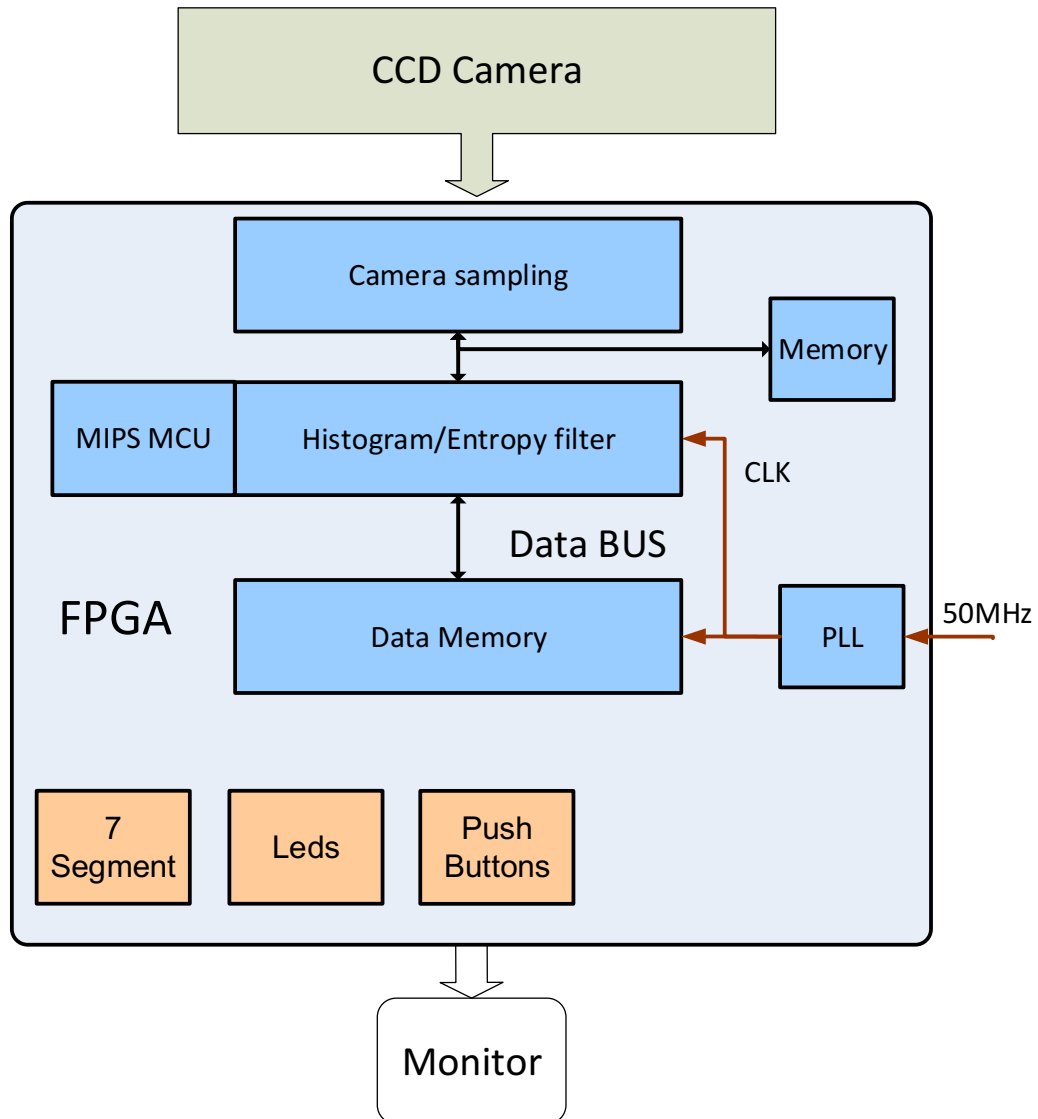


System Architecture



Processing Diagram

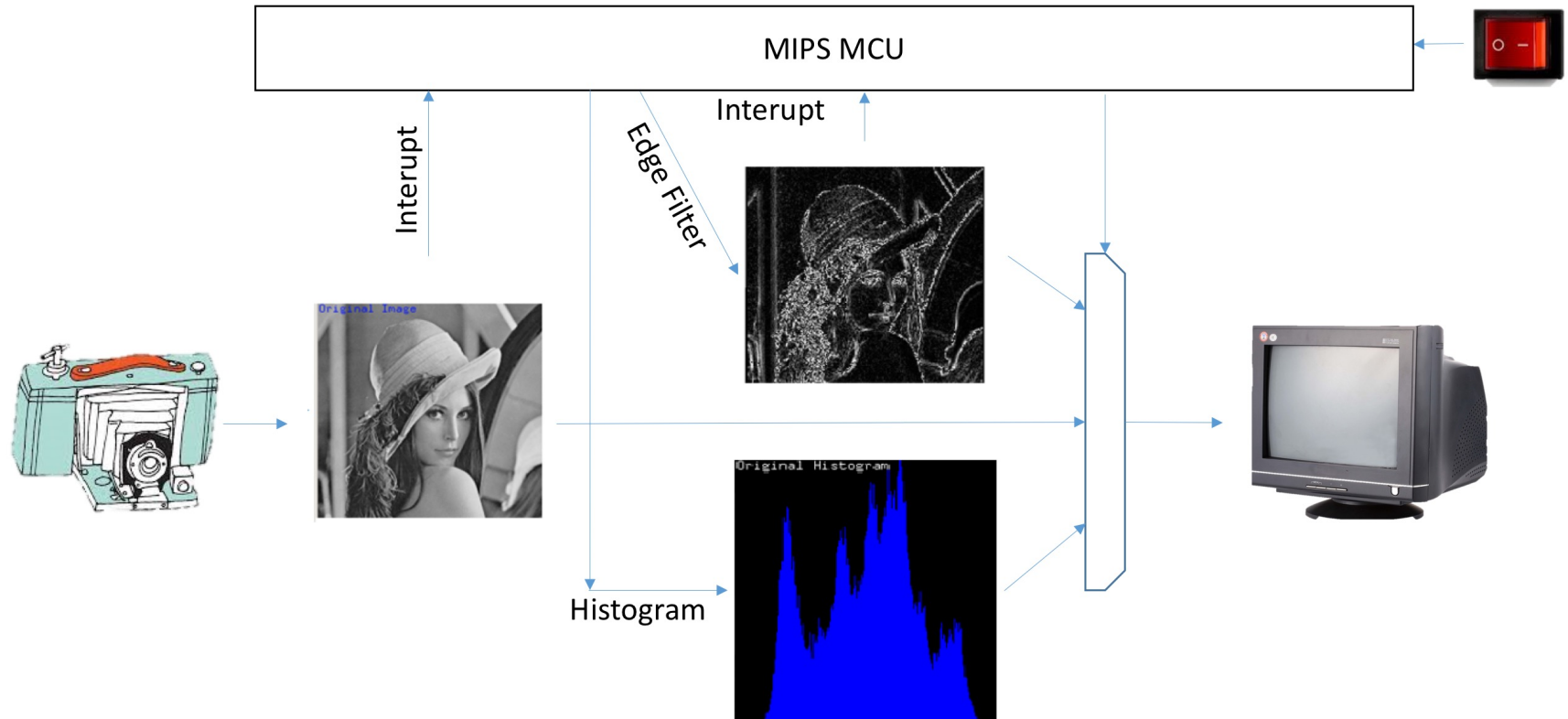
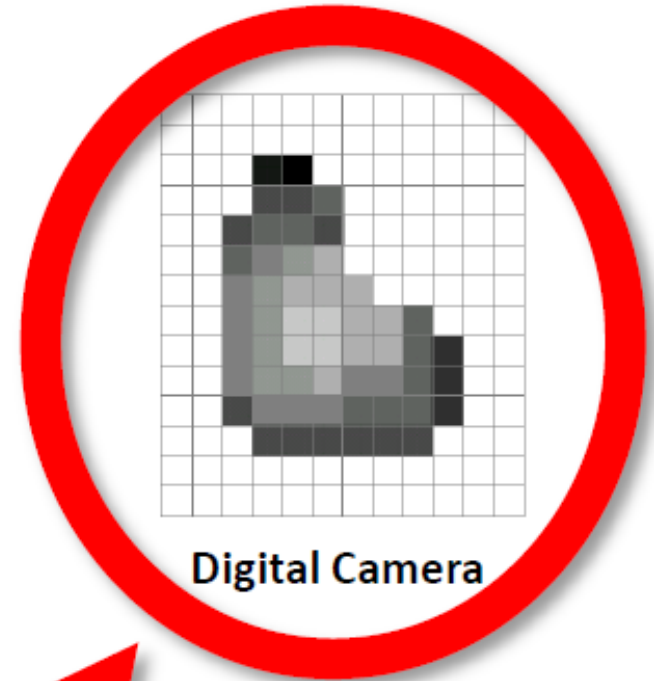
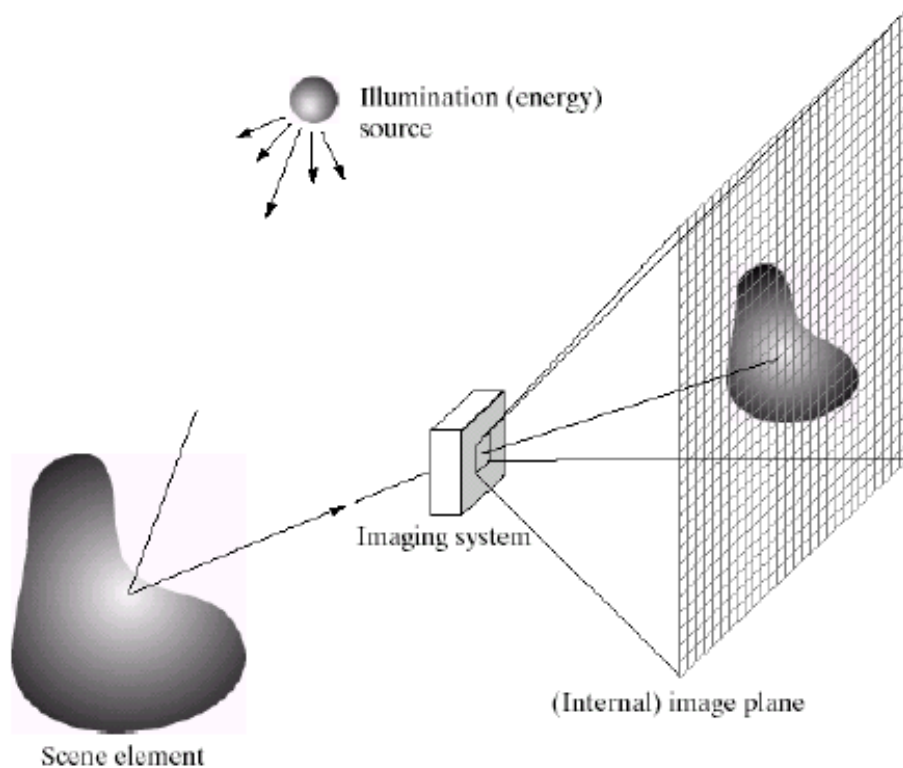


Image Processing Basics

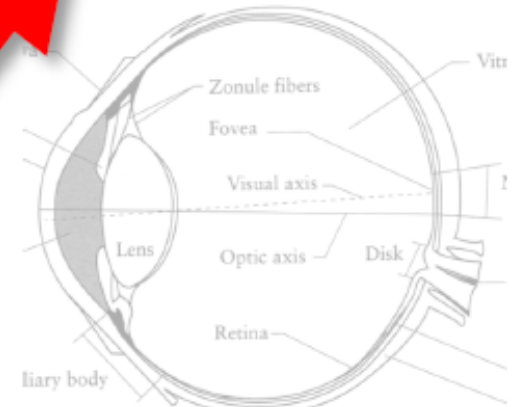


What is an image?



We'll focus on these in this class

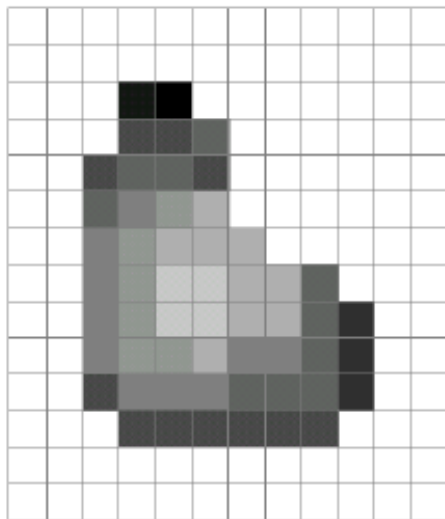
(More on this process later)



The Eye

What is an image?

- A grid (matrix) of intensity values



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255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	20	0	255	255	255	255	255	255	255
255	255	255	75	75	75	255	255	255	255	255	255
255	255	75	95	95	75	255	255	255	255	255	255
255	255	96	127	145	175	255	255	255	255	255	255
255	255	127	145	175	175	175	255	255	255	255	255
255	255	127	145	200	200	175	175	95	255	255	255
255	255	127	145	200	200	175	175	95	47	255	255
255	255	127	145	145	175	127	127	95	47	255	255
255	255	74	127	127	127	95	95	95	47	255	255
255	255	255	74	74	74	74	74	74	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255

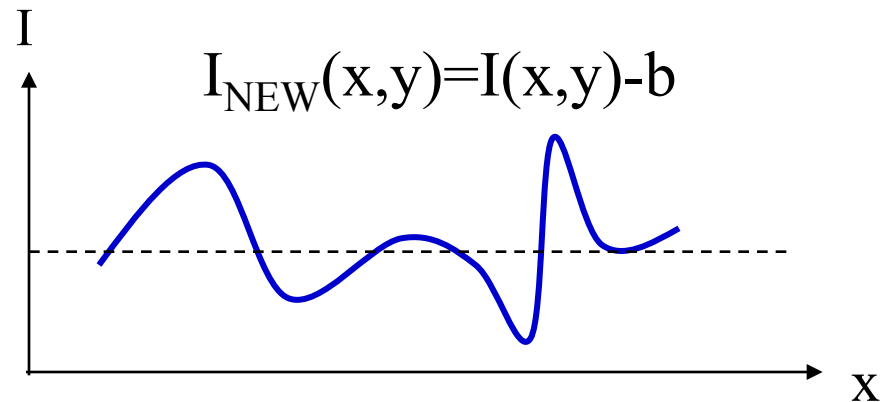
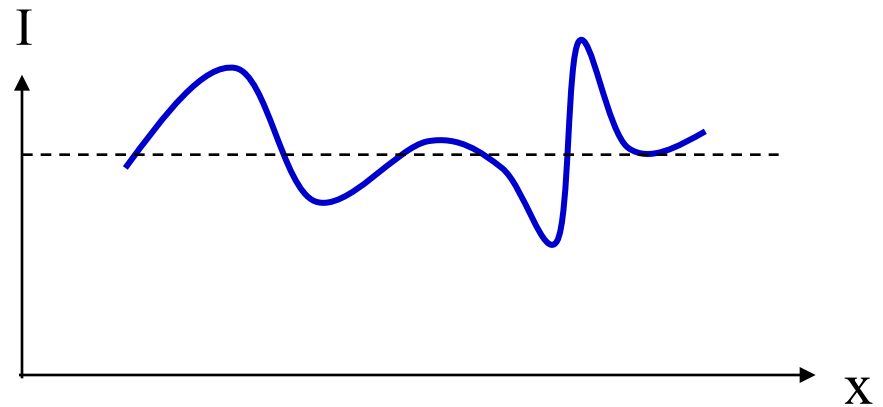
(common to use one byte per value: 0 = black, 255 = white)

Image Characteristics



Image Mean

$$I_{av} = \frac{\sum_i \sum_j I(i,j)}{\sum_i \sum_j 1}$$



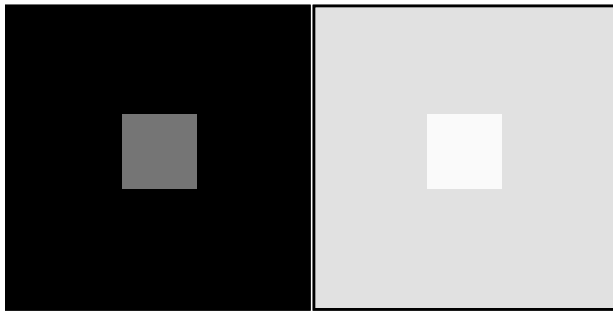


Changing the image mean

Image Contrast

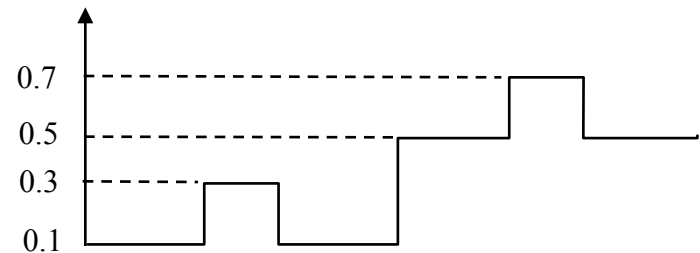
- The **local contrast** at an image point denotes the (relative) difference between the intensity of the point and the intensity of its neighborhood:

$$C = \left| \frac{I_p - I_n}{I_n} \right|$$



$$C = \left| \frac{0.3 - 0.1}{0.1} \right| = 2$$

$$C = \left| \frac{0.7 - 0.5}{0.5} \right| = 0.4$$



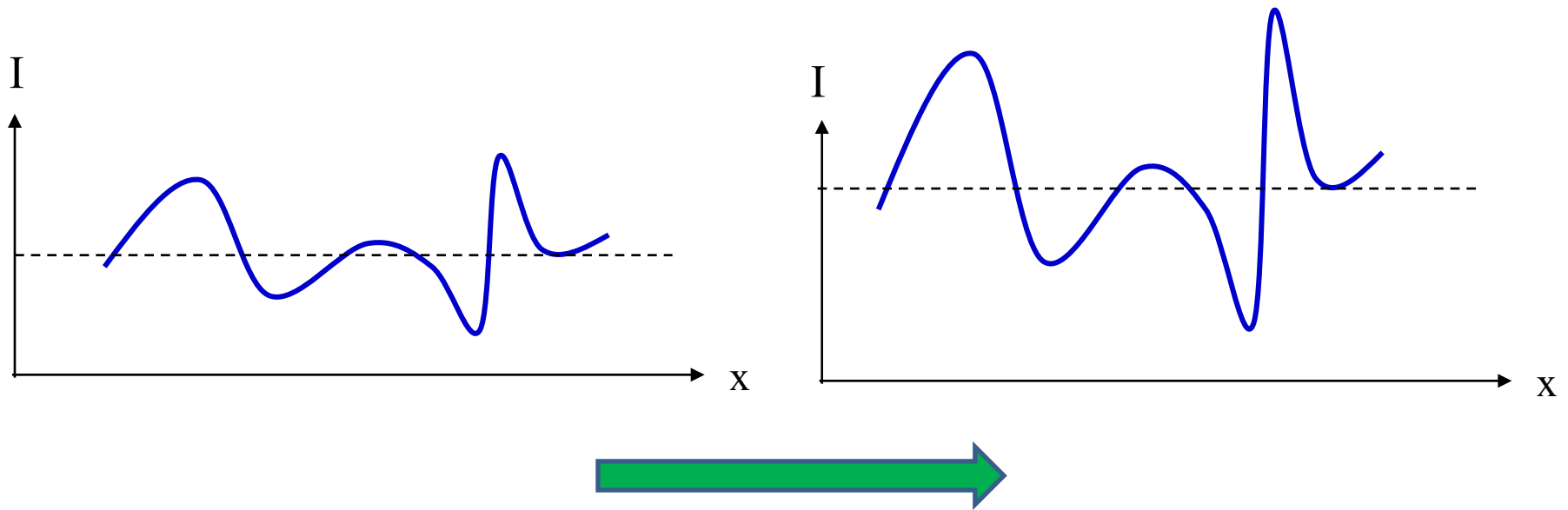
- The contrast definition of the entire image is ambiguous
- In general it is said that the image contrast is high if the image gray-levels fill the entire range



Low contrast



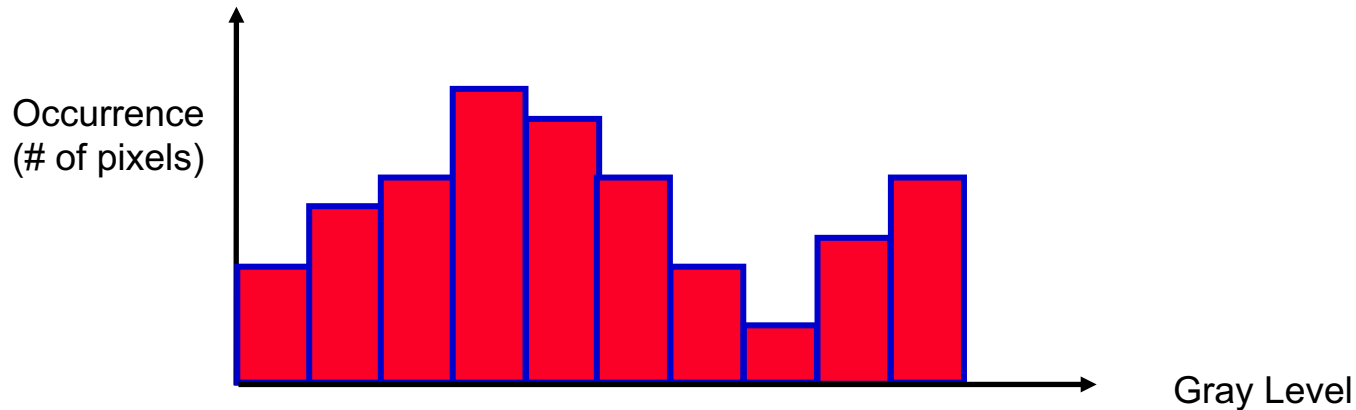
High contrast



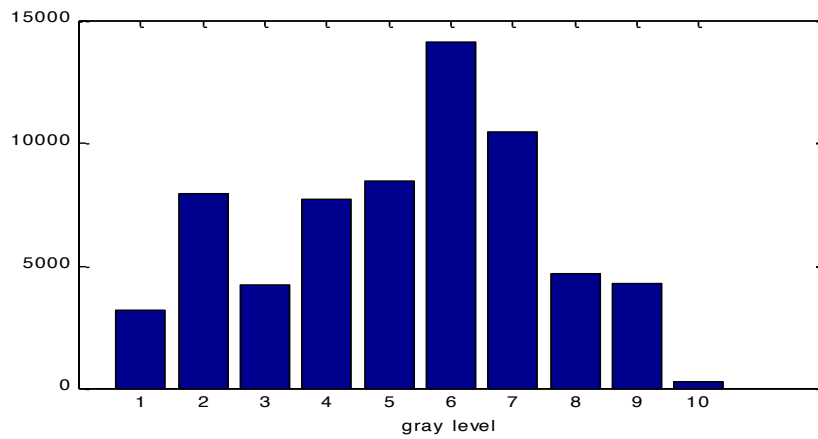
$$I_{\text{NEW}}(x,y) = \alpha \cdot I(x,y) + \beta$$

- How can we maximize the image contrast using the above operation?
- Problems:
 - Global (non-adaptive) operation.
 - Outlier sensitive.

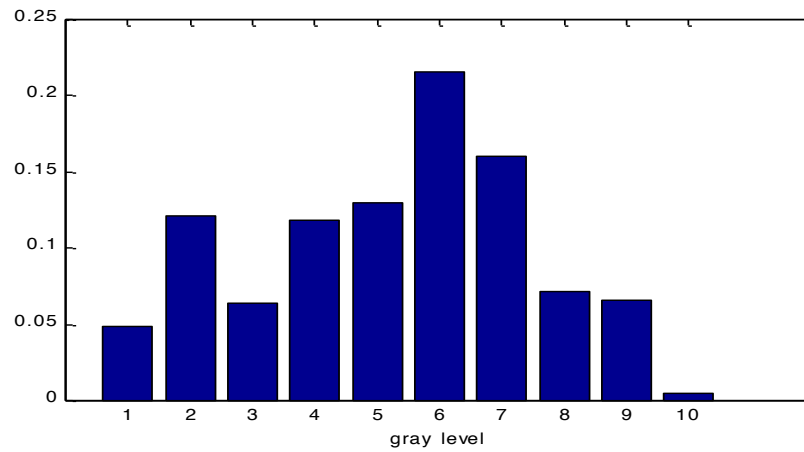
The Image Histogram



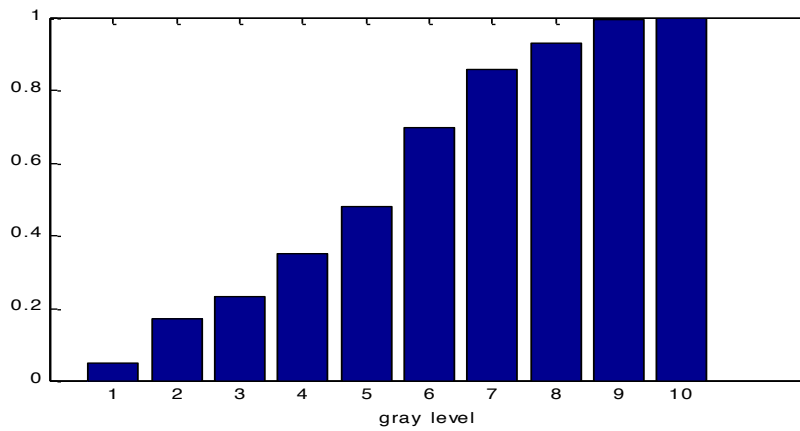
- $H(k)$ specifies the # of pixels with gray-value k
- Let N be the number of pixels: $N = \sum_k H(k)$
- $P(k) = H(k)/N$ defines the normalized histogram
- $C(k) = \sum_{i=1}^k H(i)$ defines the accumulated histogram



Histogram

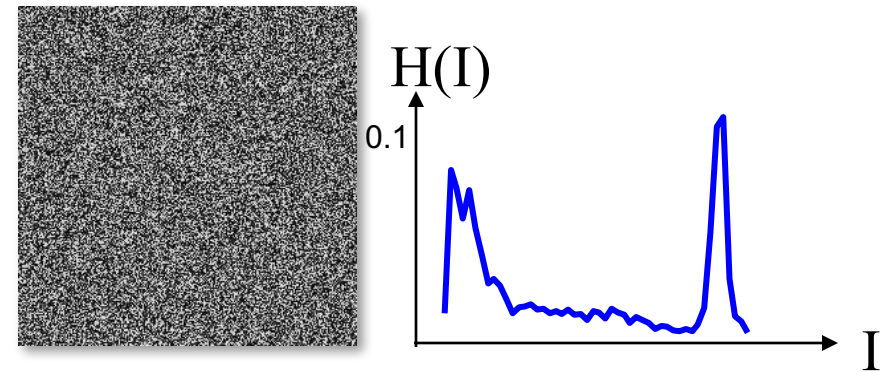
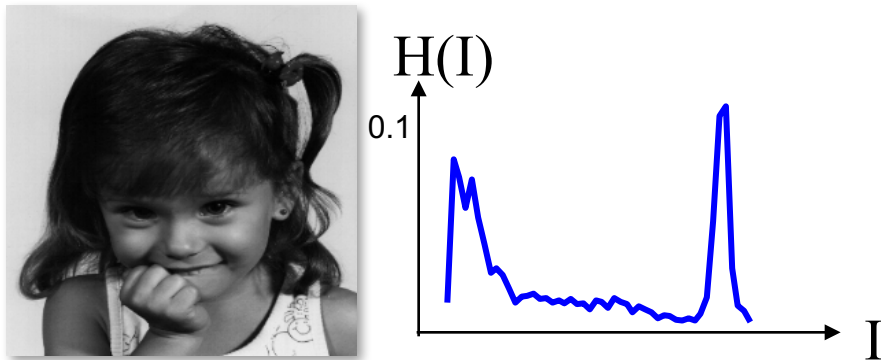
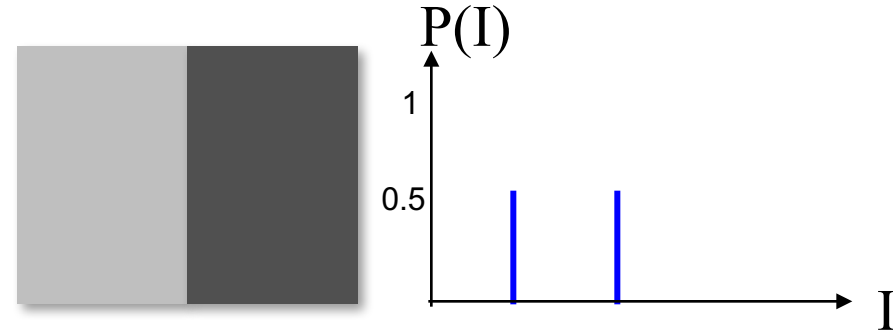
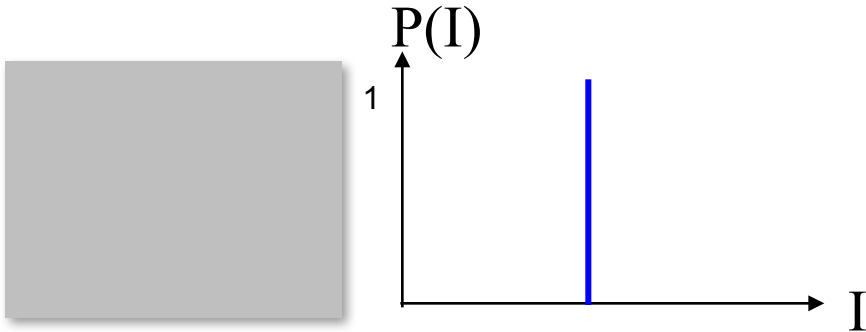


Normalized Histogram



Accumulated Histogram

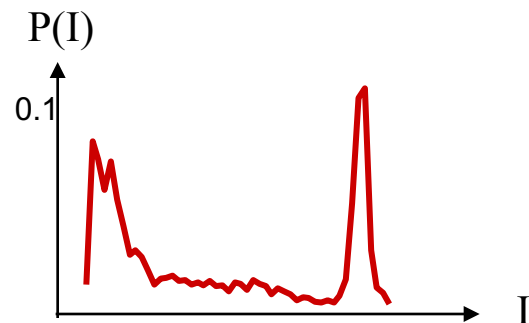
Examples



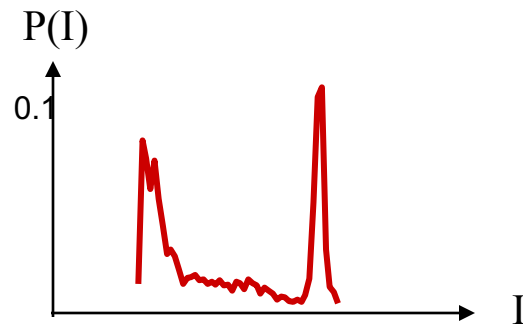
Pixel permutation of
the left image

- The image histogram does not fully represent the image

Original image



Decreasing contrast



Increasing average

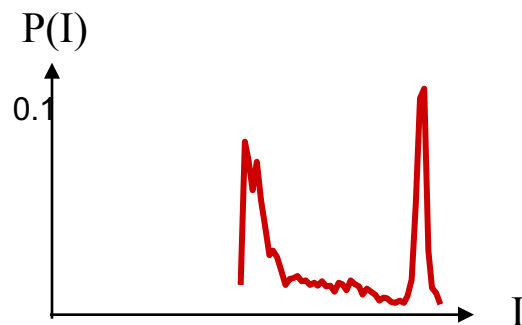
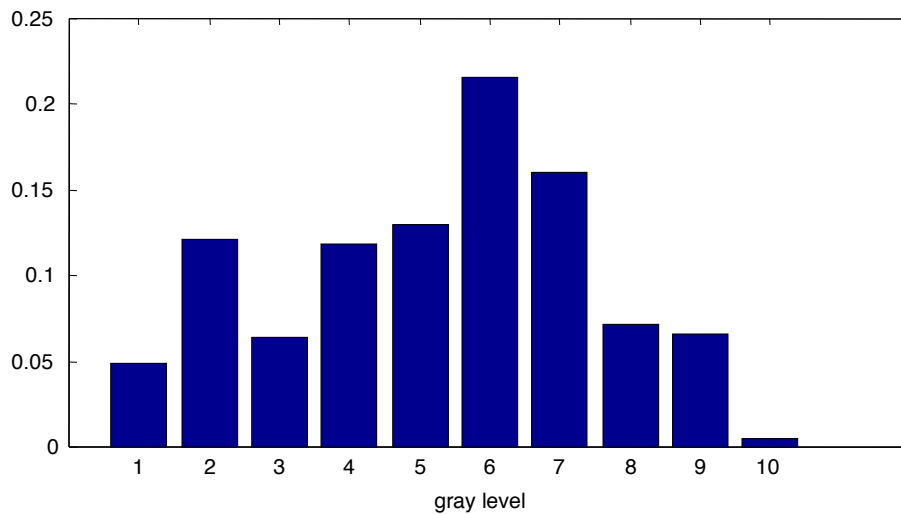


Image Statistics

- The image mean: $E\{I\} = \frac{1}{N} \sum_{i,j} I(i,j) = \frac{1}{N} \sum_k k H(k) = \sum_k k P(k)$
- Generally: $E\{g(k)\} = \sum_k g(k) P(k)$

- The image s.t.d. : $\sigma(I) = \sqrt{E\{(I - E\{I\})^2\}} = \sqrt{E(I^2) - E^2(I)}$

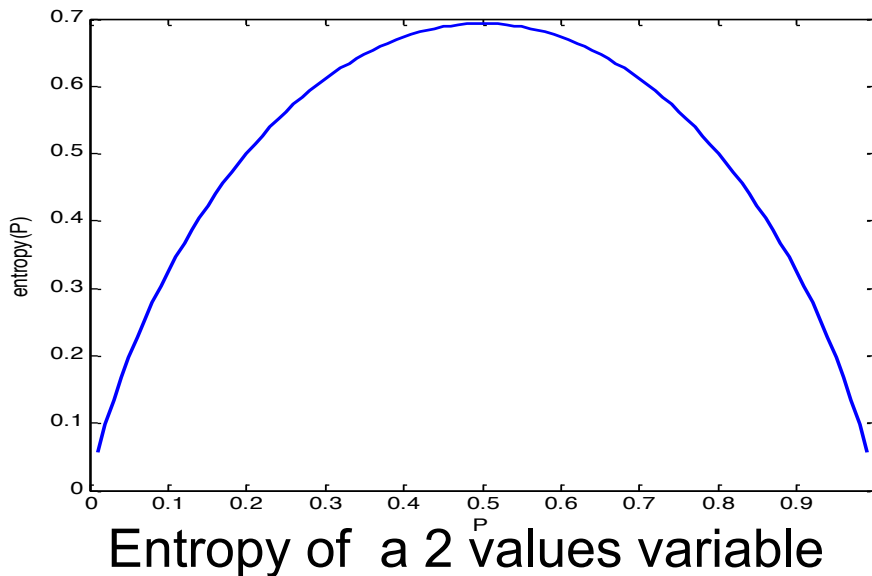


where $E\{I^2\} = \sum_k k^2 P(k)$

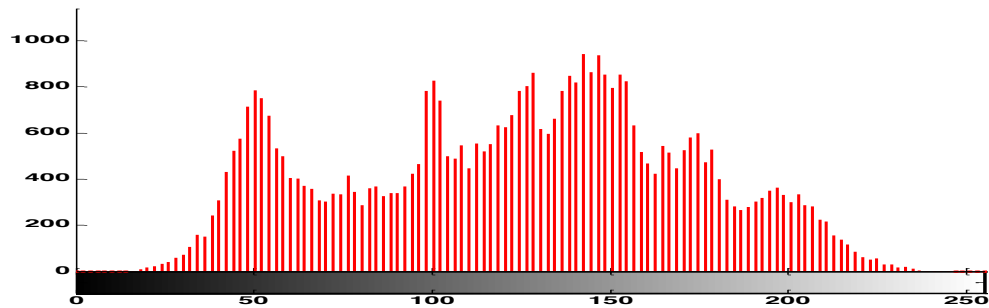
Image Entropy

$$Entropy(I) = - \sum_k P(k) \log P(k)$$

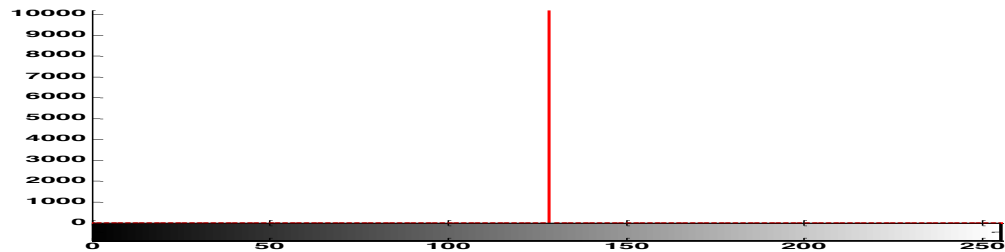
- The image entropy specifies the uncertainty in the image values.
- Measures the averaged amount of information required to encode the image values.



- An infrequent event provides more information than a frequent event
- Entropy is a measure of histogram dispersion



entropy=7.4635



entropy=0

Image filtering

- Modify the pixels in an image based on some function of a local neighborhood of each pixel

10	5	3
4	5	1
1	1	7

Local image data

Some function

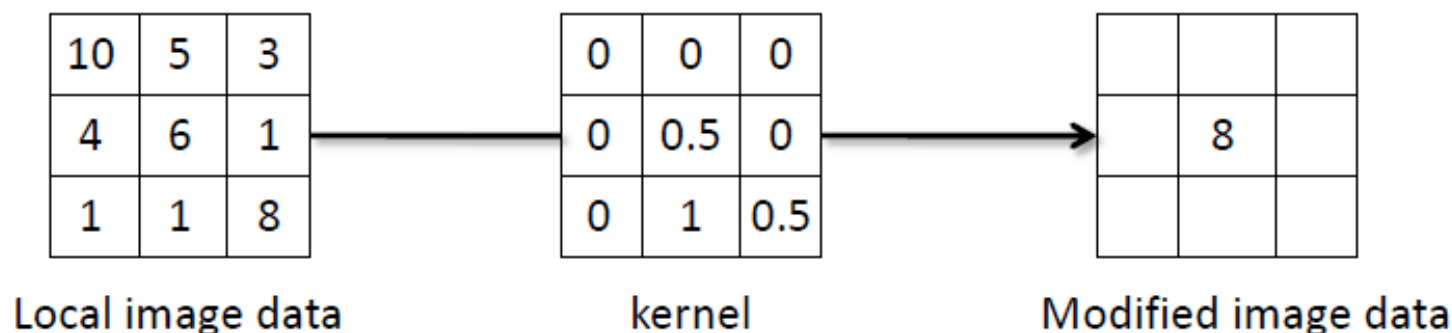


	7	

Modified image data

Linear filtering

- One simple version: linear filtering (cross-correlation, convolution)
 - Replace each pixel by a linear combination of its neighbors
- The prescription for the linear combination is called the “kernel” (or “mask”, “filter”)



Mean filtering

H



0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

F

=

	0	10	20	30	30	30	20	10	
	0	20	40	60	60	60	40	20	
	0	30	60	90	90	90	60	30	
	0	30	50	80	80	90	60	30	
	0	30	50	80	80	90	60	30	
	0	20	30	50	50	60	40	20	
	10	20	30	30	30	30	20	10	
	10	10	10	0	0	0	0	0	

G

Linear filters: examples



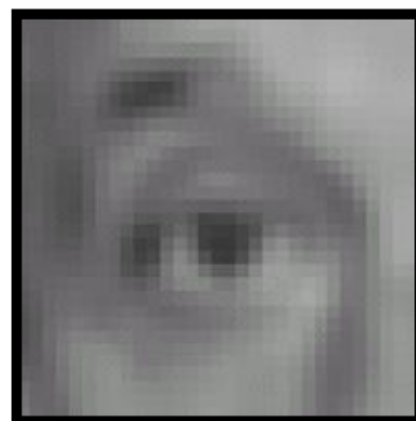
Original



$\frac{1}{9}$

1	1	1
1	1	1
1	1	1

=



Blur (with a mean filter)

Linear filters: examples



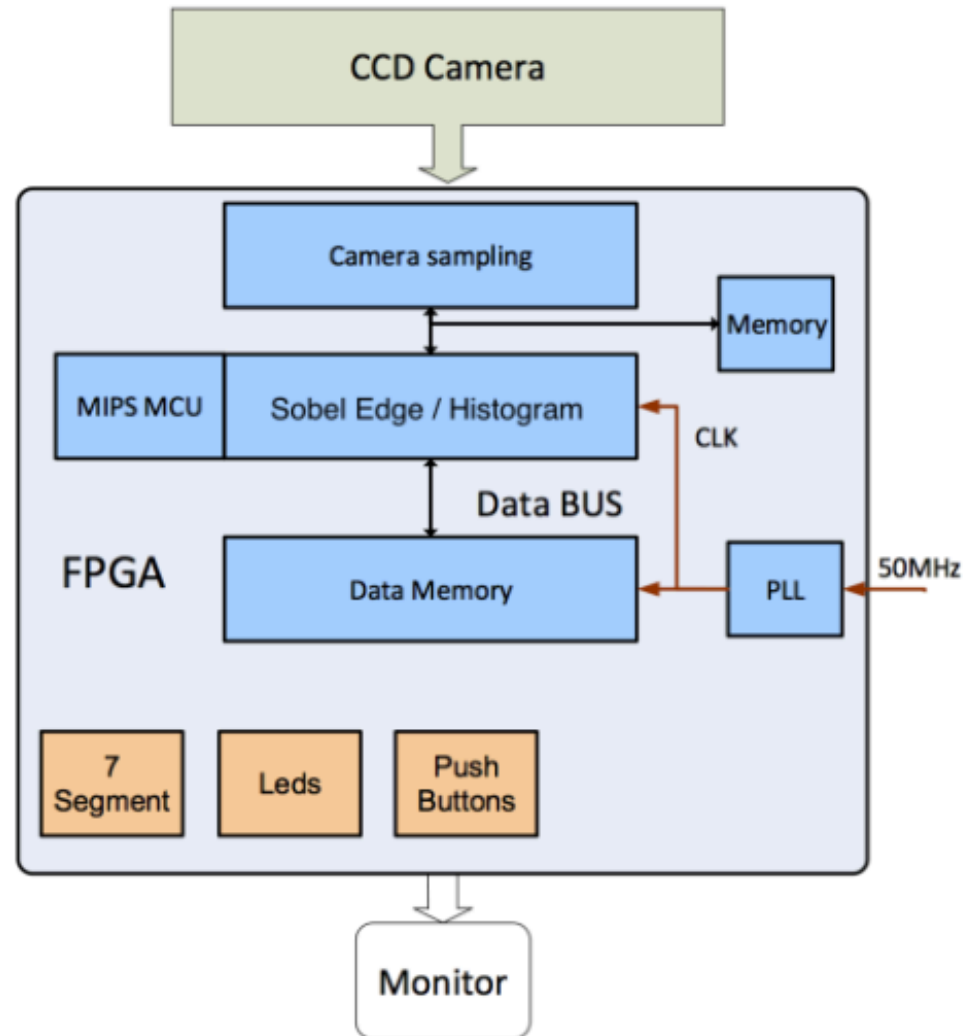
Original

$$* \left(\begin{bmatrix} 0 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 0 \end{bmatrix} - \frac{1}{9} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \right) =$$



Sharpening filter
(accentuates edges)

System Architecture



Processing Diagram

