Computer Vision

Paulo Dias, António Neves

deti departamento de electrónica telecomunicações e informática

universidade de aveiro

Sumary

- Low level image processing
  - Arithmetic operations
  - Pixel relations
- Intensity level slicing / threshold
- Histograms
  - Contrast Stretching
  - Histogram equalization
- Filtering
  - Image smoothing
  - Image sharpening
- Geometrical transformations

Sumary

- Low level image processing
  - Arithmetic operations
  - Pixel relations
- Intensity level slicing / threshold
- Histograms
  - Contrast Stretching
  - Histogram equalization
- Filtering
  - Image smoothing
  - Image sharpening
- Geometrical transformations

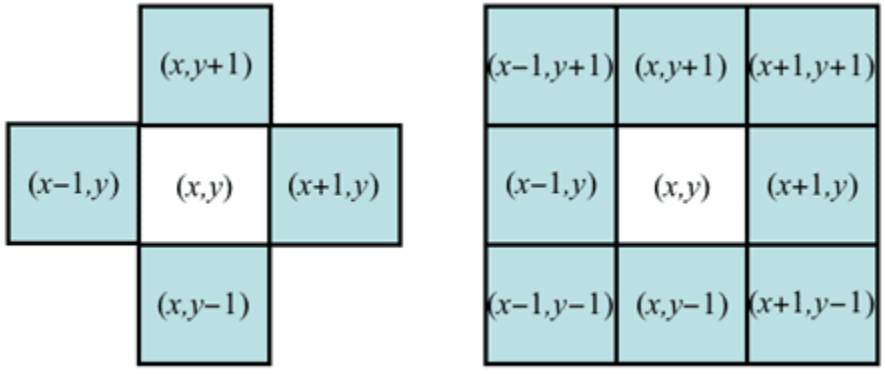
Aritmethics operation

- It is possible to apply several arithmetic operations in images
  - Addition
  - Substraction
  - Multiplication
  - Division
- and logical operations (AND, OR, NOT…)

https://docs.opencv.org/4.x/d0/d86/tutorial_py_image_arithmetics.html

Pixel neighbours

- Many image processing operations make use of spatial relationships between pixels.
- A number of methods have been devised to specify pixel neighbours and calculate distance.
- The 4-neighbours of a pixel (x,y) are the closest pixels in horizontal and vertical directions (D4).
- The 8-neighbors are the 4-neighbors plus the four closest pixels in diagonal direction (D8).



4-neighbourhood 8-neighbourhood

Pixel Distance

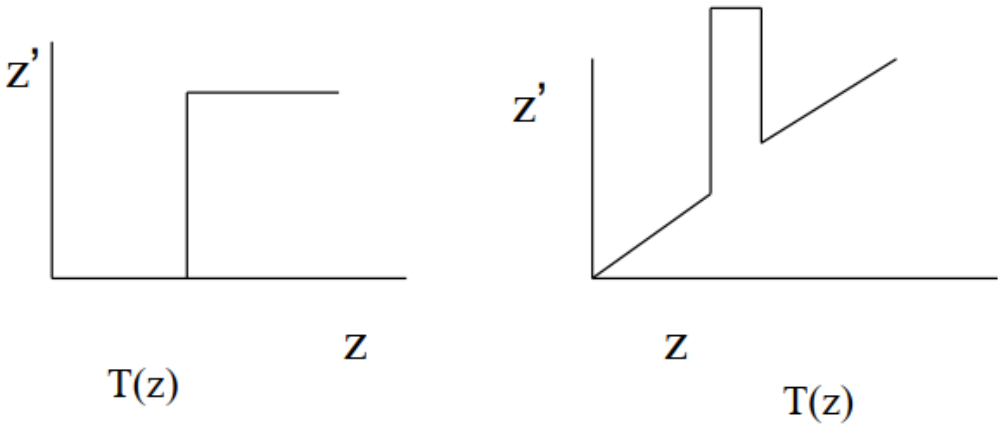
- The distance between pixels (x,y) and (u,v) can be calculated in several ways:
  - Euclidean (L2): $D = \sqrt{[(x - u)^2 + (y - v)^2]}$
  - City-block (L1): $\mathrm{D} = |x - u| + |y - v|$
  - Chessboard (Linf): $\mathrm{D} = \max(|x - u|, |y - v|)$
  - …
- Although Euclidean distance is more accurate, the sqrt makes it expensive to calculate.

Sumary

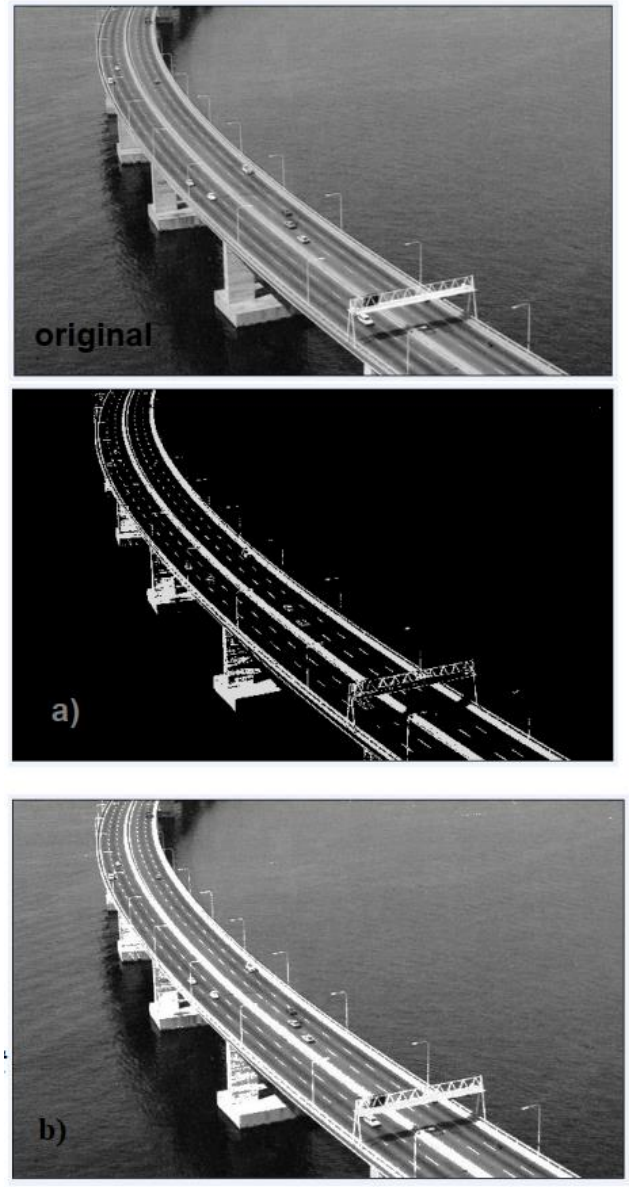
- Low level image processing
  - Arithmetic operations
  - Pixel relations
- Intensity level slicing / threshold
- Histograms
  - Contrast Stretching
  - Histogram equalization
- Filtering
  - Image smoothing
  - Image sharpening
- Geometrical transformations

Intensity level slicing

- Intensity level slicing means highlighting a specific range of intensities in an image.



a) Threshold b) Highlight a band of interest

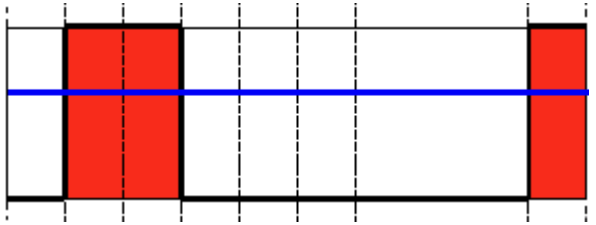


- Threshold is a specific case of intensity level slicing

OpenCV - `cv::threshold`

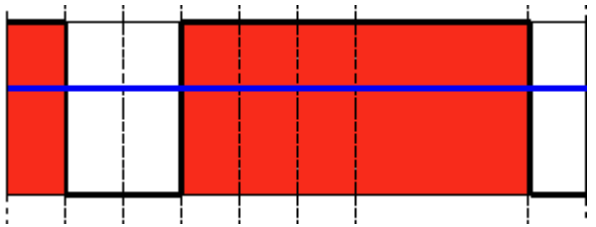
- **Threshold Binary**

$$\texttt{dst}(x,y) = \begin{cases} \texttt{maxVal} & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ 0 & \text{otherwise} \end{cases}$$



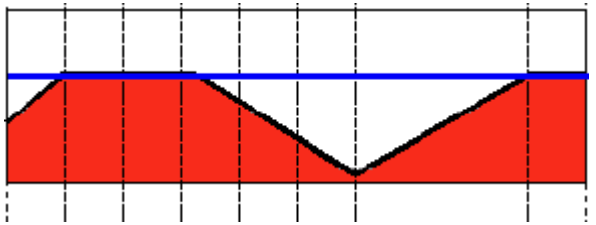
- **Threshold Binary, Inverted**

$$\texttt{dst}(x,y) = \begin{cases} 0 & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ \texttt{maxVal} & \text{otherwise} \end{cases}$$



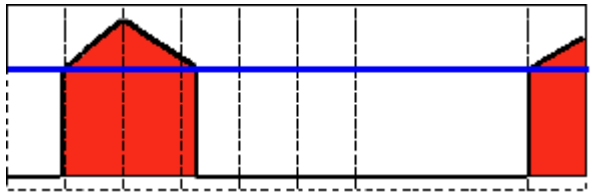
- **Truncate**

$$\texttt{dst}(x,y) = \begin{cases} \texttt{threshold} & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ \texttt{src}(x,y) & \text{otherwise} \end{cases}$$



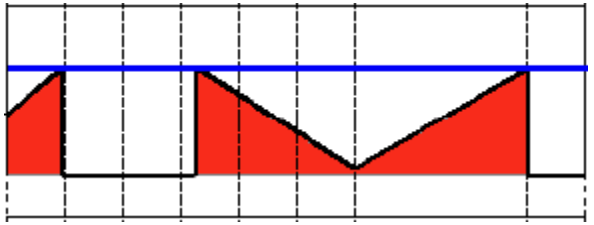
- **Threshold to Zero**

$$\texttt{dst}(x,y) = \begin{cases} \texttt{src}(x,y) & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ 0 & \text{otherwise} \end{cases}$$



- **Threshold to Zero, Inverted**

$$\texttt{dst}(x,y) = \begin{cases} 0 & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ \texttt{src}(x,y) & \text{otherwise} \end{cases}$$



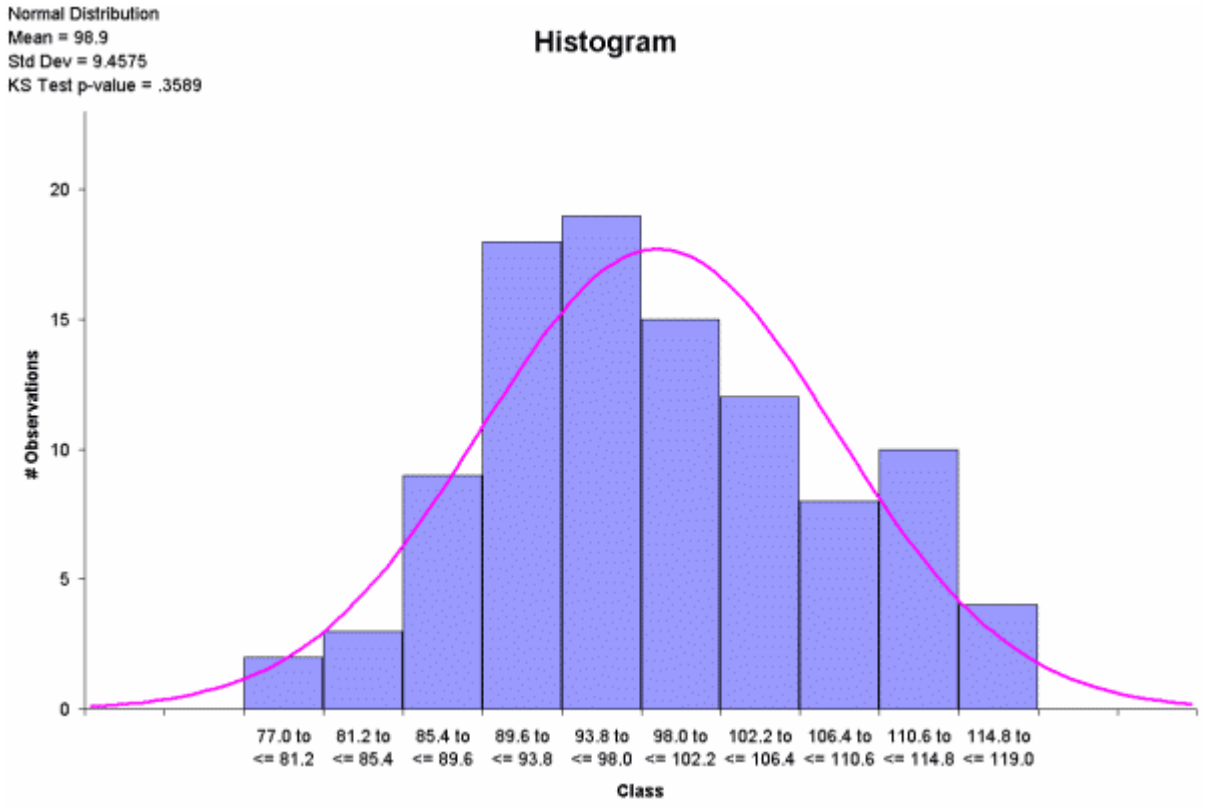
https://docs.opencv.org/3.4/db/d8e/tutorial_threshold.html

Sumary

- Low level image processing
  - Arithmetic operations
  - Pixel relations
- Intensity level slicing / threshold
- Histograms
  - Histogram equalization
- Filtering
  - Image smoothing
  - Image sharpening
- Geometrical transformations

Histograms

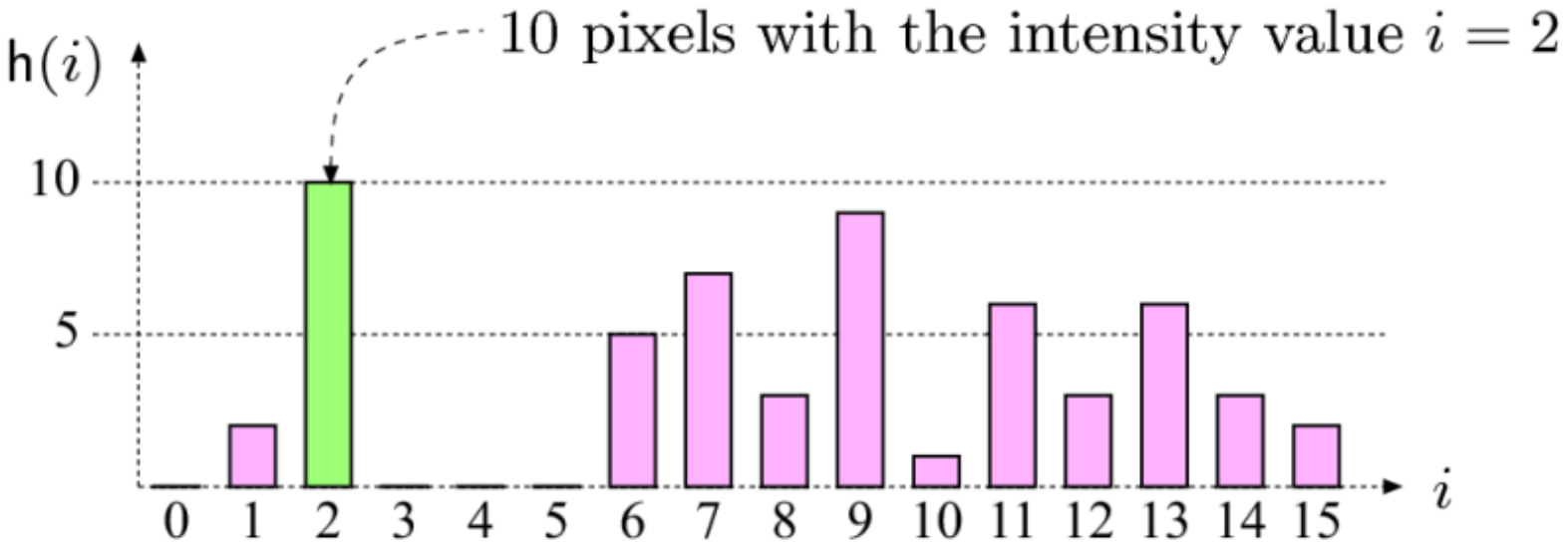
- An histogram is a graphical display of tabulated frequencies.
- Typically represented as a bar chart



Histograms

- In images, histograms allow us to see the colour or intensity distribution.
- The collected counts of data can be organized into a set of predefined bins.
- Important parts of an histogram:
  - dims: The number of parameters you want to collect data.
  - bins: The number of subdivisions in each dim.
  - range: The limits for the values to be measured.
- Operation based on histogram typically have two phases:
  - Determination and analysis of histogram
  - Image improvement based on the histogram.

Histograms

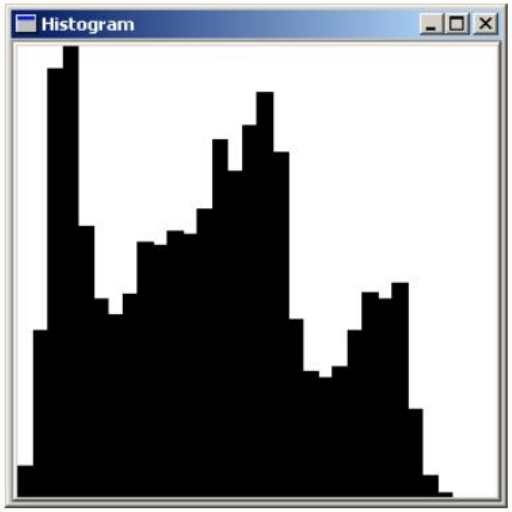


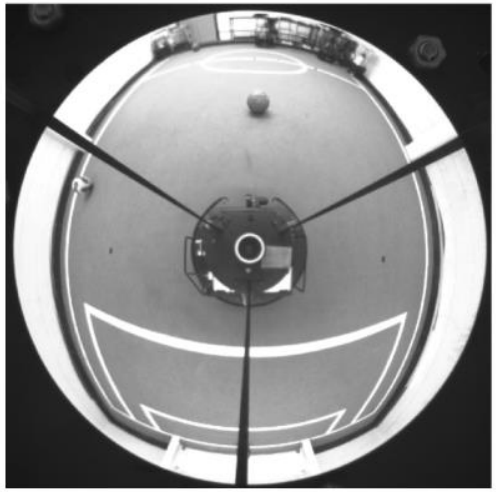
$h(i)$	0	2	10	0	0	0	5	7	3	9	1	6	3	6	3	2
i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

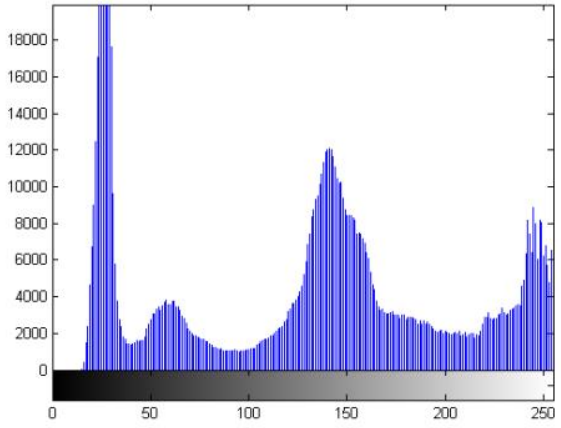
Burger and Burge

Histograms

- Examples

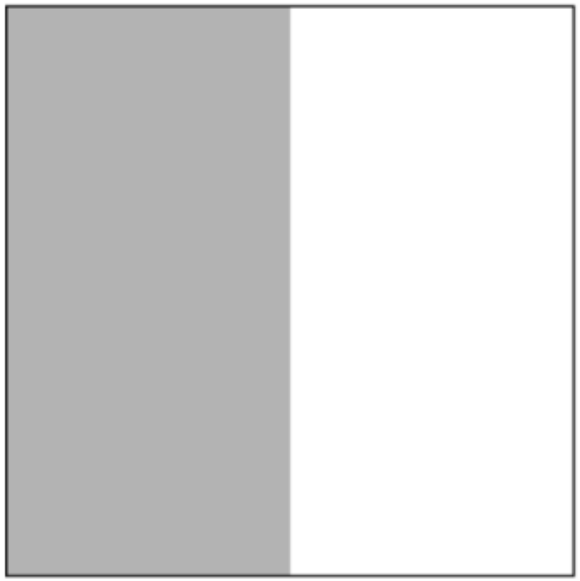


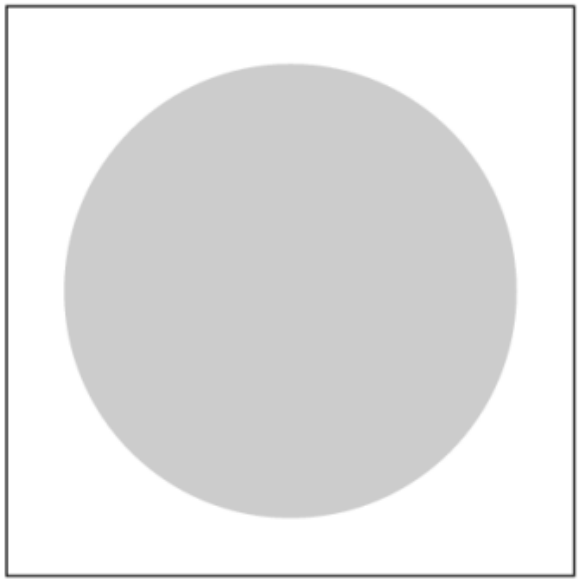


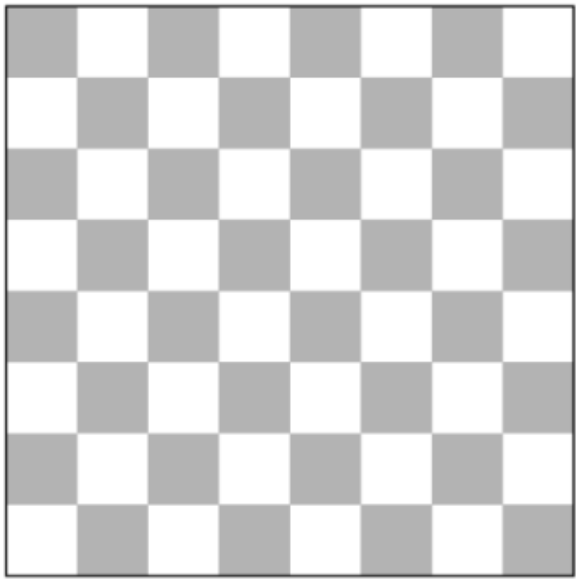


Histograms

- Histograms… same or diferent?



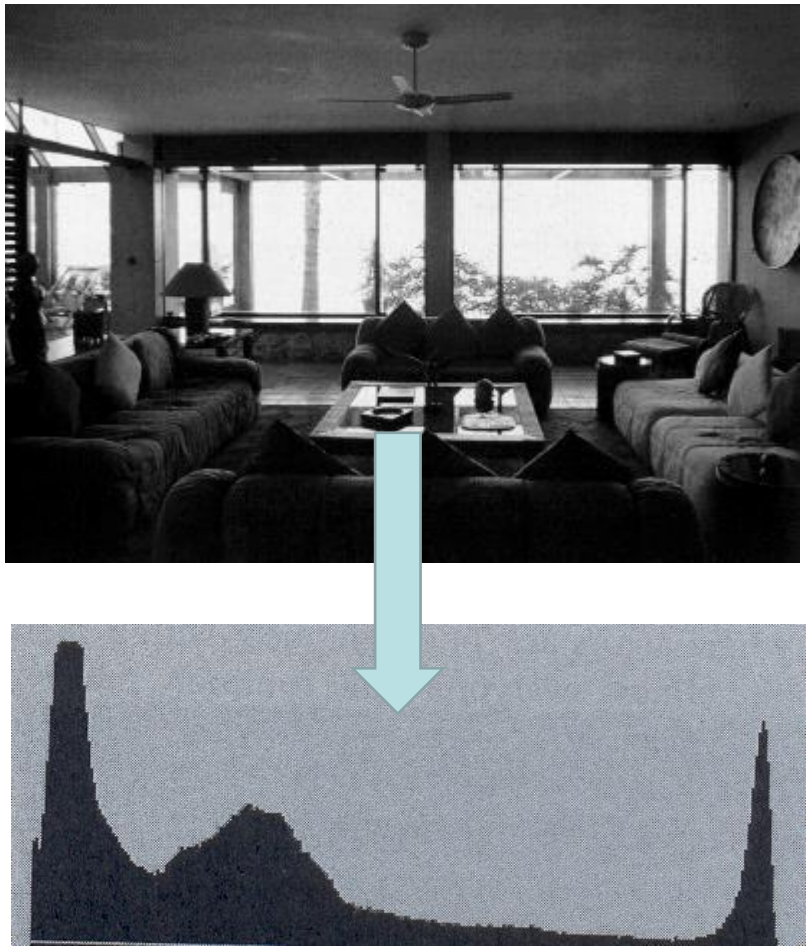




Burger and Burge

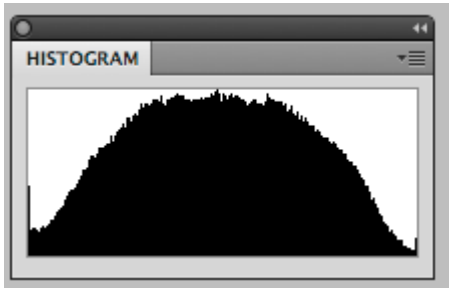
Histograms

- Which histogram to which image

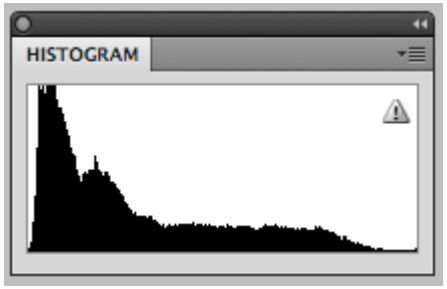


Histograms

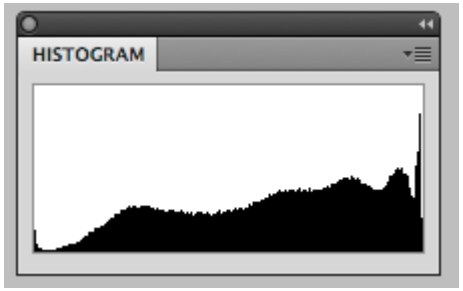
- Histograms



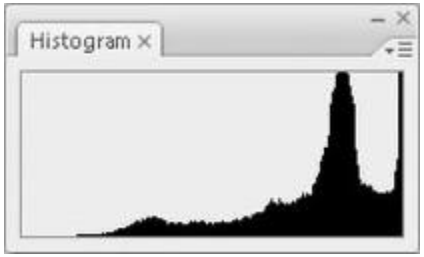
This is how an ideal histogram might look, evenly distributed, edge to edge, not up the sides.



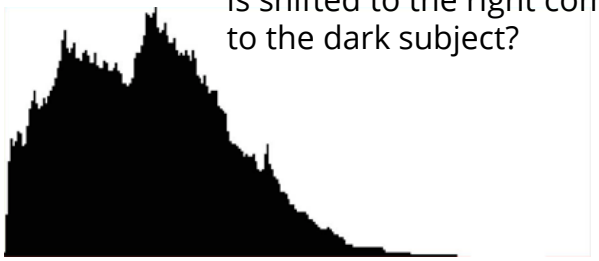
This is a histogram for a dark subject. It is not wrong; it is just more shifted to the left to represent the tones of the subject.



This is a histogram for a light subject (e.g., a white cat) with mostly light tones in the scene and few dark areas. See how it is shifted to the right compared to the dark subject?



This graph shows an overexposed image; notice the gap on the left side indicating a lack of any blacks in the image. It also means you will lose lots of detail in the white areas that may not be recoverable. In this case, shift to give your image less exposure and shoot the scene again.



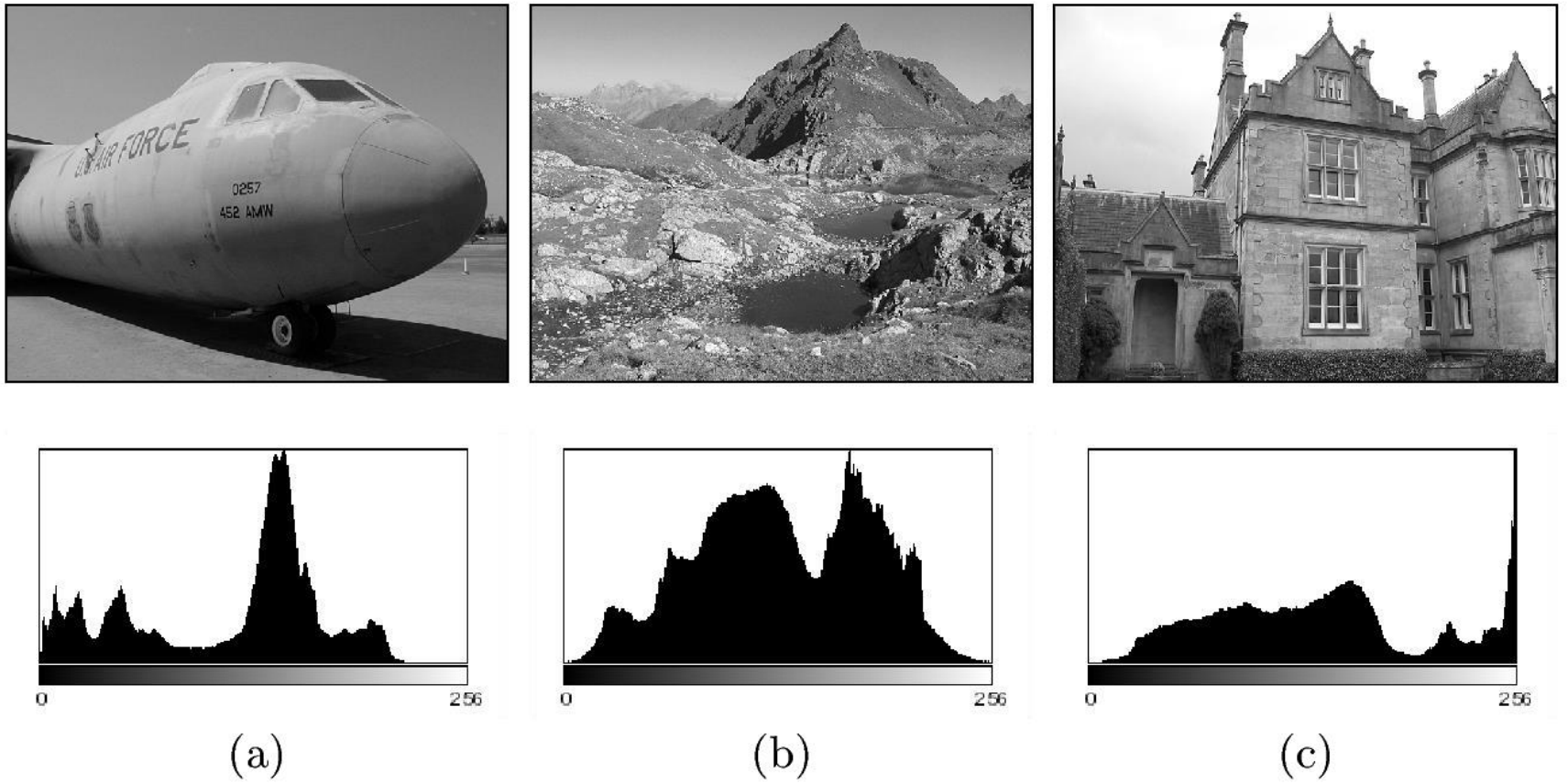
This histogram shows the opposite. Now we see a gap on the right side of the graph indicating there are no whites represented, so the image will be dark – too dark. You can safely give the image more exposure until you see the tones just touch the right edge of the histogram.

https://digital-photography-school.com/how-to-read-and-use-histograms/

Histograms

- Properties: exposition

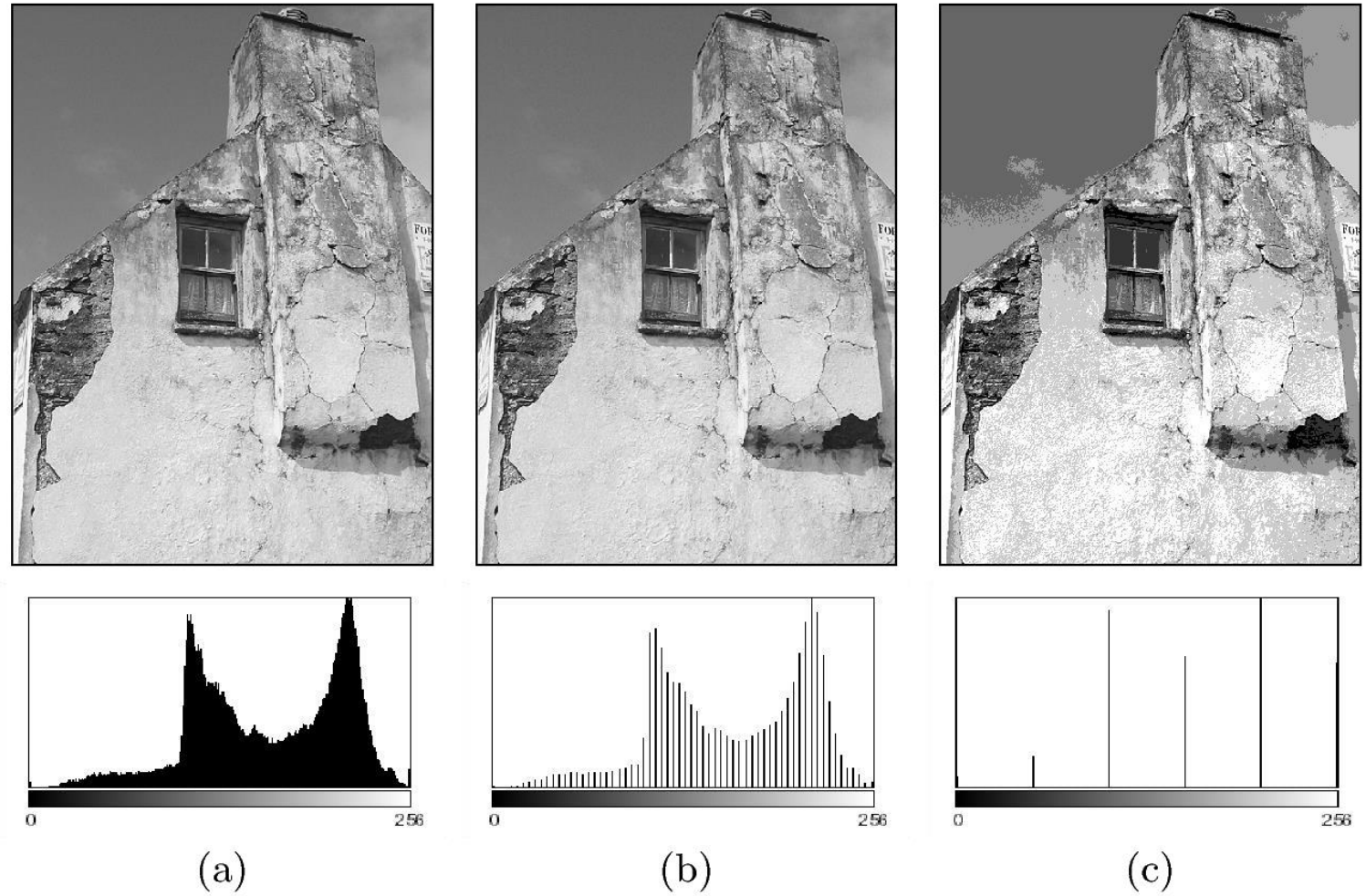
Burger and Burge



a – underexposed image – loss of details in dark areas
b - ok
c - overexposed – loss of details in bright areas

Histograms

- Properties: intensity levels

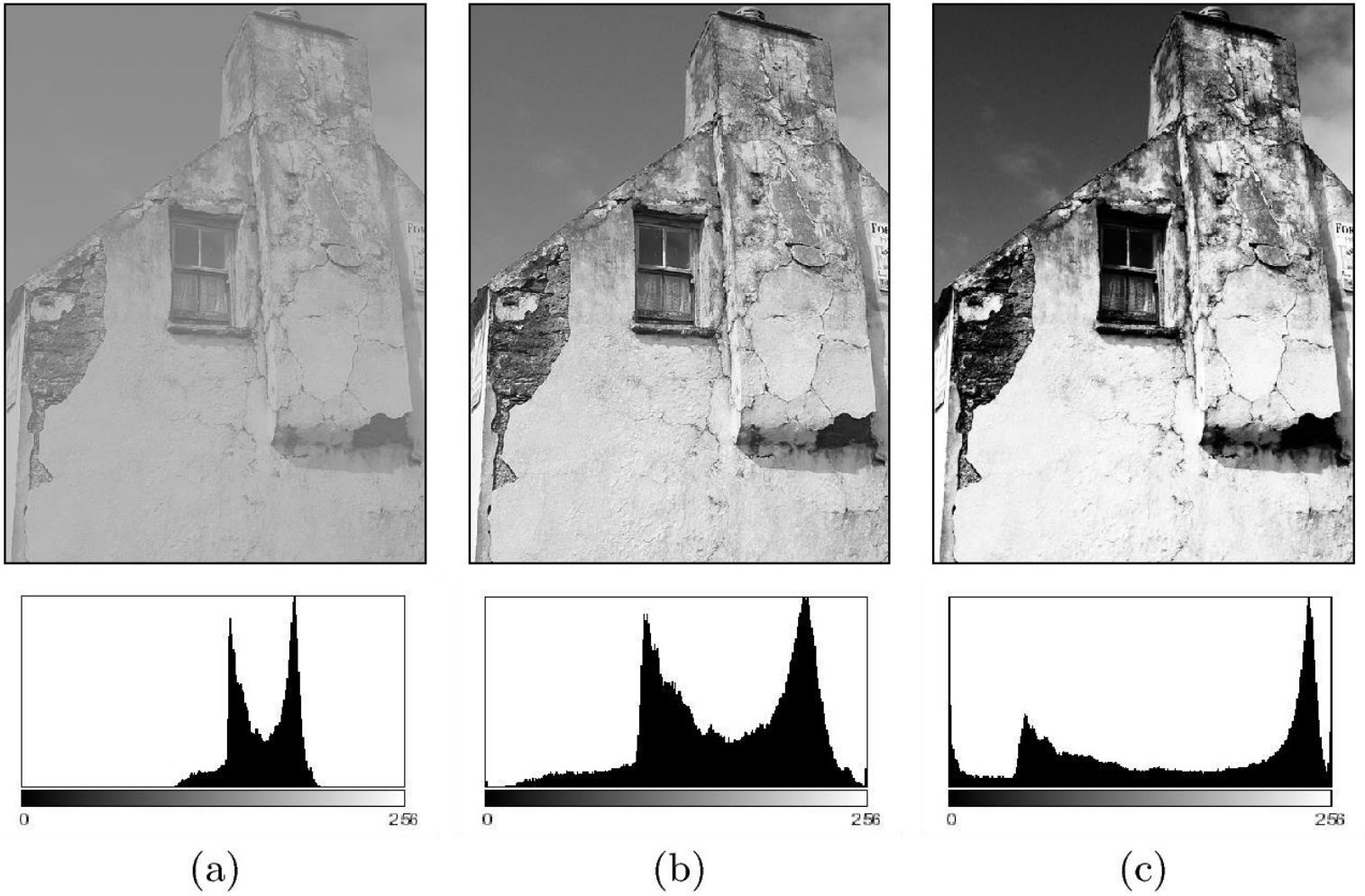


256, 64 and 6

Burger and Burge

Histograms

- Properties: contrast



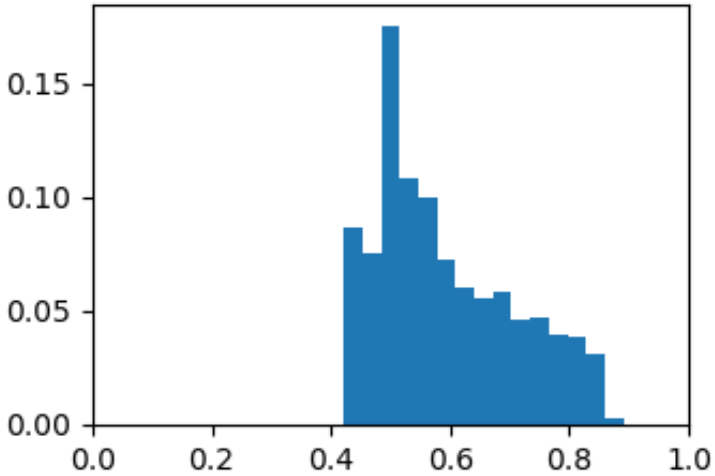
Burger and Burge

Histograms

- Contrast stretching

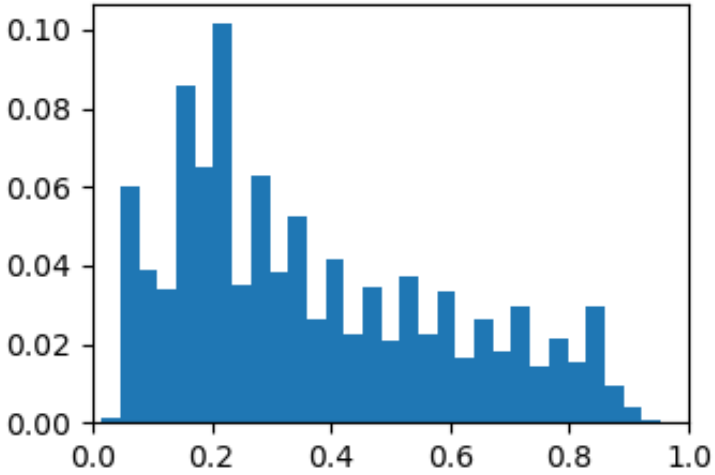
Low contrast orginal

Histogram of low contrast image



Contrast Stretched

Histogram of contrast stretched image

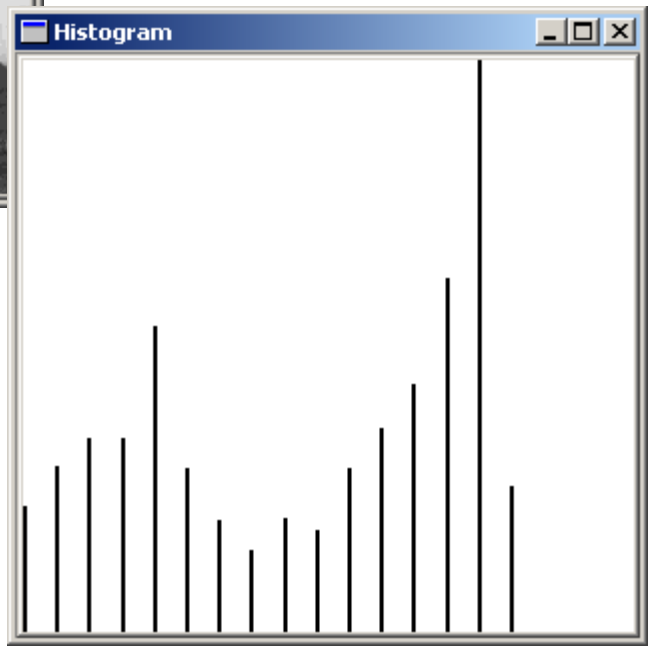


$$g = \frac{f - f_{\min}}{f_{\max} - f_{\min}}$$

https://staff.fnwi.uva.nl/r.vandenboomgaard/IPCV20162017/LectureNotes/IP/PointOperators/ImageStretching.html

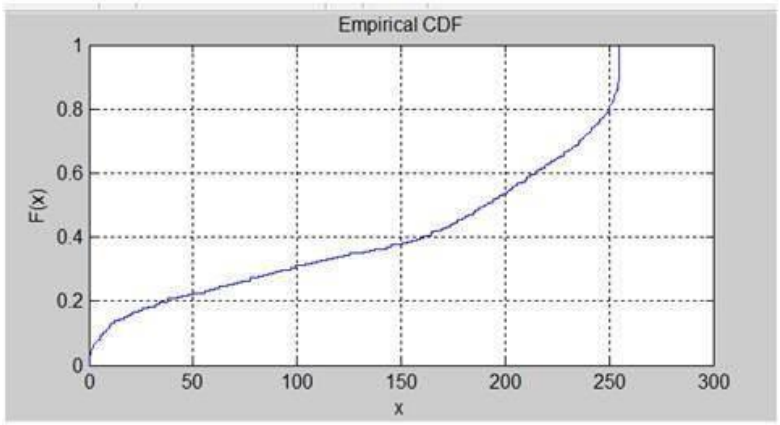
Histograms

- Contrast stretching (another exemple)

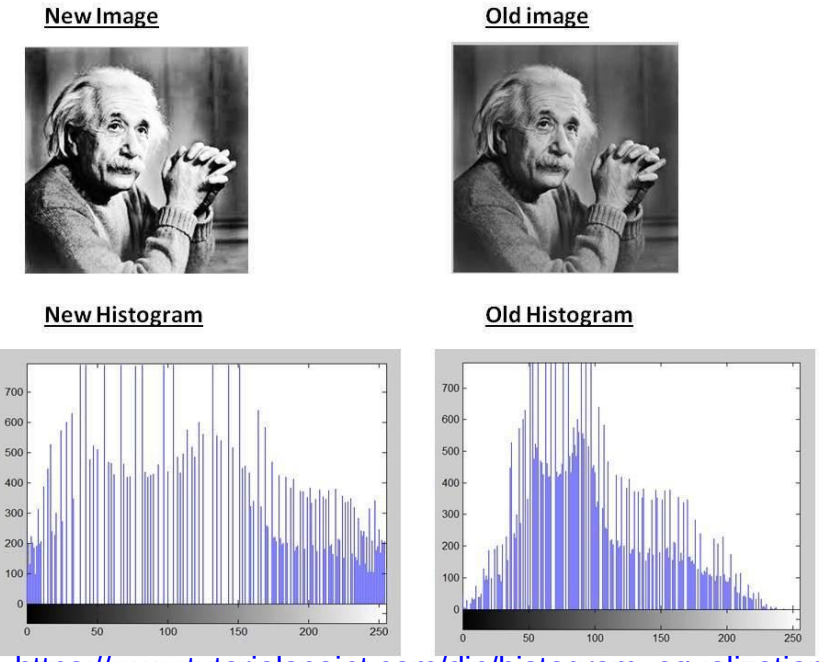


Histograms

- Histogram equalization
  - Can be seen as an extension of contrast stretching
  - Histogram is analysed by a function T(z) to reshape the image to make its histogram flat and wide
  - A typical solution is to use the cumulative histogram (integral of intensity histogram) as the intensity mapping function.



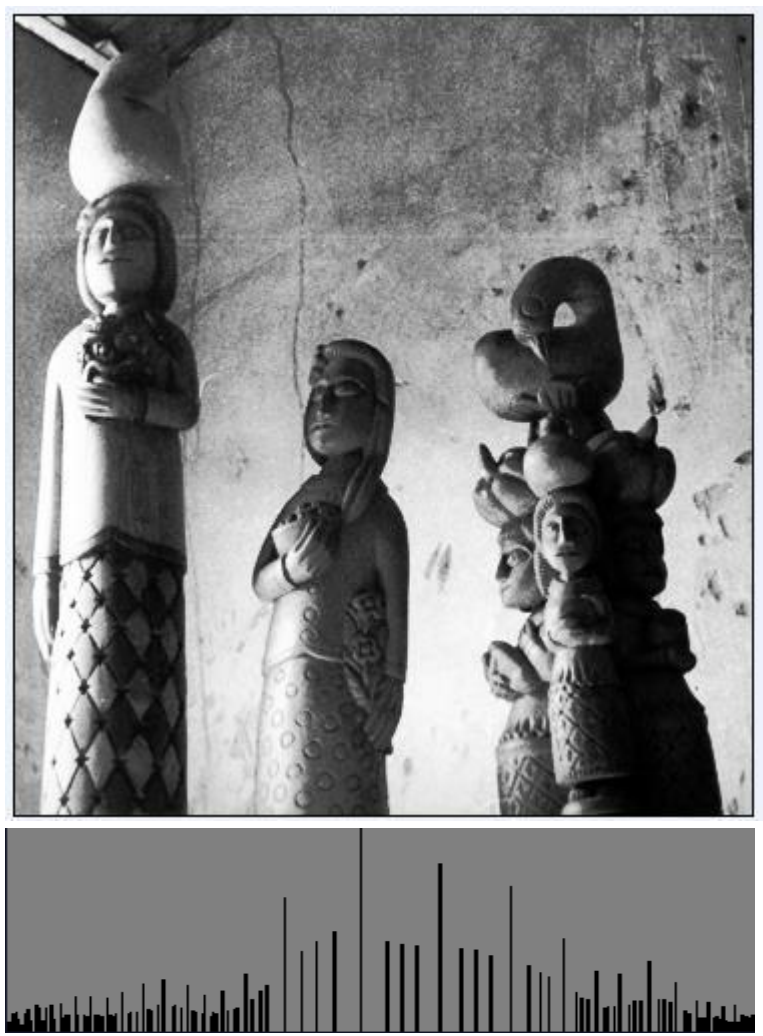
Cumulative Distributive function of the image



https://www.tutorialspoint.com/dip/histogram_equalization.htm

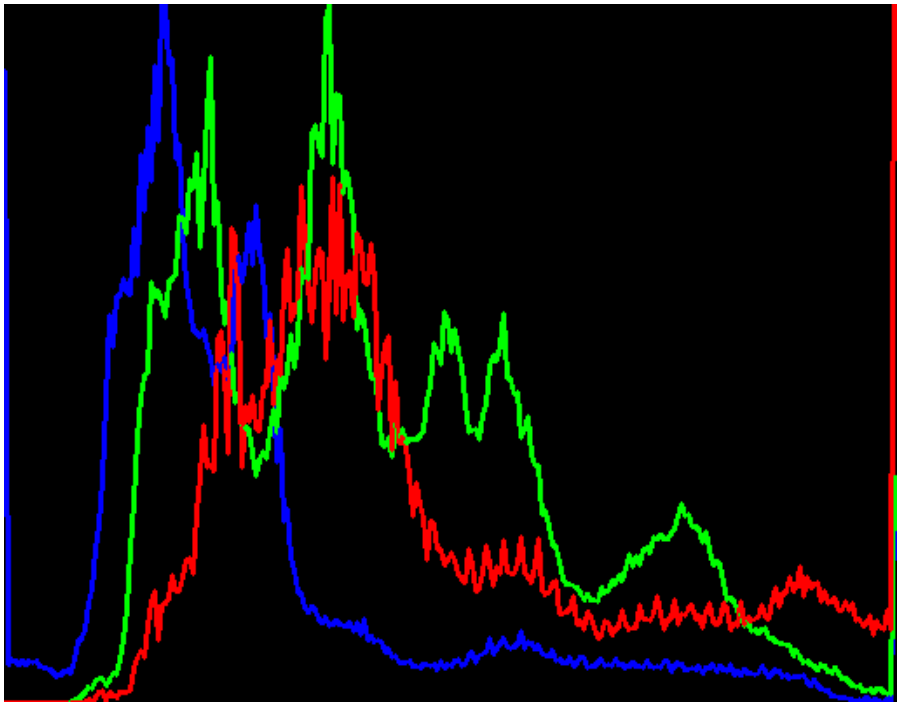
Histograms

- Histogram equalization



Histograms

- Colour histogram



Sumary

- Low level image processing
  - Arithmetic operations
  - Pixel relations
- Intensity level slicing / threshold
- Histograms
  - Histogram equalization
- Filtering
  - Image smoothing
  - Image sharpening
- Geometrical transformations

Filtering

- Image smoothing or blurring
  - Also known as neighbourhood averaging
  - Used to remove noise or a pre-processing for edge detection
  - Filtering operation in which a weighted array is moved over the original image while computing the pixel as a weighted average:
  - $\mathrm{I}'(u,v) = \sum_{i=0,j=0}^{n,m} R(i,j).I\left(u - \left(\frac{n-1}{2}\right) + i, v - \left(\frac{m-1}{2}\right) + j\right)$

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

3x3 average filter with 1/9 weight, acnhored in center of array

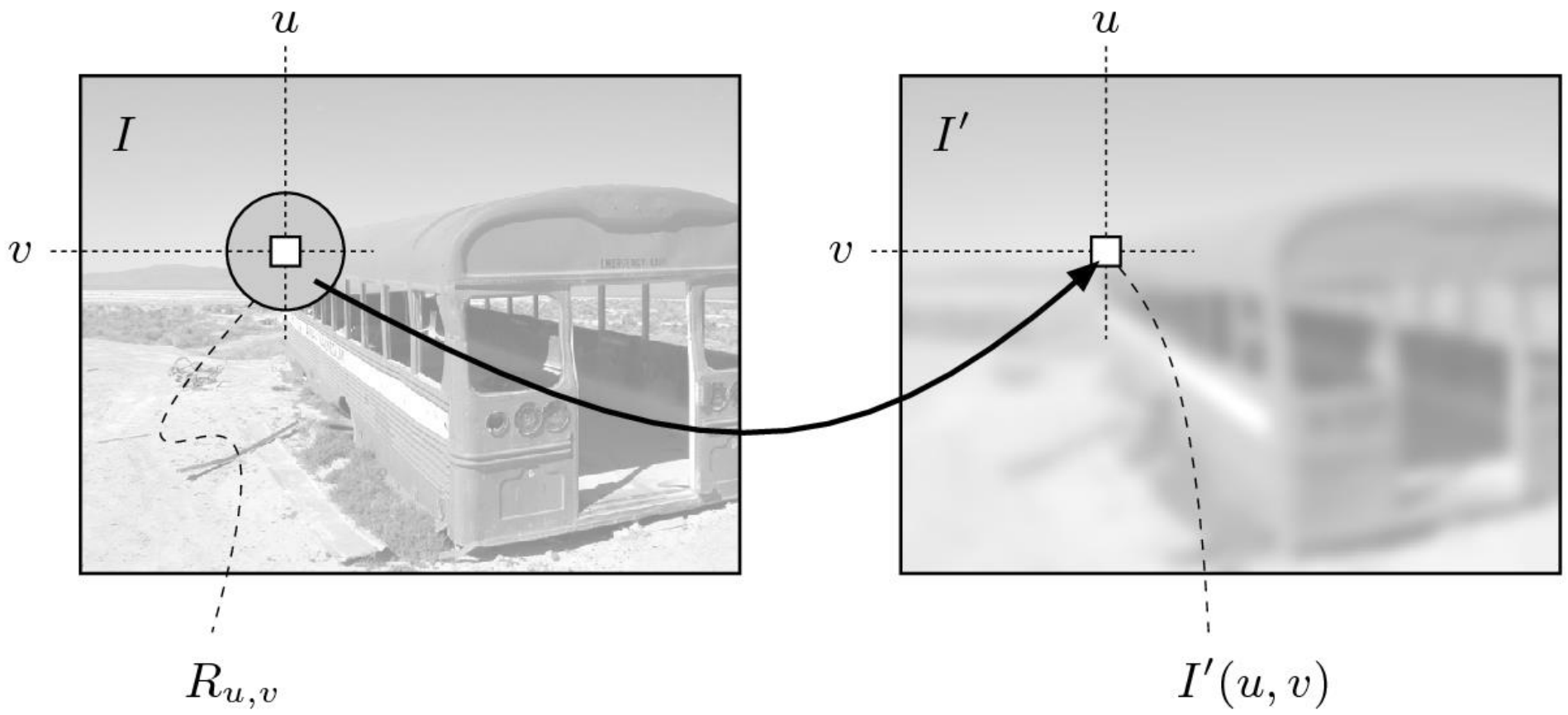
Filtering

- Image smoothing or blurring

Burger and Burge

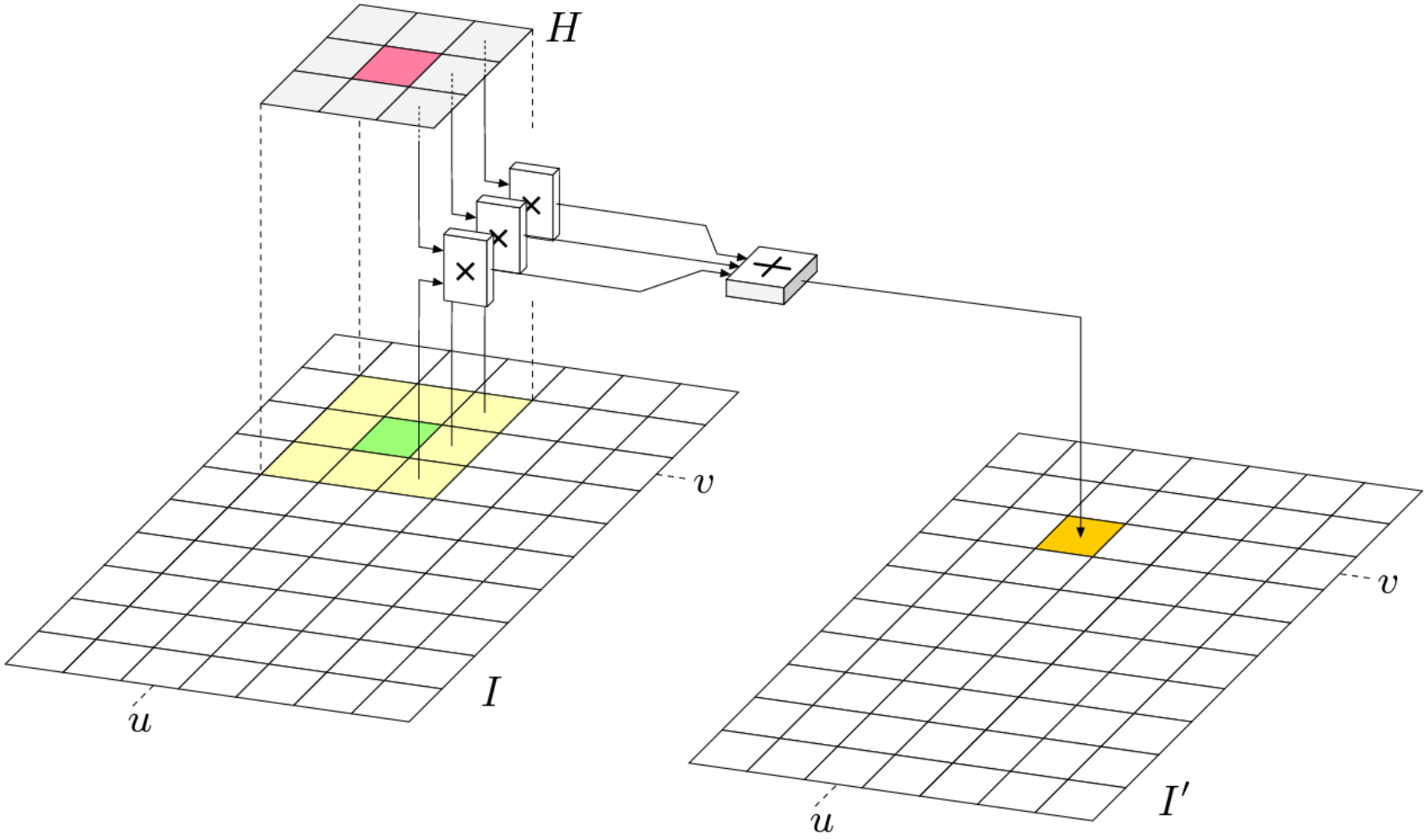
Filtering

- Image smoothing or blurring



Filtering

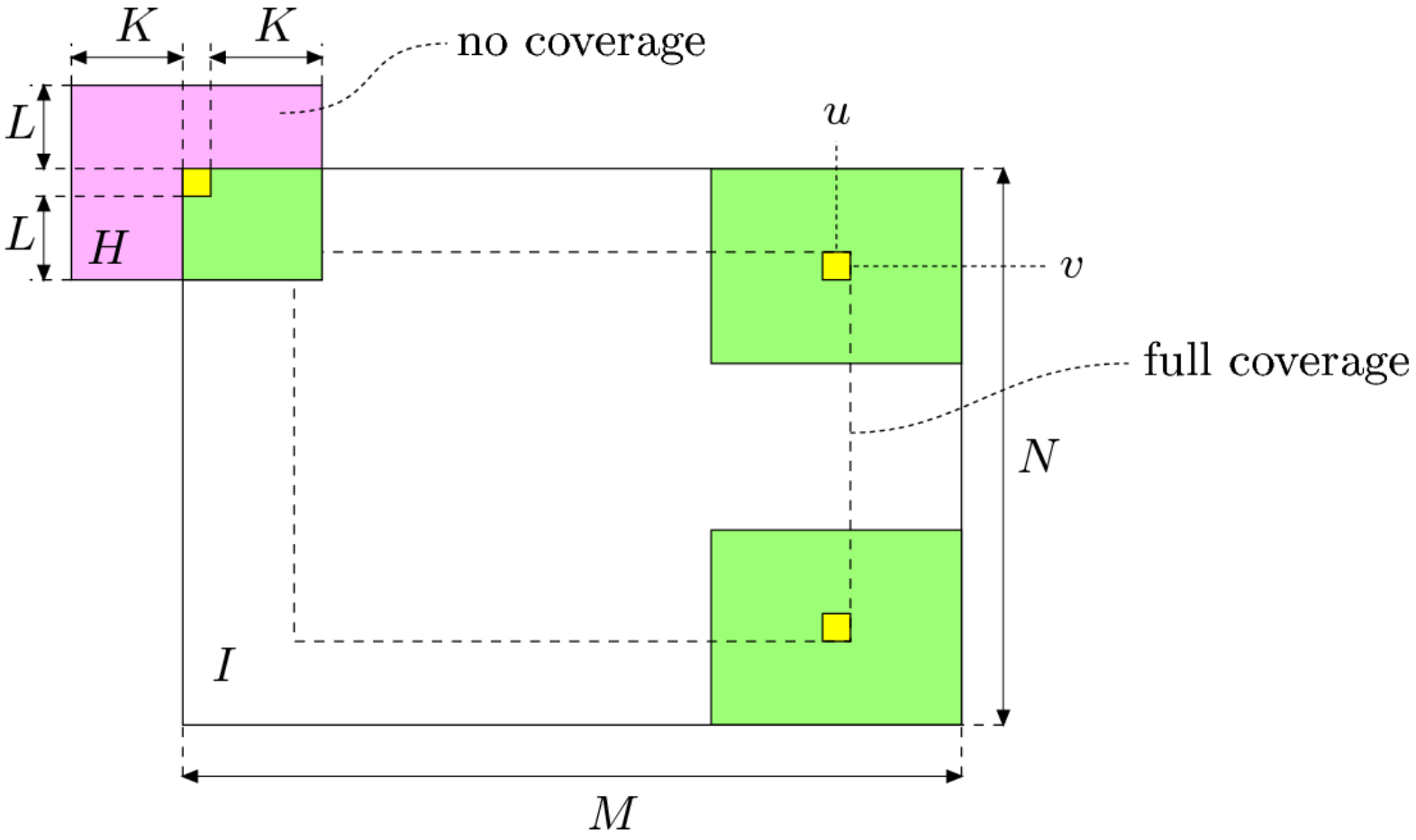
- Image smoothing or blurring



Burger and Burge

Filtering

- Image smoothing or blurring
  - What to do at borders



Burger and Burge

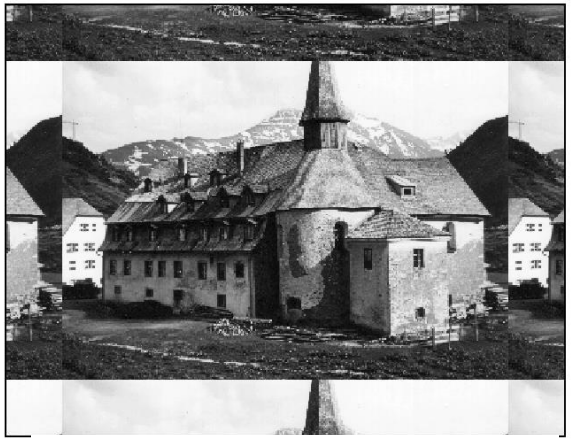
Filtering

- Image smoothing or blurring
  - What to do at borders

Constant Value

Value of closest border

Mirrored at image Boundary



Periodically repeat along axis

Burger and Burge

Filtering

- Average filter for noise reduction
  - Kind of the low pass filter, the larger the size, the larger the cut-off frequency.
  - This is an approximation since smoothing operation is performed in space and not in frequency domain.

Filtering

- Average filter for noise reduction

Original

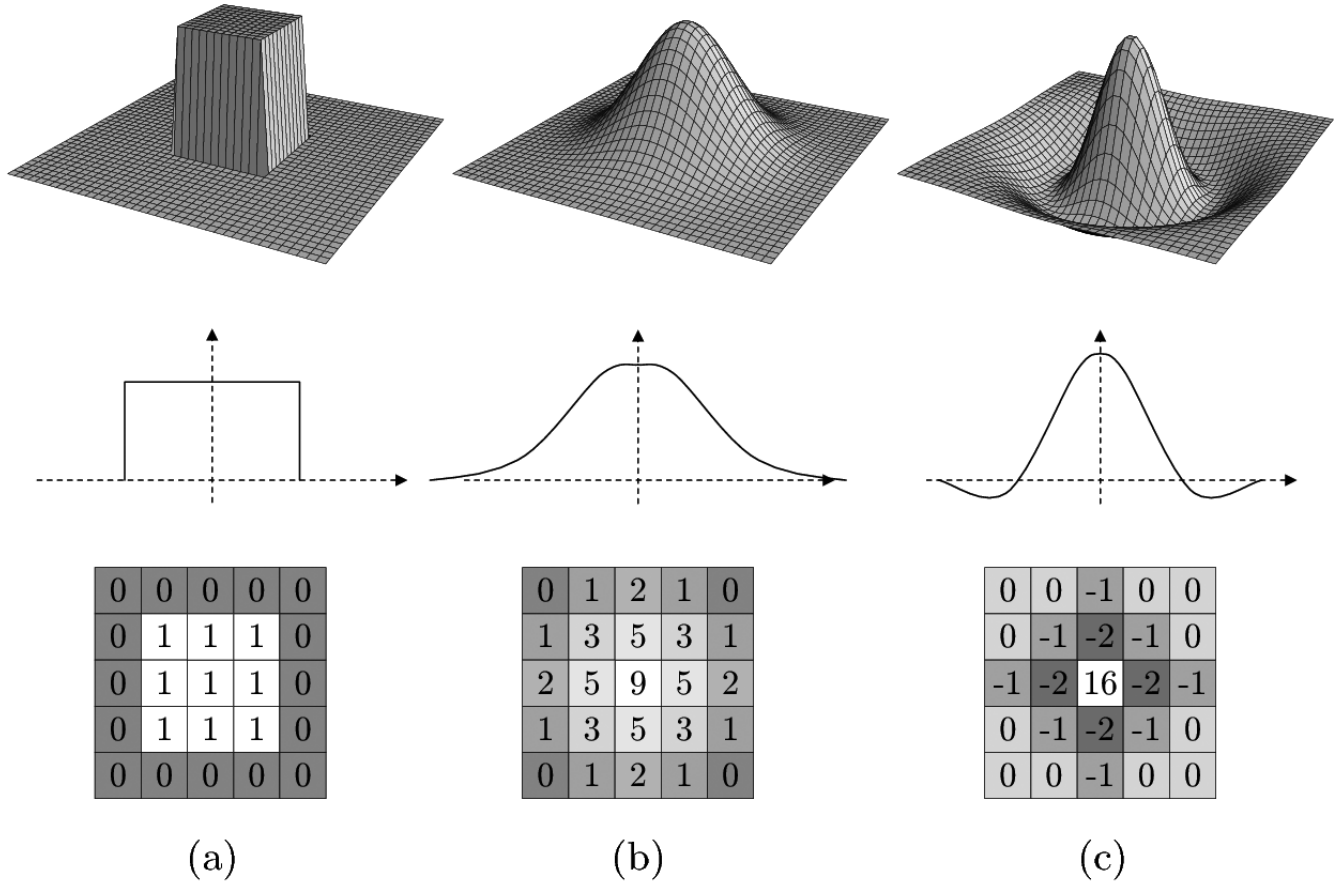
Noisy

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

Blurred image

Filtering

- Typical linear filter



0	0	0	0	0
0	1	1	1	0
0	1	1	1	0
0	1	1	1	0
0	0	0	0	0

(a)

0	1	2	1	0
1	3	5	3	1
2	5	9	5	2
1	3	5	3	1
0	1	2	1	0

(b)

0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

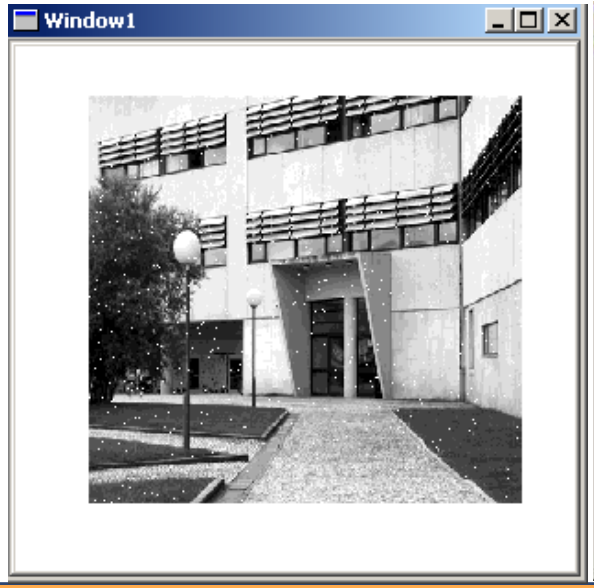
(c)

a – Box filter
b – Gaussian Filter
c – “Laplace” or “Mexican hat” filter

Burger and Burge

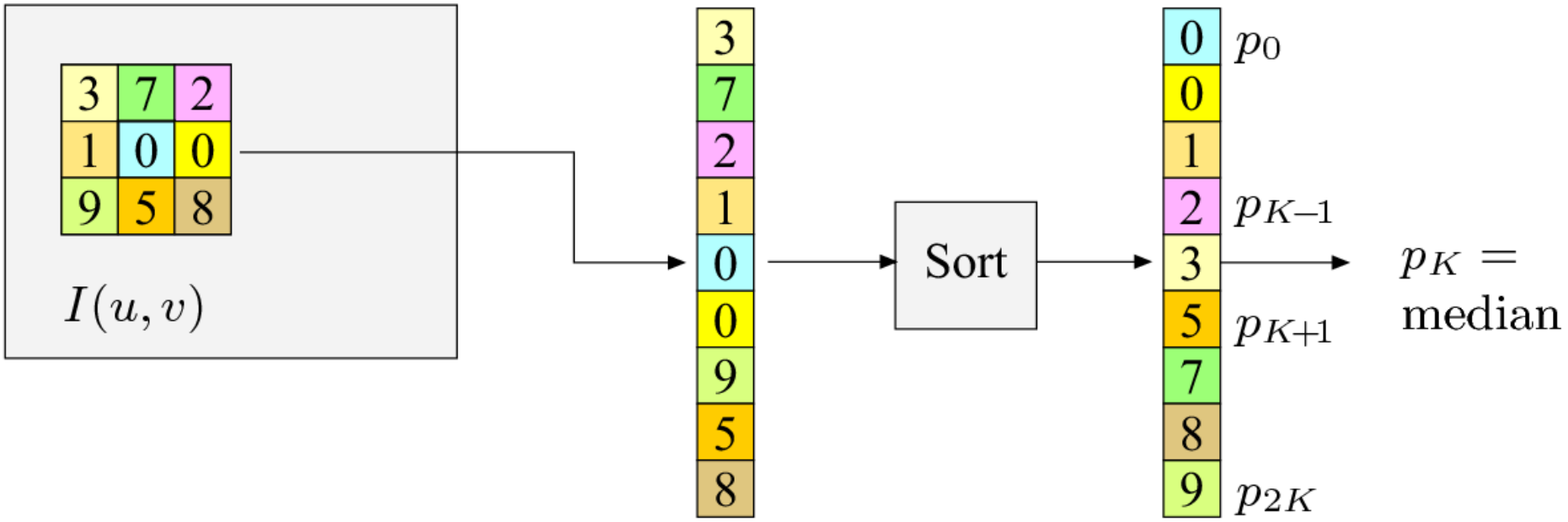
Filtering

Blurring in openCV



Filtering

- Median Filter



Burger and Burge

Filtering

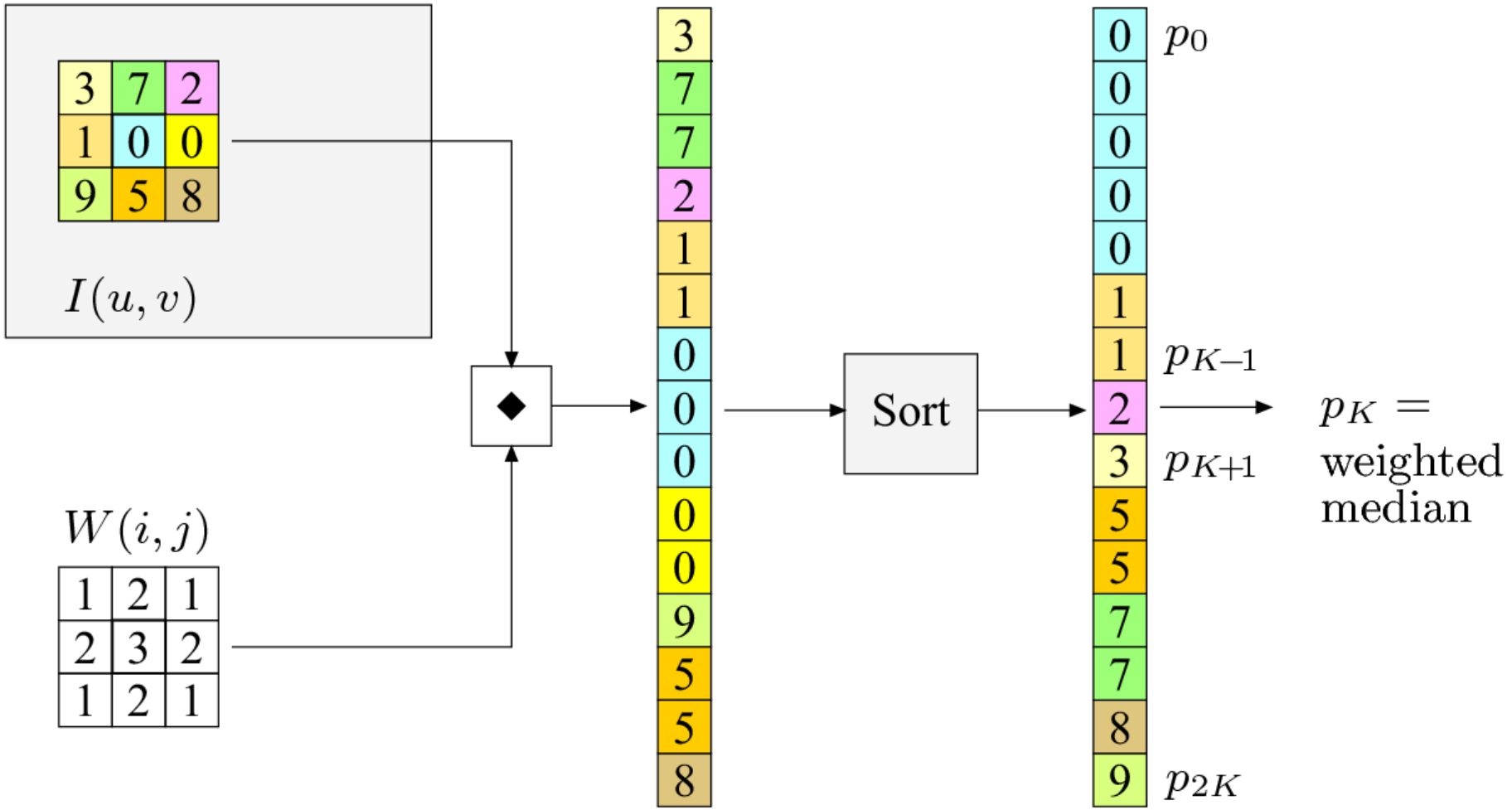
- Average vs median Filter

(a) (b) (c)

Burger and Burge

Filtering

- Weighted Median Filter



Burger and Burge

Filtering

- Minimum vs Maximum filter

(a) (b) (c)

Burger and Burge

Sumary

- Low level image processing
  - Arithmetic operations
  - Pixel relations
- Intensity level slicing / threshold
- Histograms
  - Histogram equalization
- Filtering
  - Image smoothing
  - Image sharpening
- Geometrical transformations

Geometrical transformations

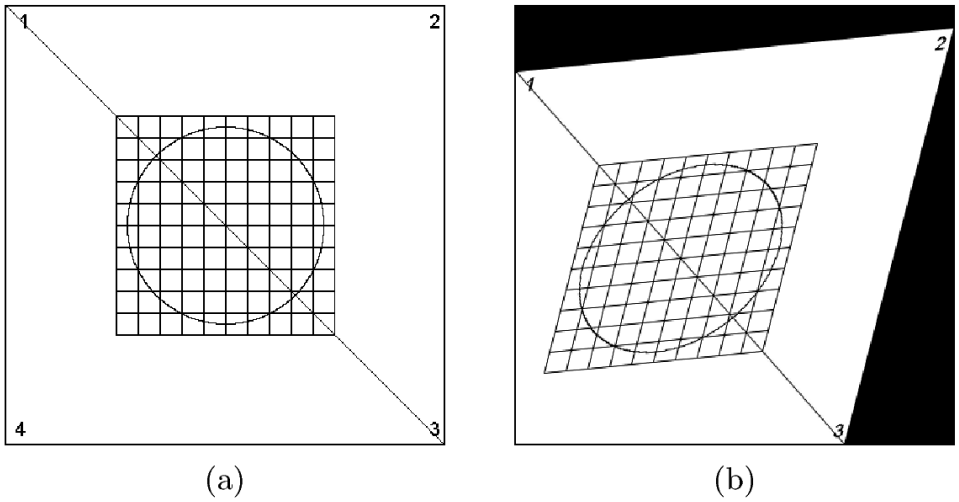
- Geometric operation transform a given image I to a new image I′

$$I'(x',y') \leftarrow I(x, y)$$

- Value of image I at original location (x,y) moves to new position (x′,y′) in transformed image I′ based on a geometric mapping T

$$(x',y') = T(x, y)$$

Geometrical Transformation



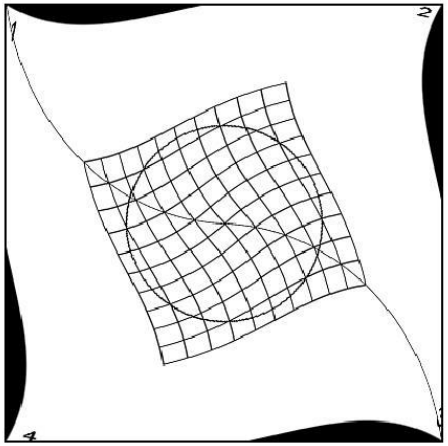
Linear:

- Affine
  - Translation, rotation, and scaling
  - Dreserves lines and parallelism
- Projective
  - Particular case of affine
  - Does not preserve parralelism

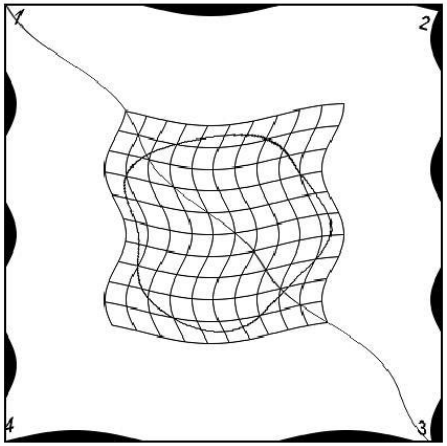
Burger and Burge

Geometrical Transformation

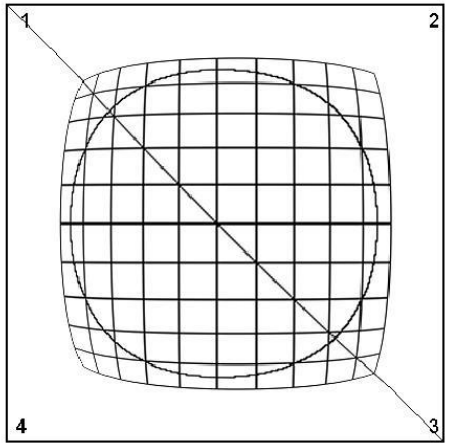
- Non linear: twirl, ripple, sphere, …



Twirl



Ripple

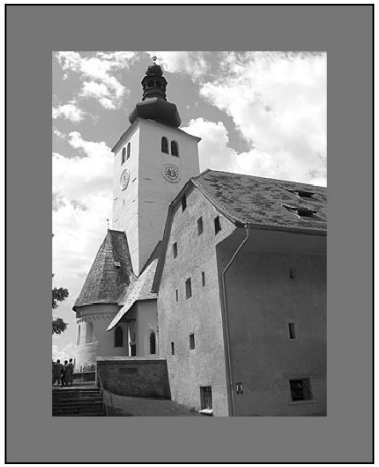


Sphere

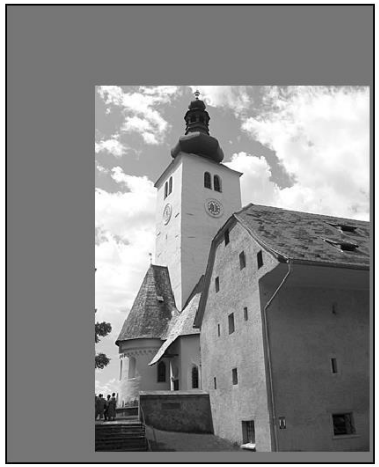
Burger and Burge

Geometrical Transformation

- Which ones



Original



Translation

Scaling (contract [x] and stretch [y])

Rotation

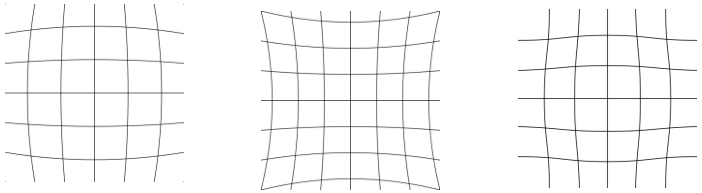
Projective

Non Linear

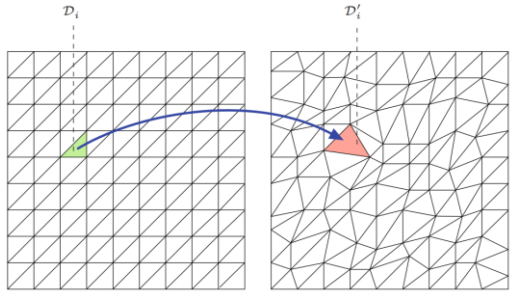
Burger and Burge

Geometrical transformations

- Geometrical transformations used for:
  - Correction of distortion (Camera lens correction)



  - Texture mapping (Computer Graphics)



  - Morphing (Special effects in movies)