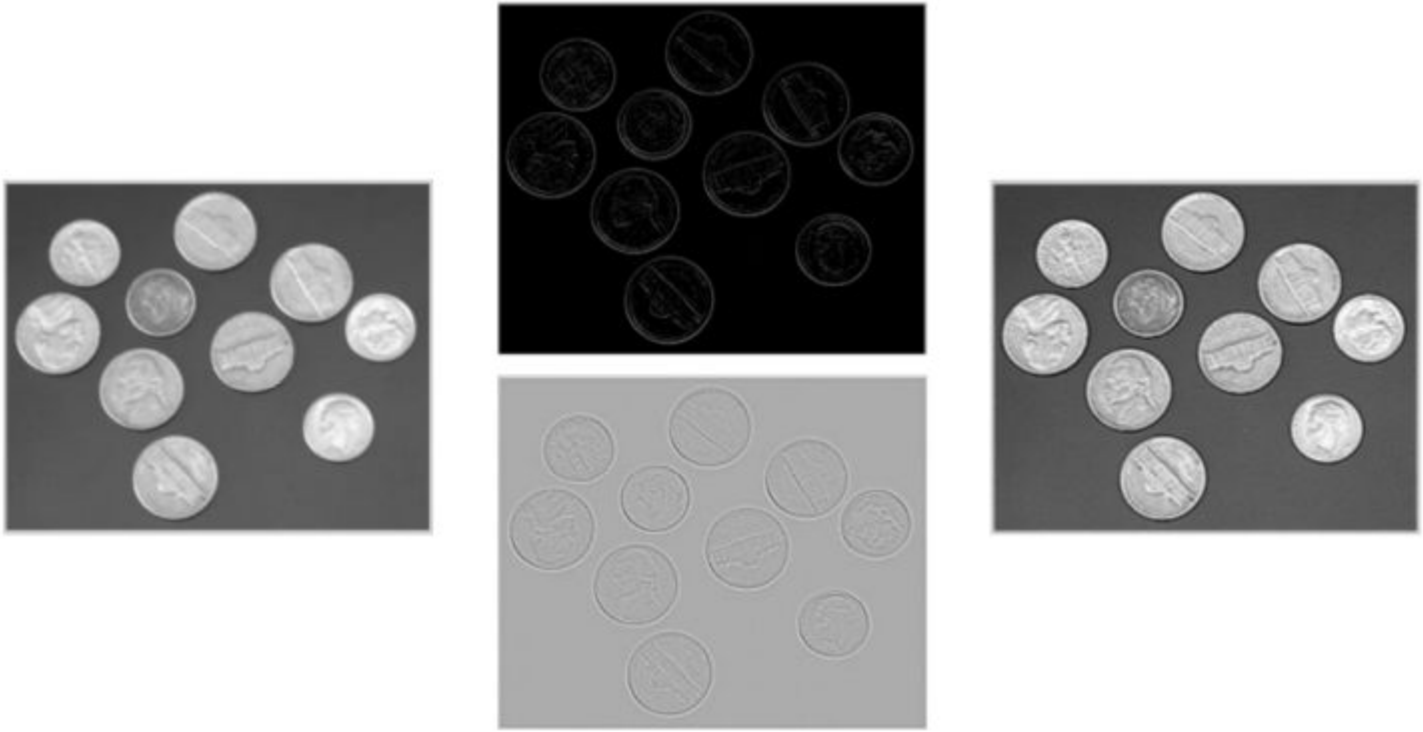
Application for Noise removal using 15×15 mask

Sharpening with Laplacian Filters

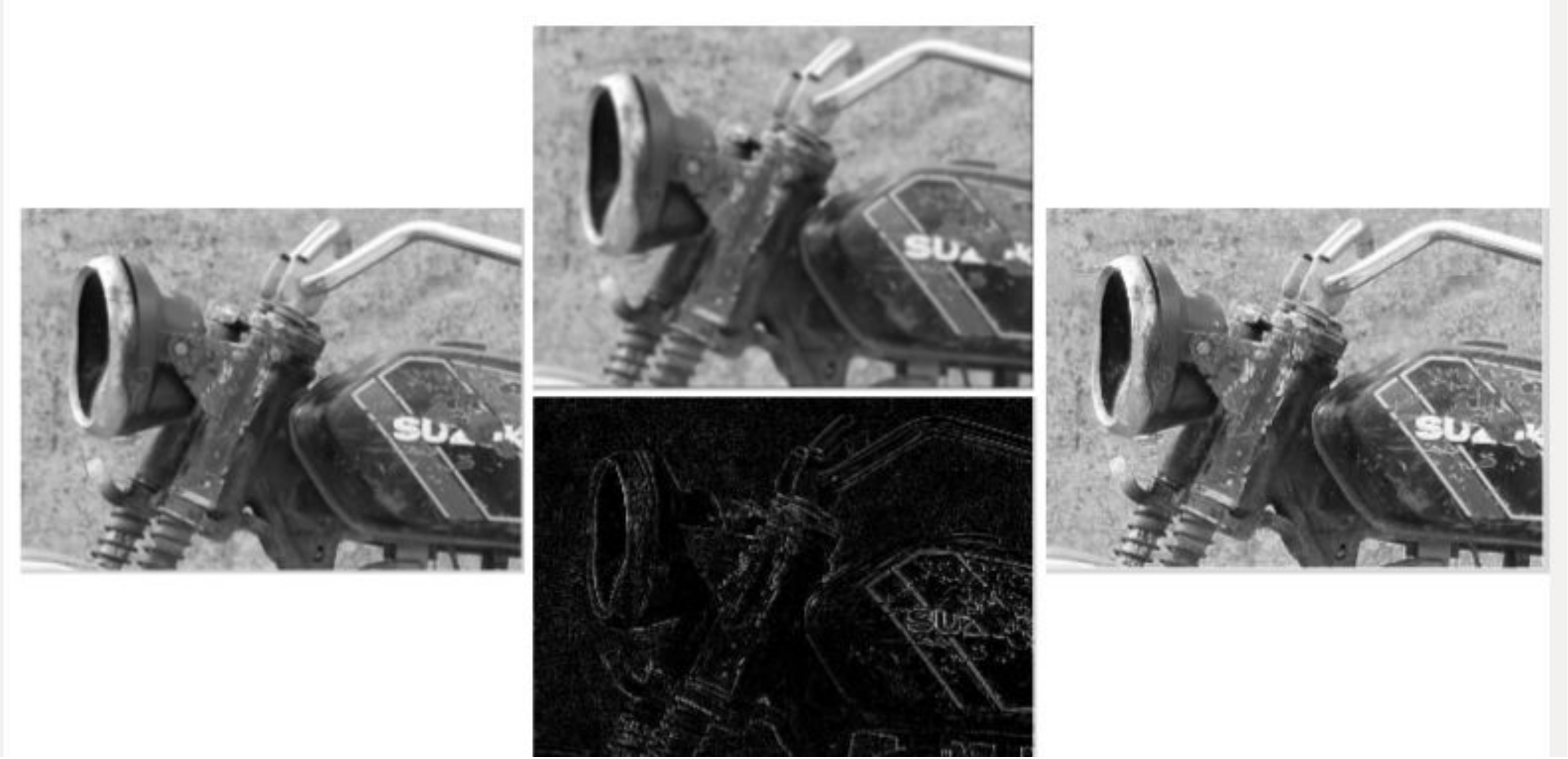


Sharpening with laplacian Filters

Laplacian Filters



Unsharp Masking (and Highboost Filtering)



Unsharp Masking and Highboost Filtering

Unsharp Masking and Highboost Filtering

Other Spatial Filters (first order derivative)

+1	0
0	-1

0	+1
-1	0

Robert Cross Gradient Operator

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

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

Sobel Gradient Operator

Other Spatial Filters (first order derivative)

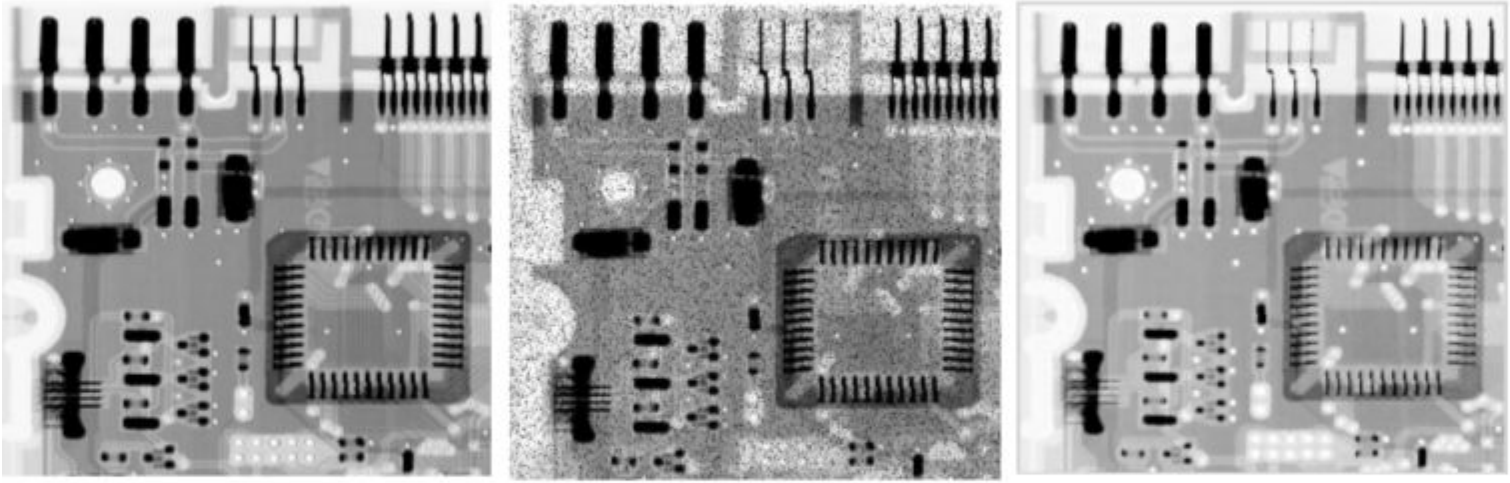
0	+1
-1	0

+1	0
0	-1

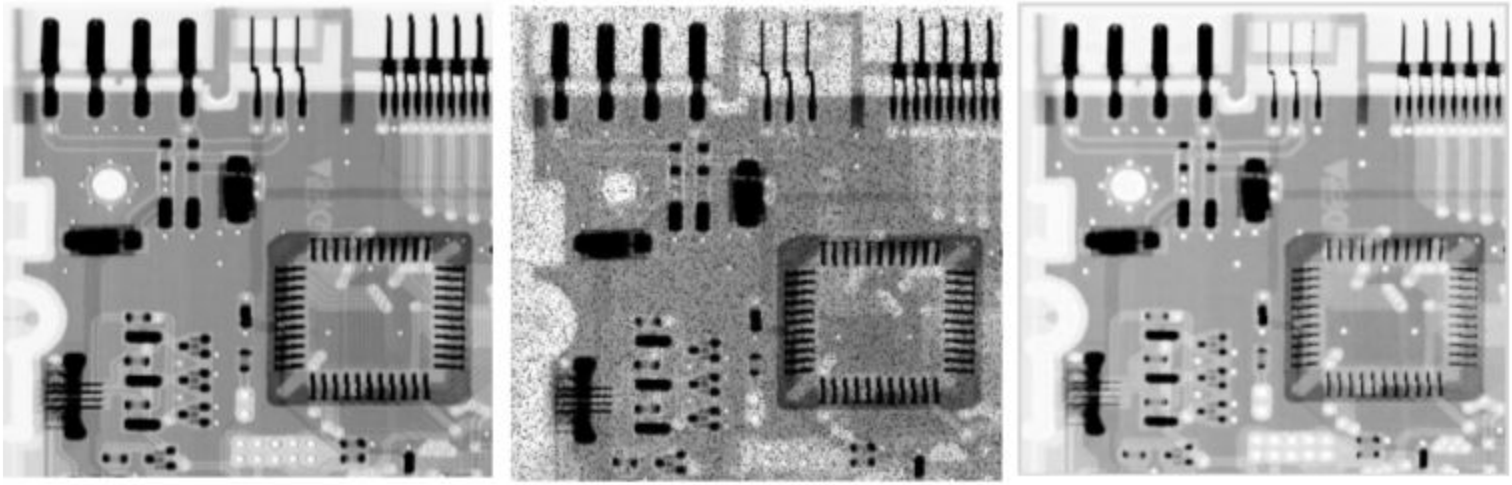
-1	0	+1
-2	0	+2
-1	0	+1

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

Other Spatial Filters (non linear) - Pepper Noise

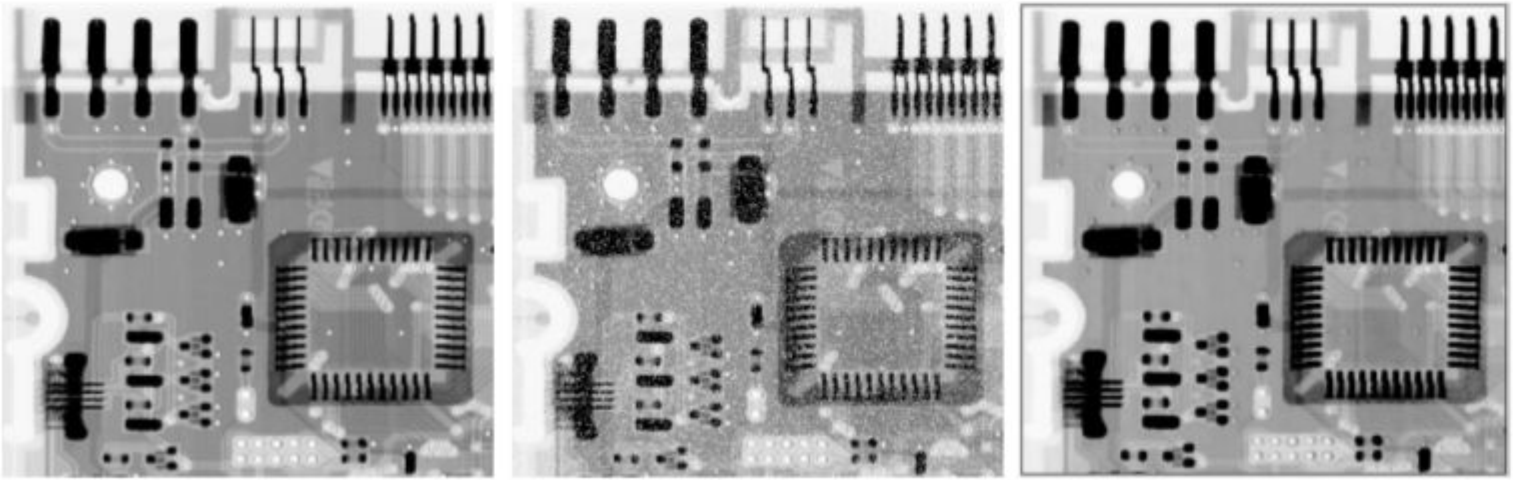


Other Spatial FIlters (non linear) - Pepper Noise

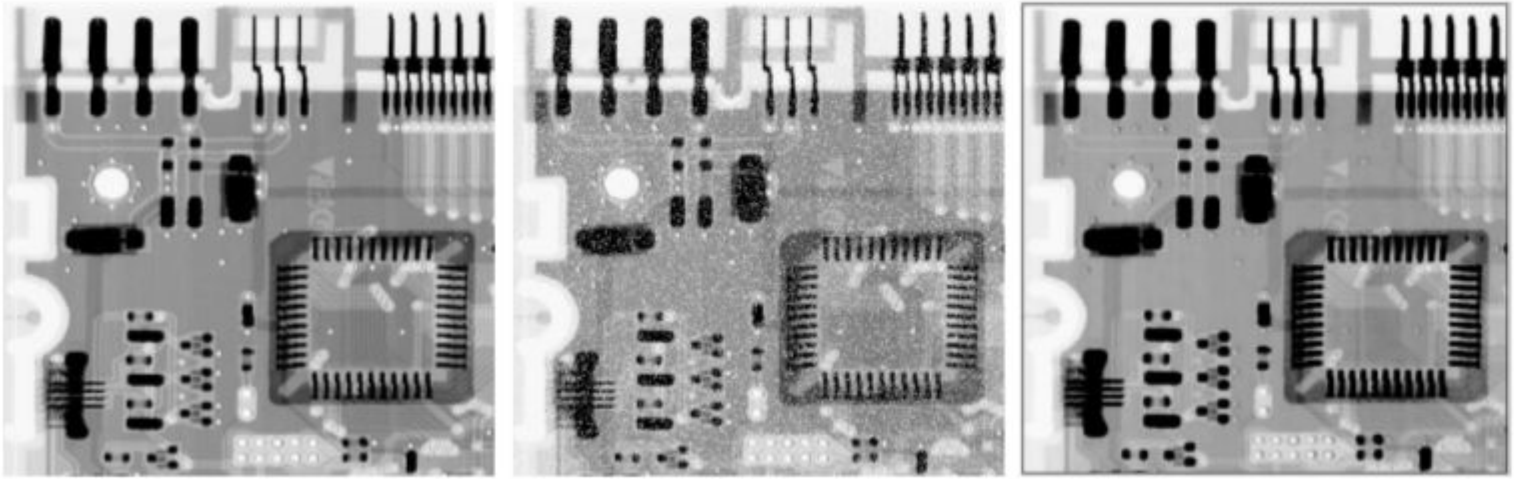


max filter

Other Spatial FIlters (non linear) - Salt Noise

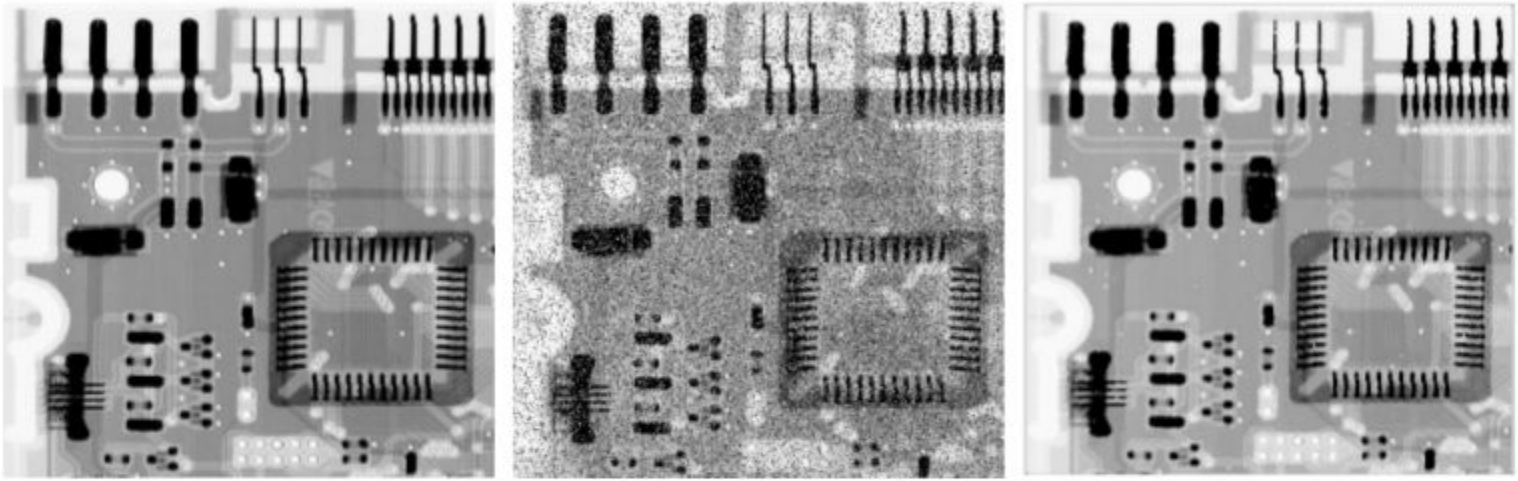


Other Spatial FIlters (non linear) - Pepper Noise



min filter

Other Spatial FIlters (non linear) - Salt and Pepper Noise (Median Filter)



max, min, median → also known as order statistic filters

Bilateral Filtering

Original image taken from cs.cityu.edu.hk

Bilateral Filtering

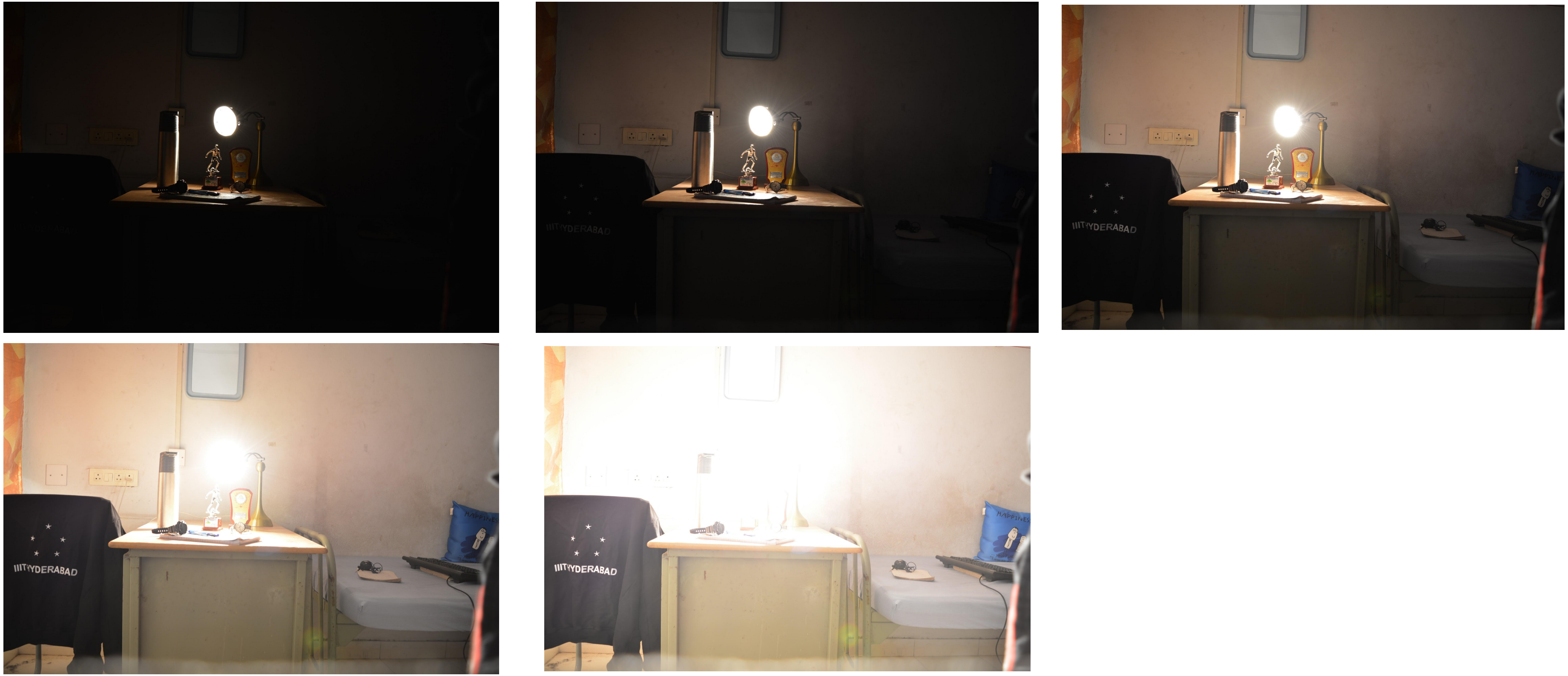
Original image from mfullywoodco.hol.e

High Dynamic Ranging

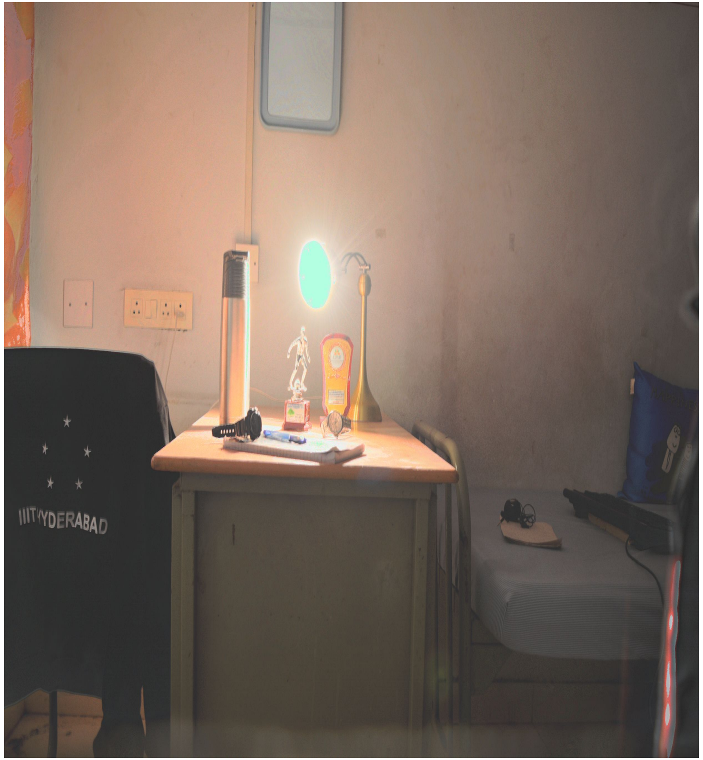
- For a scene, dynamic range refers to ratio between the brightest and darkest parts of the scene.
- The Dynamic Range of real-world scenes can be quite high - ratios of 100,000:1 are common in the natural world.
- Dynamic range of JPEG format image won't exceed 255:1, so it is considered as LDR (Low Dynamic Range).
- HDR imaging - generating images with a greater range of luminance levels than which can be achieved by taking only a single photograph with a fixed exposure.

High Dynamic Ranging

High Dynamic Ranging



High Dynamic Ranging



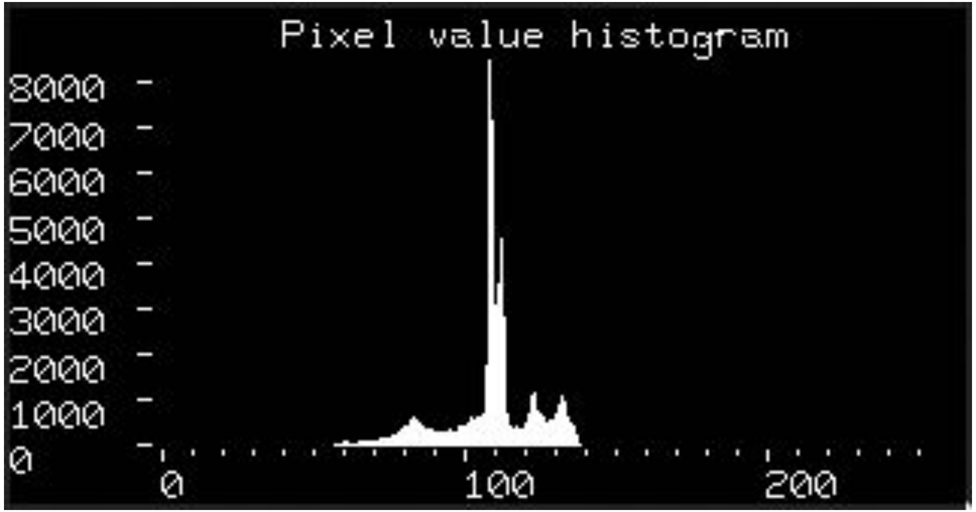
Contrast Stretching

- It attempts to improve the contrast in an image by `stretching' the range of intensity values it contains to span a desired range of value.

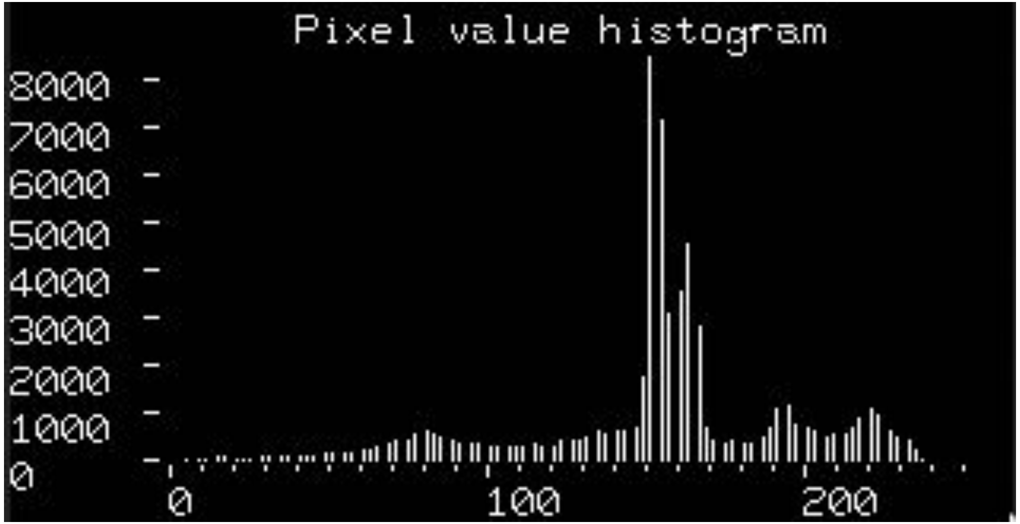
- It differs from the more sophisticated histogram equalization in that it can only apply a *linear* scaling function to the image pixel values. As a result the `enhancement' is less harsh.

$$P_{out} = (P_{in} - c)\left(\frac{b-a}{d-c}\right) + a$$

Contrast Stretching



Contrast Stretching



Contrast Stretching

References

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2. http://www.cs.umd.edu/~djacobs/CMSC426/Convolution.pdf
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