**NUS-ISS**
*Vision Systems*

# Module 3 - Foundations of computer vision system (2) - Local feature and representation, part 2

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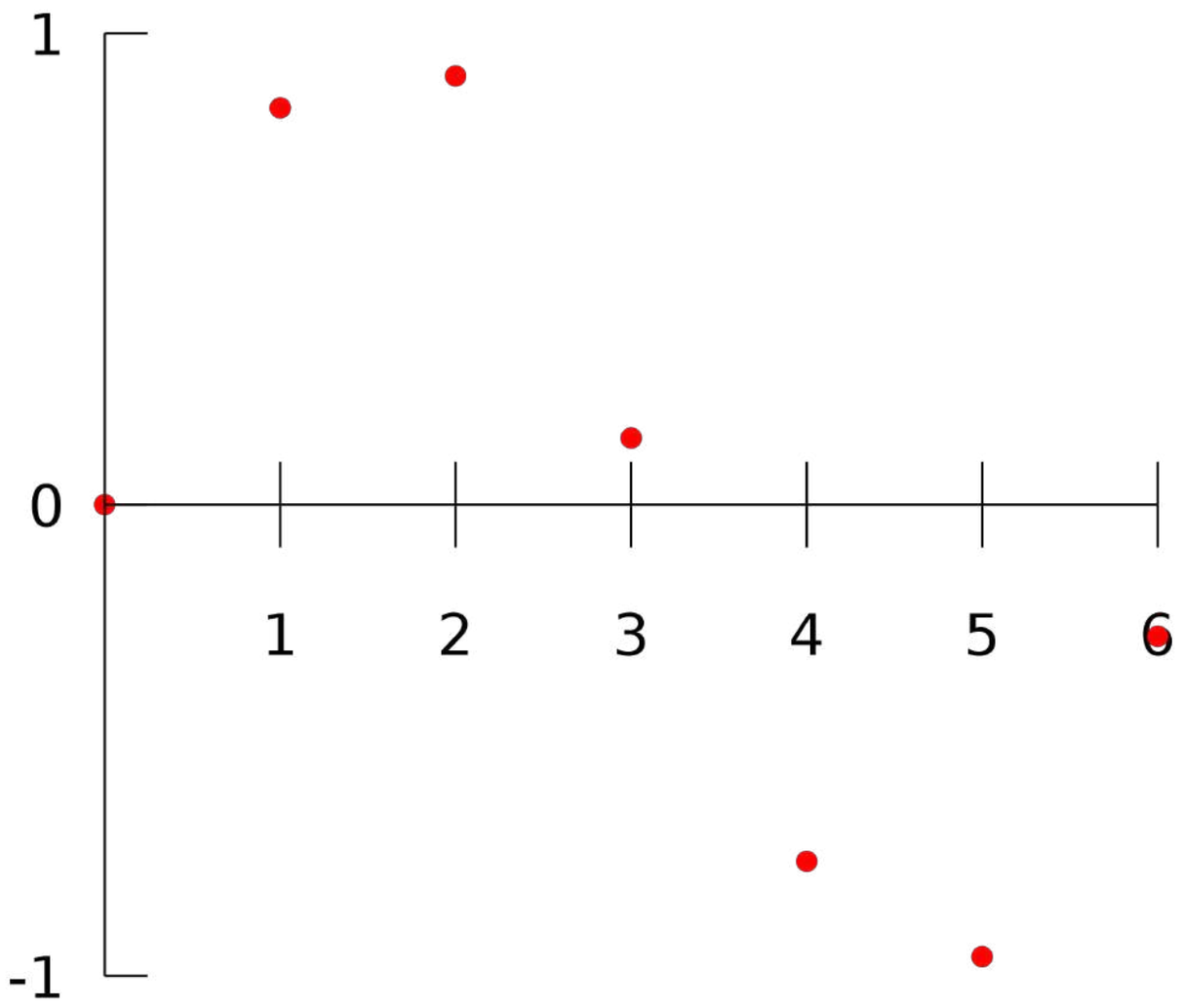
# Learning objectives

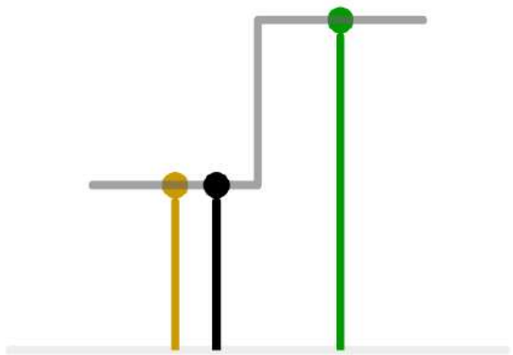
- Rescale / resize image
- Perform image translation and rotation
- Perform histogram equalization
- Perform image thresholding

# What is interpolation?

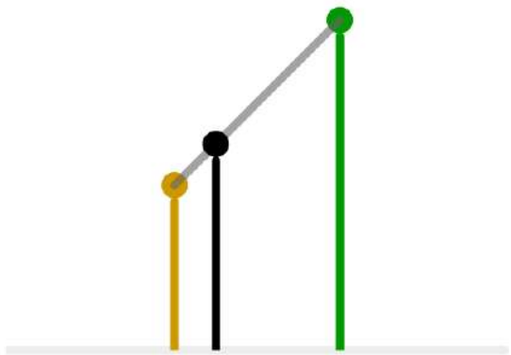



Source: https://en.wikipedia.org/wiki/Interpolation#/media/File:Interpolation_Data.svg

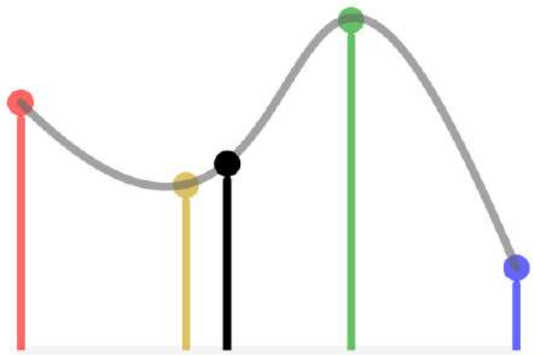
# Types of interpolation



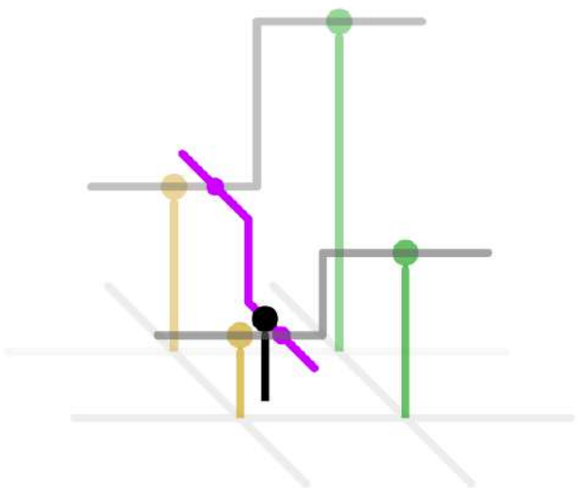
1D nearest-neighbour



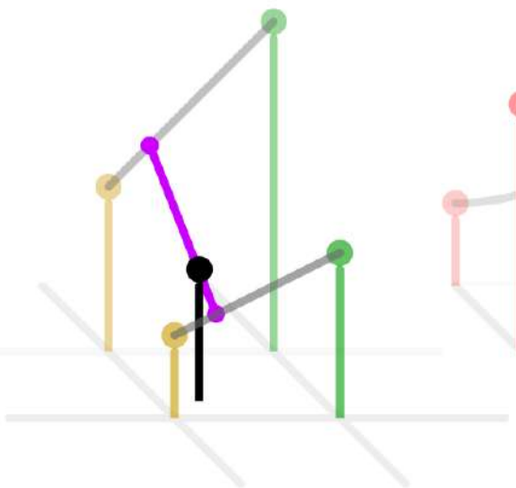
Linear



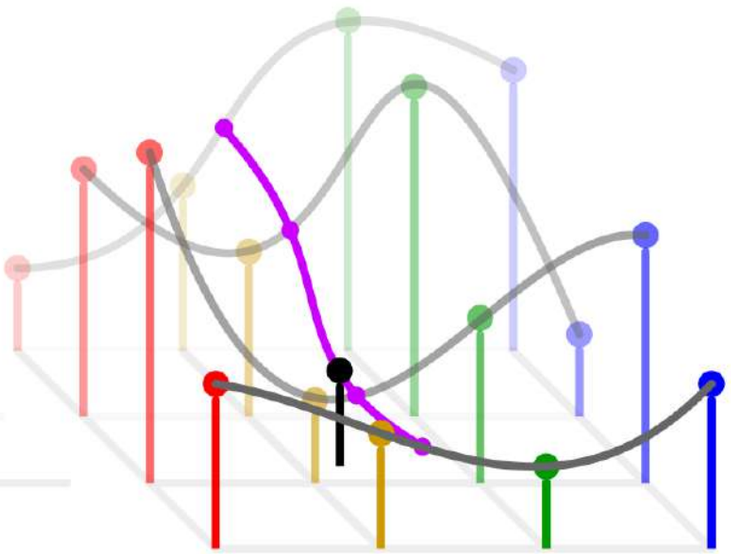
Cubic



2D nearest-neighbour



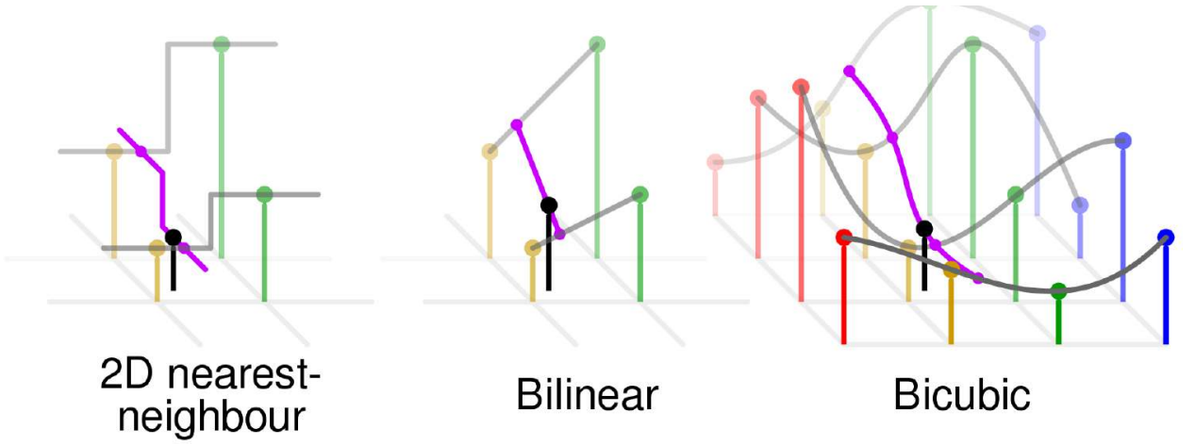
Bilinear

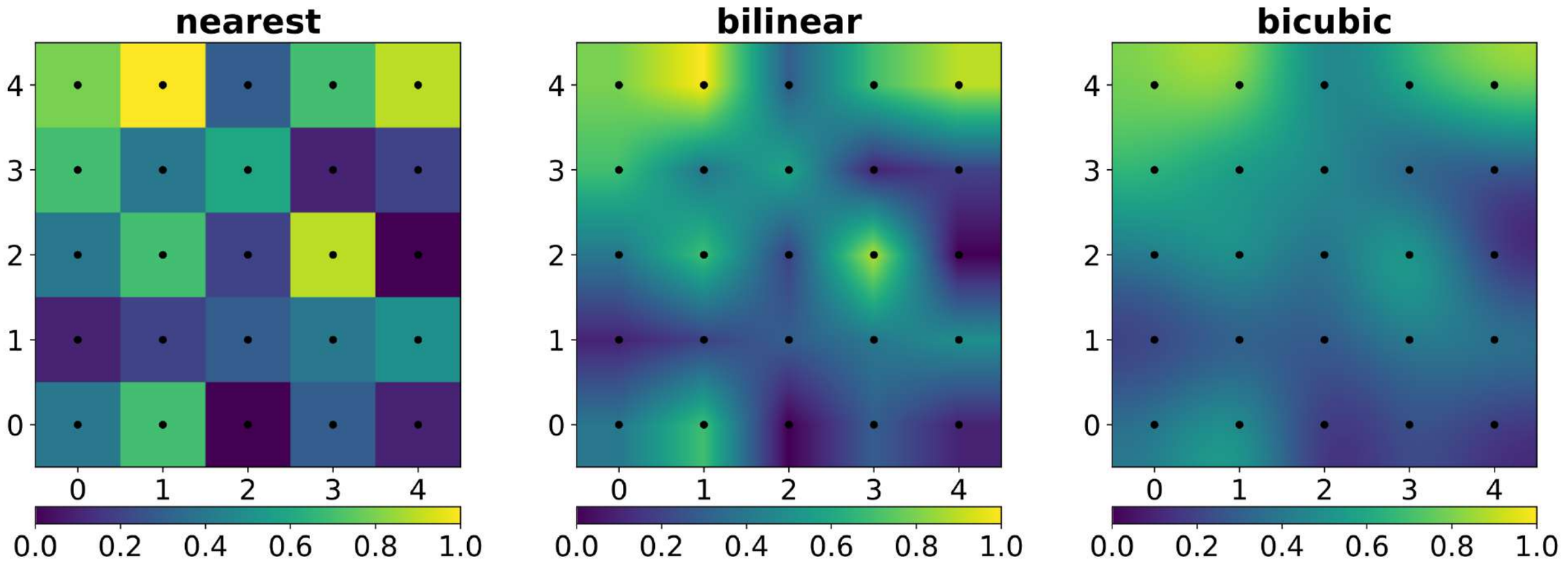


Bicubic

Source: https://en.wikipedia.org/wiki/Bicubic_interpolation

# Types of interpolation



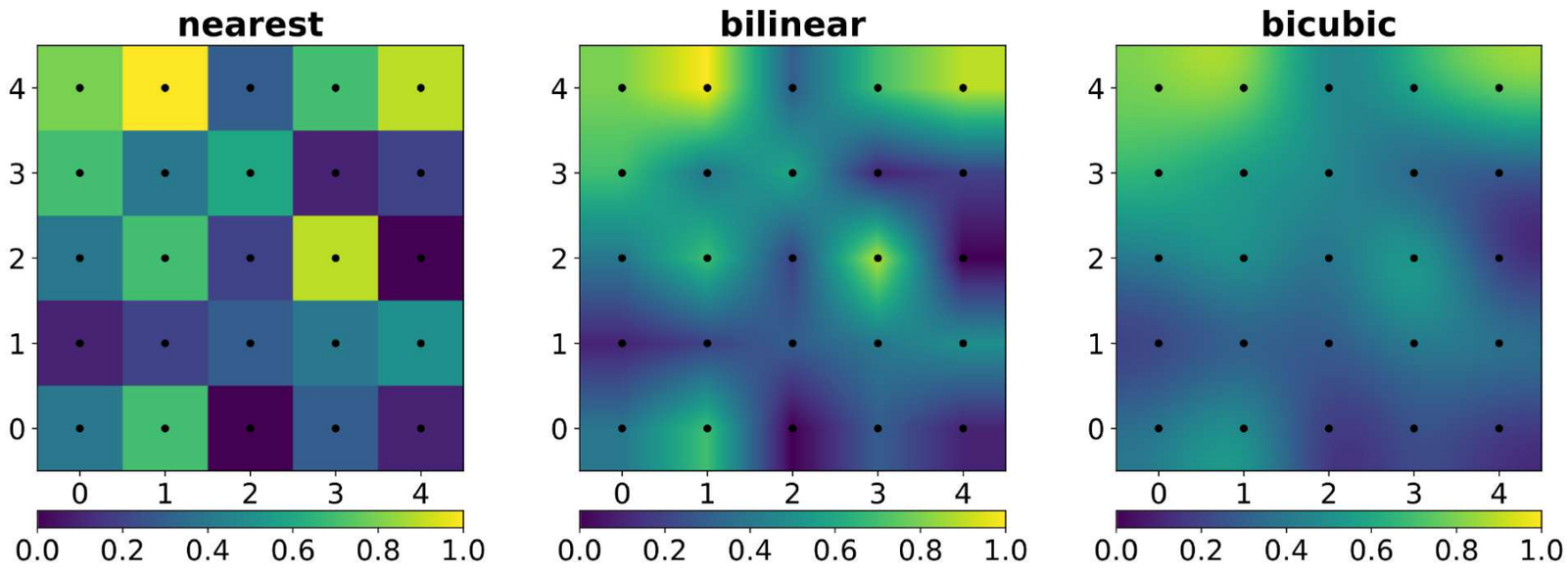




Source: https://en.wikipedia.org/wiki/Bicubic_interpolation

## Roles of interpolation in image processing?

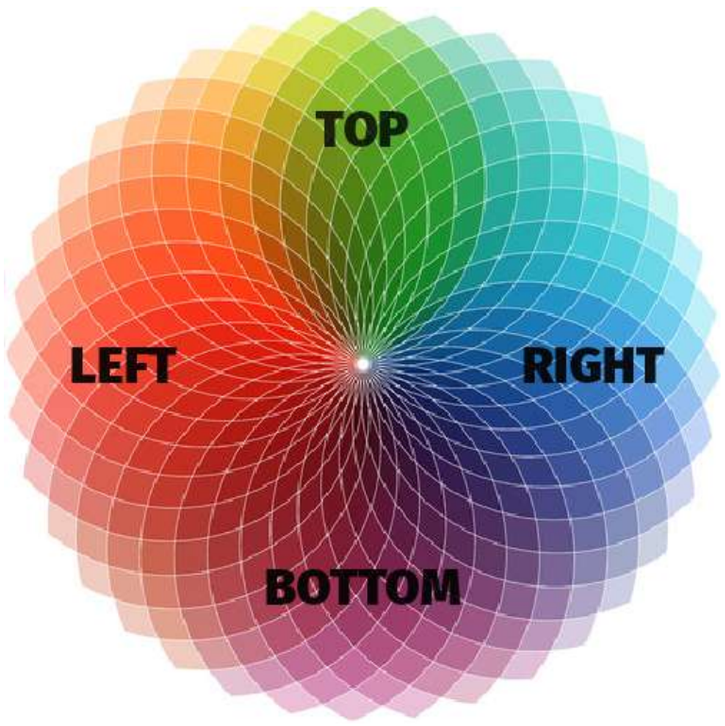
- Whenever we perform a geometric transformation on image, interpolation is always involved

- The choice of interpolation method affects the output and the calculation speed




Source: https://en.wikipedia.org/wiki/Bicubic_interpolation

# Rescale image




cc.png

- Load the image and the necessary libraries

```
> import cv2
> import numpy as np
> import matplotlib.pyplot as plt

> src   = cv2.imread('cc.png')
```

- Check the shape and the type of the image

```
> src.shape
: (501, 501, 3)

> src.dtype
: dtype('uint8')

> print('img height: %d' % (src.shape[0]))
: img height: 501
```

# Rescale image

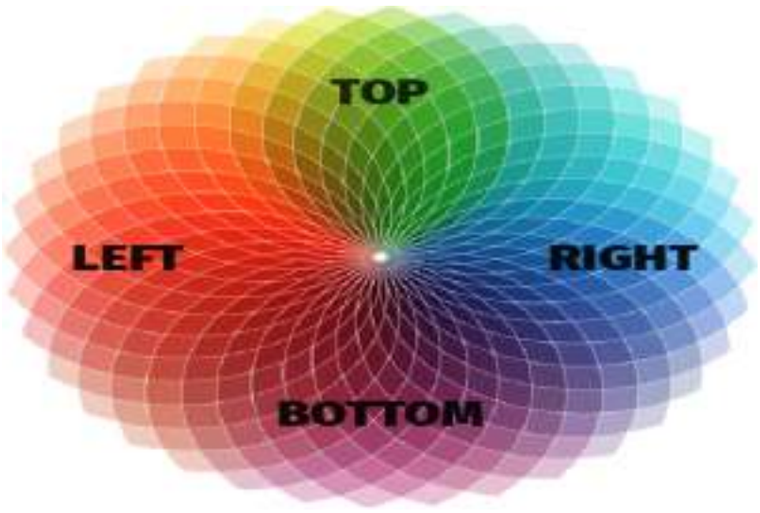
- Two ways to rescale image. First method: specify the output size

```
> rsz1 = cv2.resize(src,      width  height
                    output size  dsize=(300,200),
                interpolation method  interpolation=cv2.INTER_AREA)
```

- Check the shape of the image

```
> rsz1.shape
: (200, 300, 3)

> print('img height: %d' % (rsz1.shape[0]))
: img height: 200
```

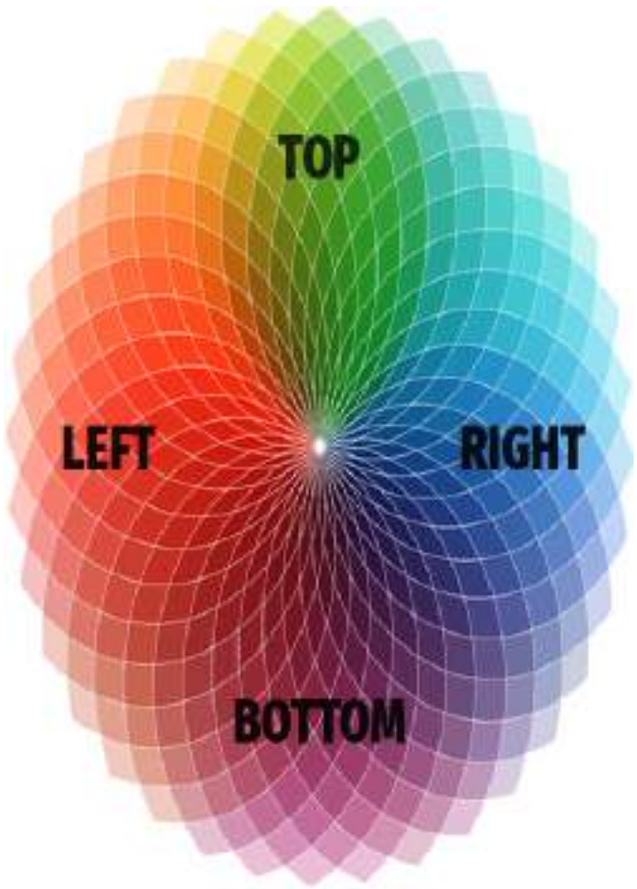



rsz1

# Rescale image

- Second method: specify scale factor in x and y directions

```
> rsz2 = cv2.resize(src,
                    dsize=None,      # output size
                    fx=0.5,          # scale factor for width
                    fy=0.7,          # scale factor for height
                    interpolation=cv2.INTER_LINEAR)
```




rsz2

- `dsize` must be set to `None` to avoid error

- Check the shape of the image

```
> rsz2.shape
: (351, 250, 3)

> print('img height: %d' % (rsz2.shape[0]))
: img height: 351
```

# Interpolation methods

- Opencv provides a number of interpolation methods for geometric transformation

- Some of the common used methods

```
cv2.INTER_AREA
cv2.INTER_LINEAR
cv2.INTER_CUBIC
cv2.INTER_NEAREST
```

- 'NEAREST' has the fastest operation, but output is crude

- 'AREA' is good for shrinking image; 'CUBIC' good for enlarging image. But both operations are slow

- 'LINEAR' is somewhere in between

```
cv2.resize(src,
           dsize,
           interpolation=cv2.INTER_AREA)
```

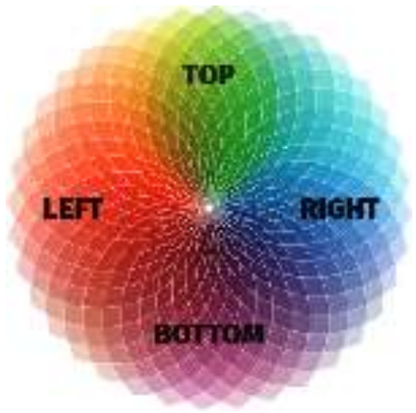
# Enlarging image

- Enlarging image rarely give satisfying output; avoid if possible
- Plan your processing flow carefully; keep the original source in your flow if possible

```
> sml = cv2.resize(src,
                   dsize=(150,150),
                   interpolation=cv2.INTER_LINEAR)
```

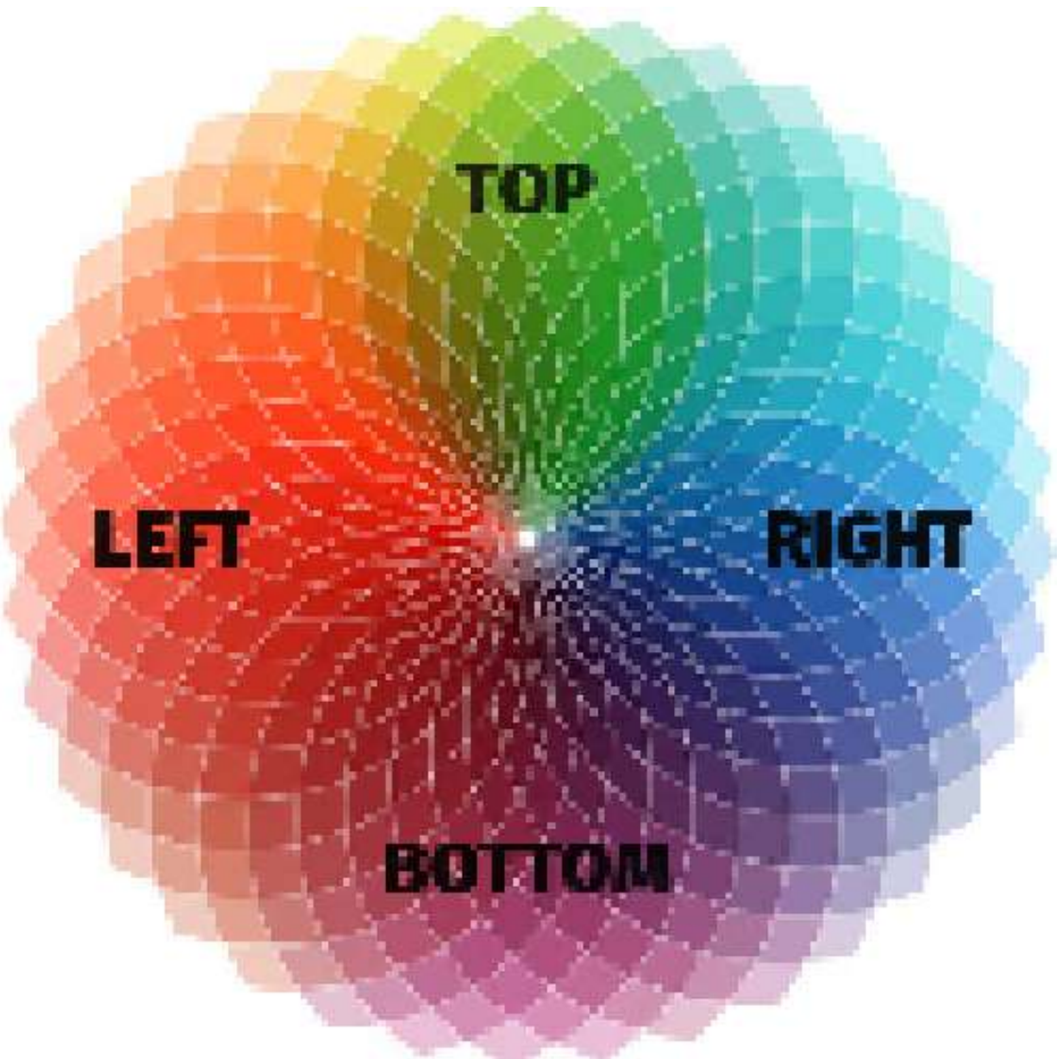
```
> bg1 = cv2.resize(sml,
                   dsize=(500,500),
                   interpolation=cv2.INTER_NEAREST)
```

```
> bg2 = cv2.resize(sml,
                   dsize=(500,500),
                   interpolation=cv2.INTER_CUBIC)
```

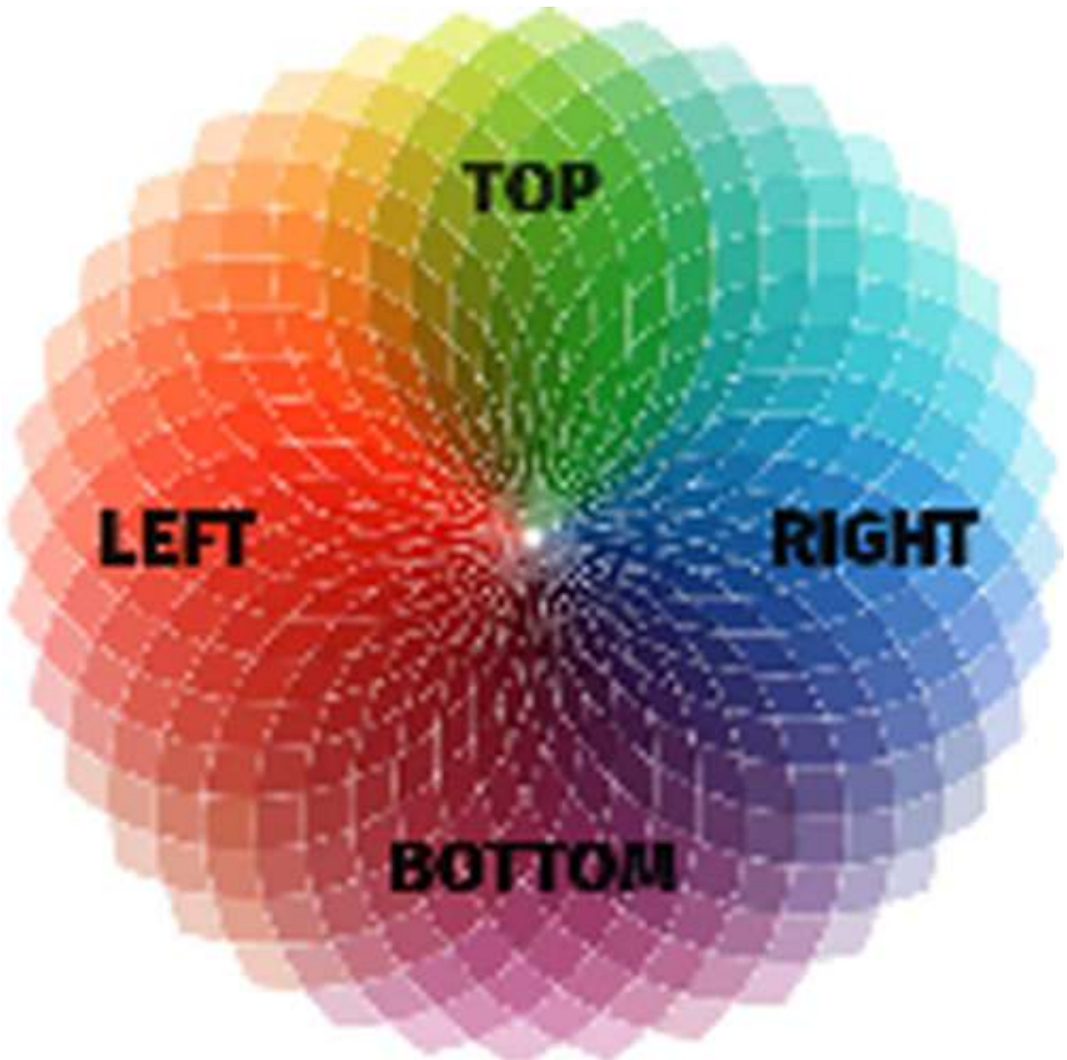



sml

# Enlarging image




nearest



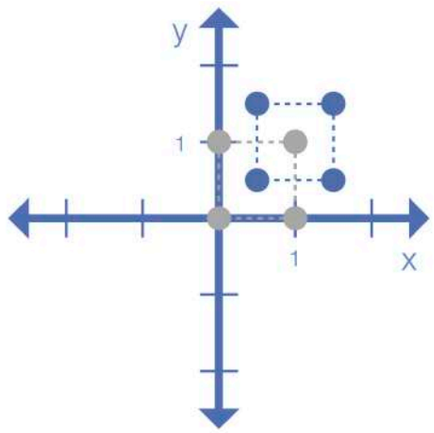

cubic

# Affine transformation

- Mathematically, scaling, translating, rotating an image are considered as affine transformation
- These transformations is ruled by a single matrix

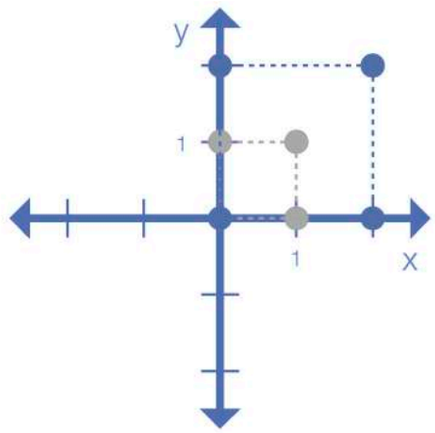
**Translate**

$$\begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$




**Scale**

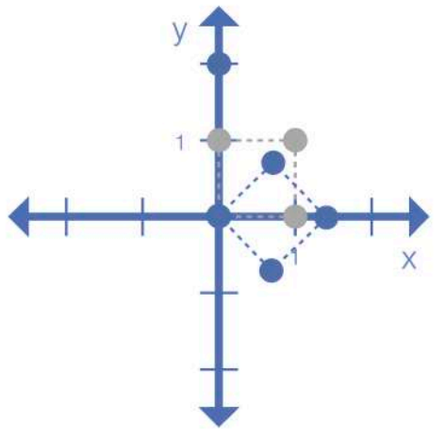
$$\begin{bmatrix} 2 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$




**Rotate**

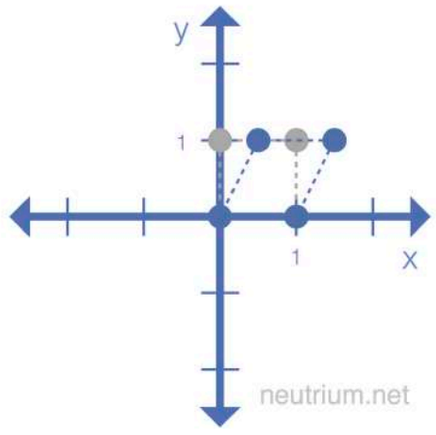
$$\begin{bmatrix} c & s & 0 \\ -s & c & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

c = s = sin(45°)




**Shear**

$$\begin{bmatrix} 1 & 0.5 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$



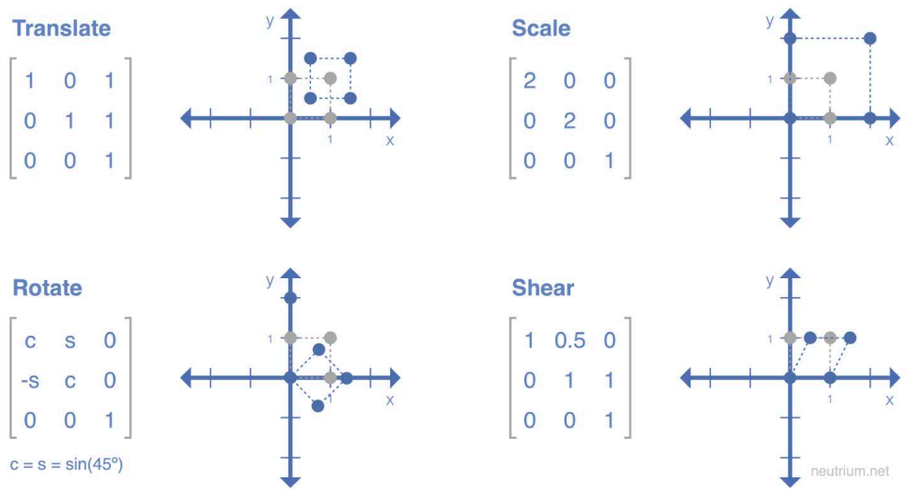

Source: https://neutrium.net/mathematics/basics-of-affine-transformation/

# Affine transformation

- In the matrix the last row is always having the values [0, 0, 1] for image processing purpose

- Thus in opencv, the last row is removed, and the ruling matrix is of this form

$$M = \begin{bmatrix} a_{11} & a_{12} & a_{tx} \\ a_{21} & a_{22} & a_{ty} \end{bmatrix}$$




Source: https://neutrium.net/mathematics/basics-of-affine-transformation/

- Except for translation, we generally do not manually calculate each value in the matrix

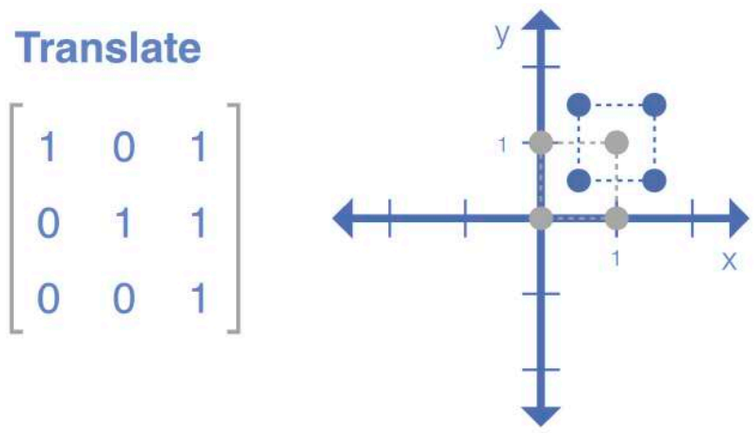
- We try to use function to get the required transformation matrix

# Translation

- For the translation, the transformation matrix looks like this

$$M = \begin{bmatrix} 1 & 0 & a_{tx} \\ 0 & 1 & a_{ty} \end{bmatrix}$$

- This assumes only translation operation is applied; no scaling or rotation is performed.




Source: https://neutrium.net/mathematics/basics-of-affine-transformation/

- $a_{tx}$ stands for the amount of distance for the image to be shifted along x axis (in pixels)
  - positive value shifts the image to the right, negative to the left
- Similary, $a_{ty}$ stands for the shift in y axis
  - positive value shifts the image to the bottom, negative to the top

# Translation

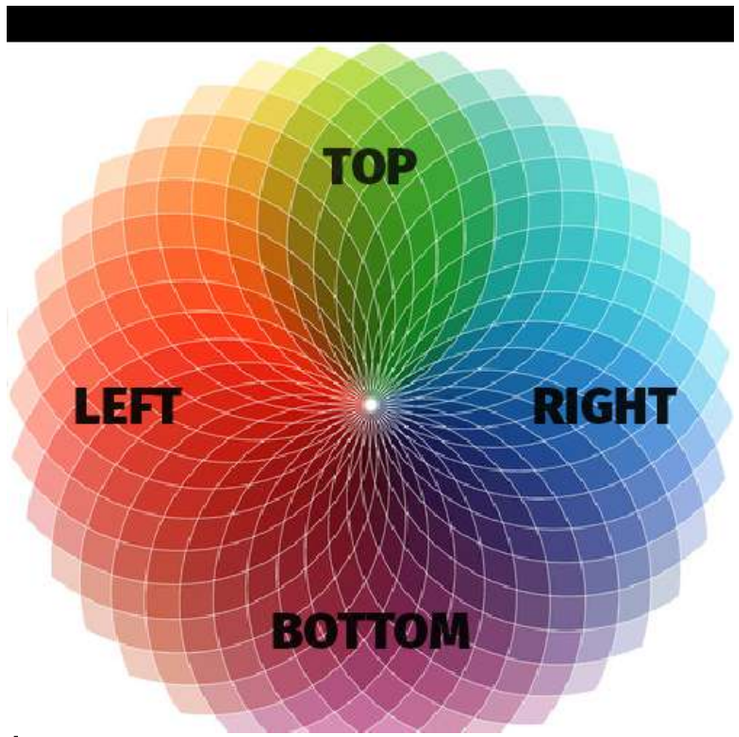
- To translate an image in opencv, the first thing we do is to create the transformation matrix

$a_{tx}$

```
> Mt = np.float32([[1, 0, 0],
                   [0, 1, 25]])
```

$a_{ty}$

- Must use `np.float32` to create the transformation matrix, else error




tr

- `Mt` shifts an image downward by 25 pixels

```
> tr = cv2.warpAffine(src,
                      Mt,
                      (501,501))
```

transformation matrix

output size

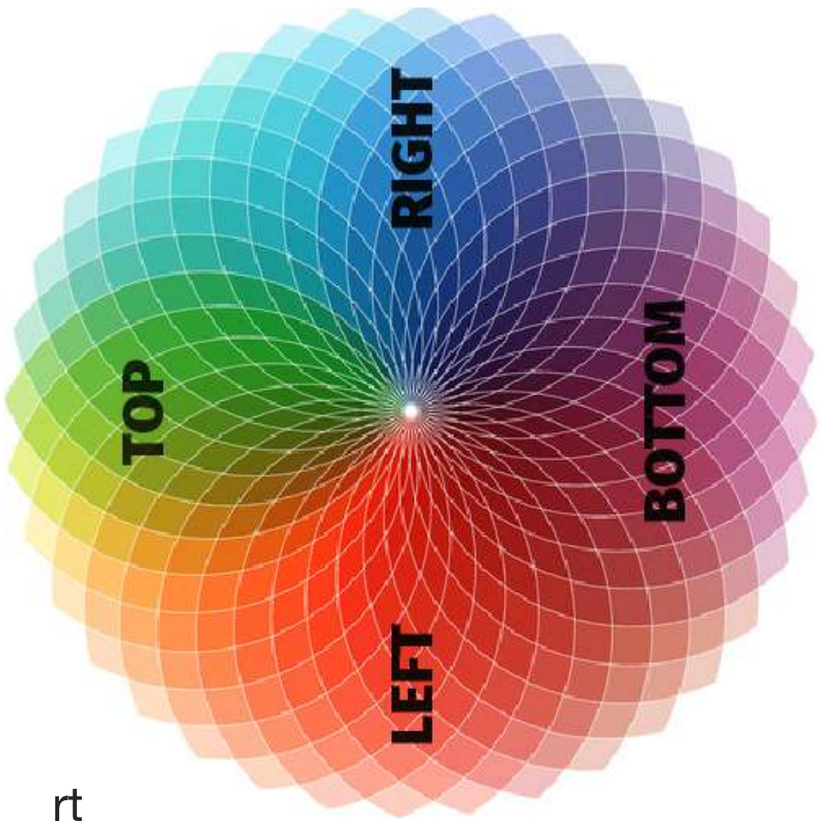
height width

# Rotation

- To create the transformation matrix for rotation, we do

```
> (row,clm,_) = src.shape

                                                    x      y
> Mr = cv2.getRotationMatrix2D((clm/2,row/2),   rotation center
                               90,              rotation angle
                               1)               scale
```




rt

- Opencv provides the function to generate transformation matrix for rotation about a center point in an image

- The rotation angle is in degree, positive value for anti-clockwise, neative value for clockwise

```
> rt = cv2.warpAffine(src,
                      transformation matrix  Mr,
                                output size  (501,501))
                                              height  width
```

# A very important use case

## On geometric transformation

Source: https://rock-it.pl/images-augmentation-for-deep-learning-with-keras/

# Image histogram

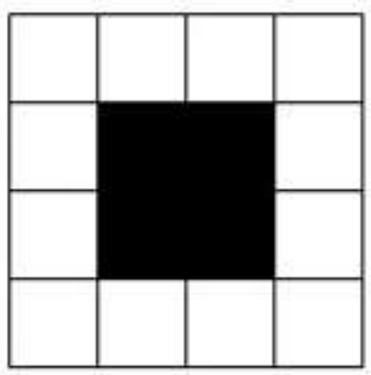
# Image histogram

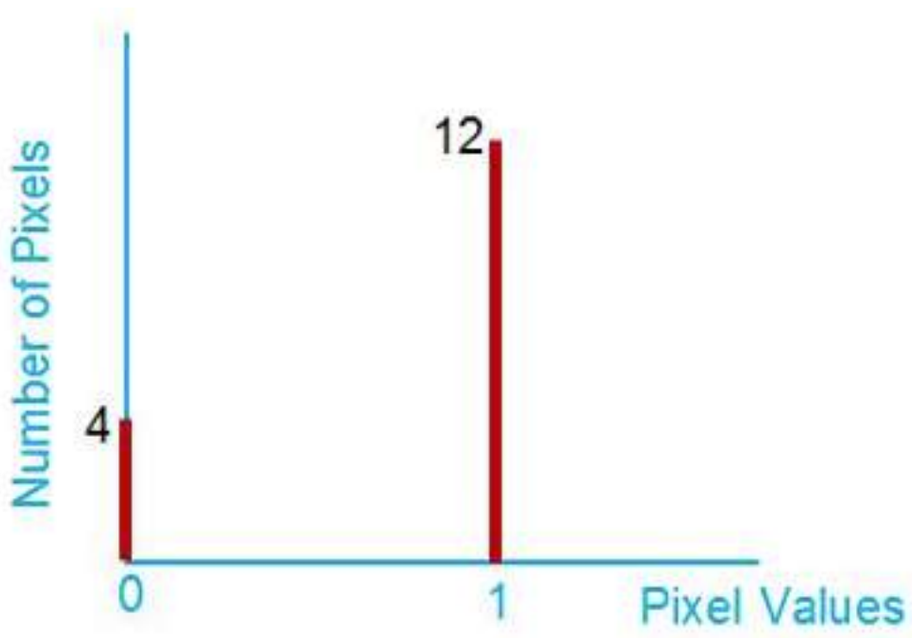
- Image histogram: a graph of pixel intensity (along x-axis) vs number of pixels (y-axis)
- x-axis has all the gray levels
- y-axis indicates the amount of pixels in image that have the particular gray-level value


Source: https://www.allaboutcircuits.com/technical-articles/image-histogram-characteristics-machine-learning-image-processing/

# Image histogram

- 4 x 4 monochrome image (black or white) image
- Count the number of black pixels (there are 4)
- Count the number of white pixels (there are 12)

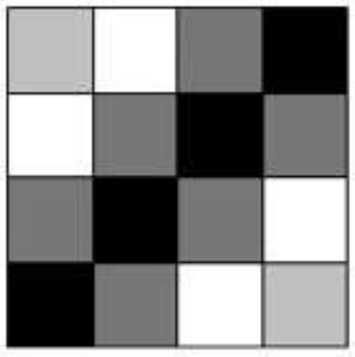


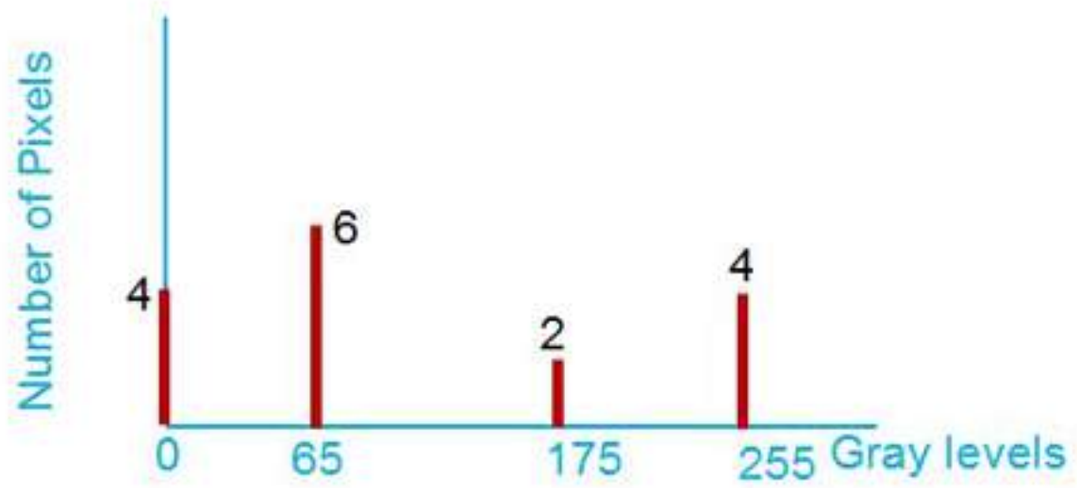



Source: https://www.allaboutcircuits.com/technical-articles/image-histogram-characteristics-machine-learning-image-processing/

# Image histogram

- 4 x 4 gray scale image
- Gray scale image are generally 8-bit, and thus it has 255 levels
- Note: in image processing, we sometimes group several levels together as one bin

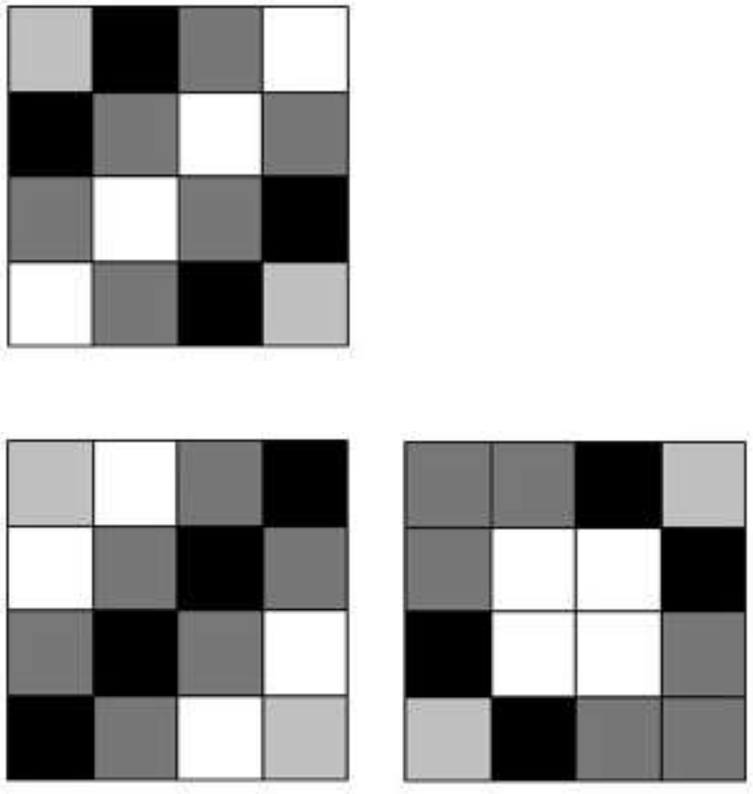


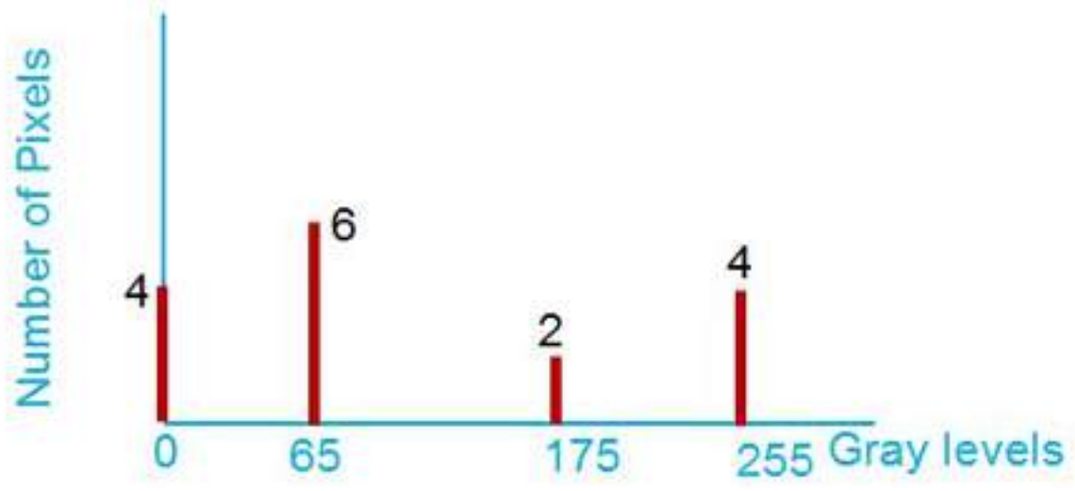



Source: https://www.allaboutcircuits.com/technical-articles/image-histogram-characteristics-machine-learning-image-processing/

# Image histogram

- Problem with histogram: provides only statistical information
- Zero information about the spatial distribution of the pixel values

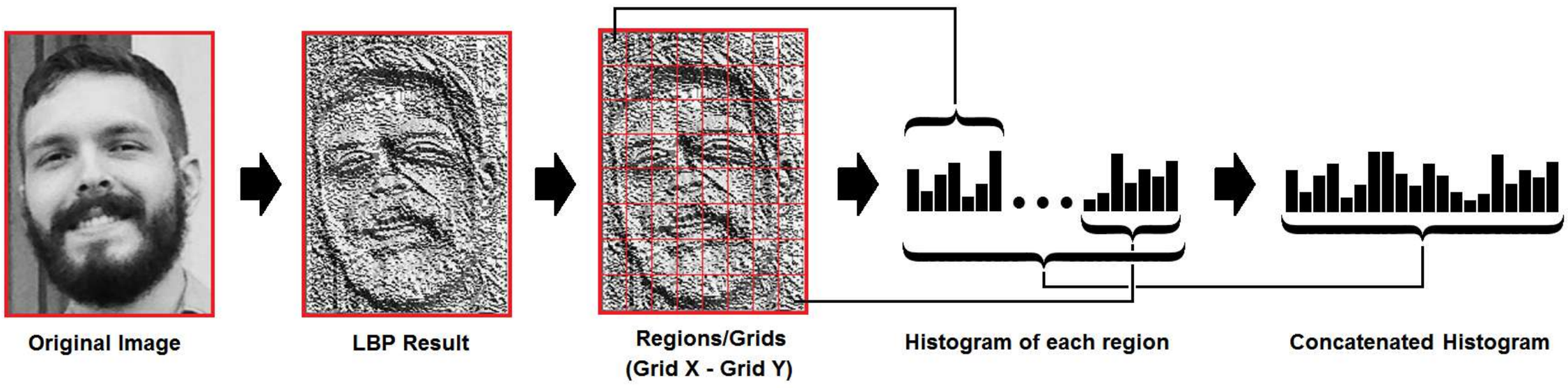





Source: https://www.allaboutcircuits.com/technical-articles/image-histogram-characteristics-machine-learning-image-processing/

# Image histogram

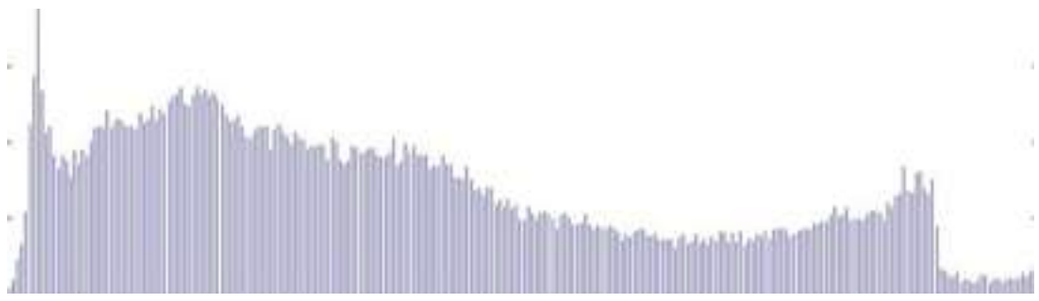
- Possible solutions: divide image into regions and do further analysis

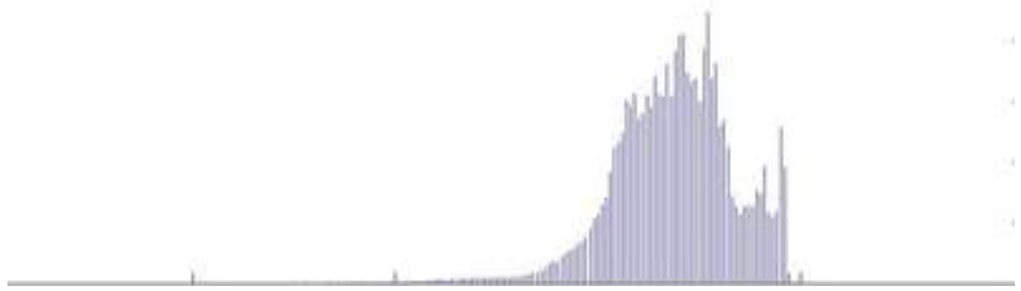



Source: https://towardsdatascience.com/face-recognition-how-lbph-works-90ec258c3d6b

# Image histogram

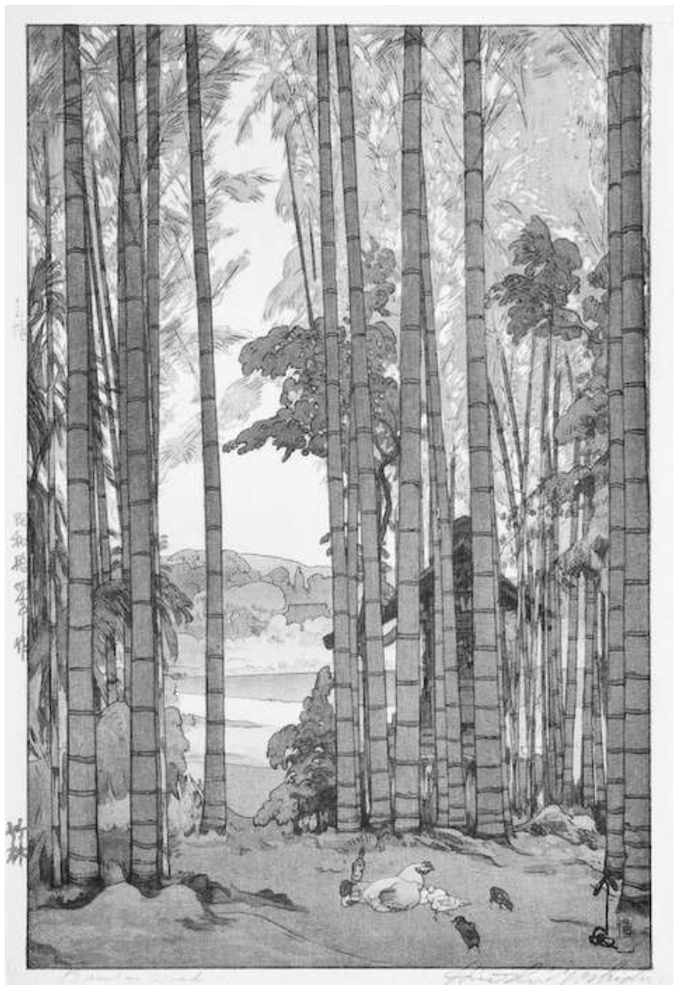
- Image of high contrast and low contrast





Source: https://www.allaboutcircuits.com/technical-articles/image-histogram-characteristics-machine-learning-image-processing/

# Image histogram



kwg.jpg

- Let us load an image

```
> kwg   = cv2.imread('kwg.jpg')
```

- Check the shape

```
> kwg.shape
: (700, 477, 3)
```

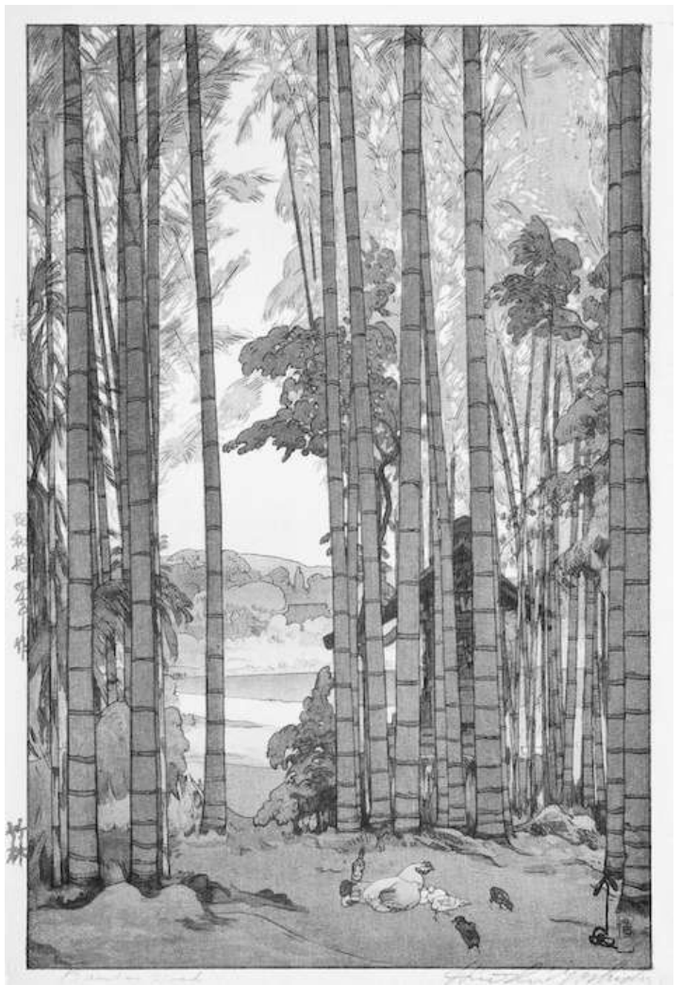
- Grayscale image by right, should have only one channel
- However, many times grayscale images are still saved in 3 channels
- To retrieve just one channel for processing, we do

```
> kwg   = kwg[:,:,0]
```

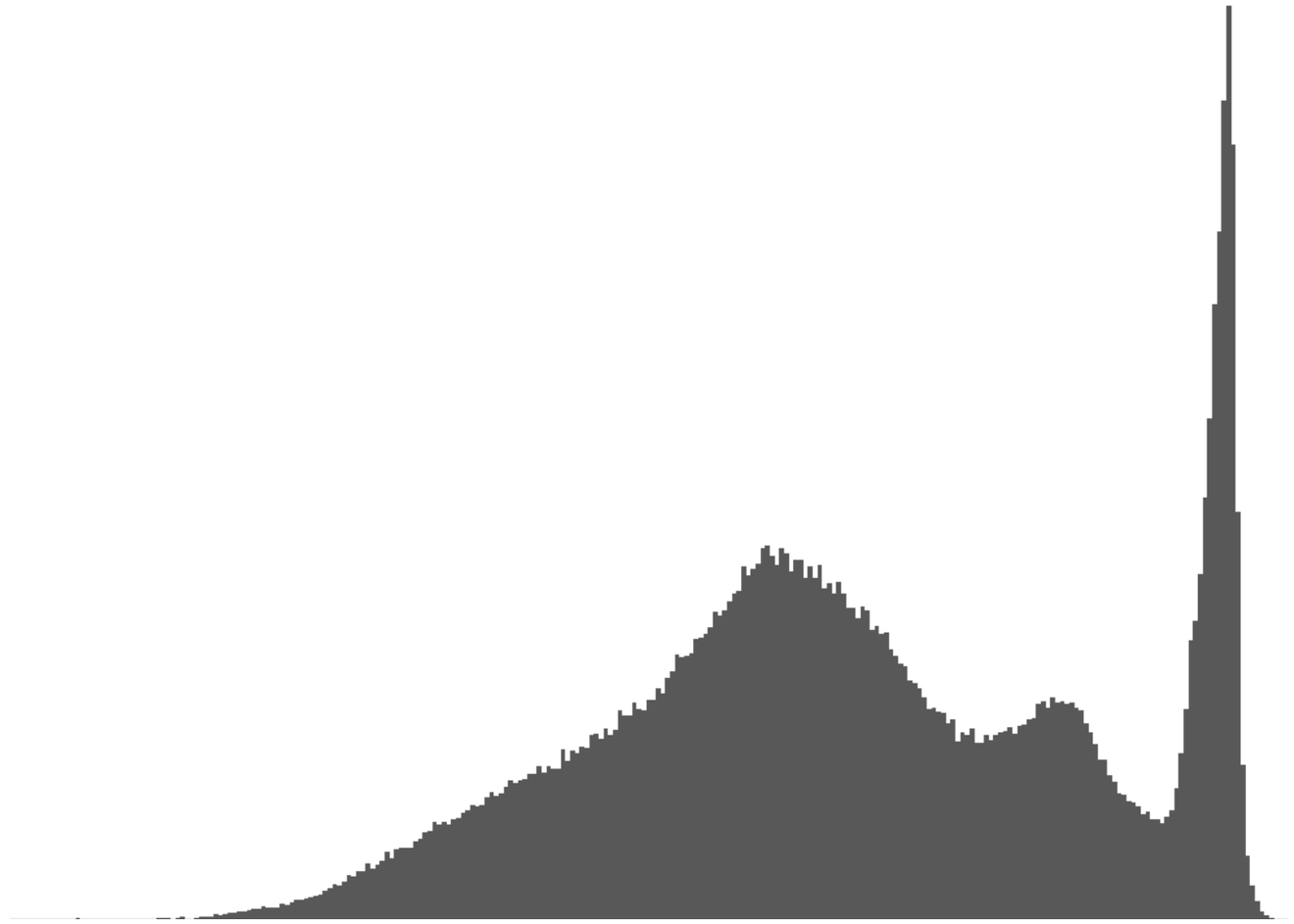
# Image histogram

- Plot the image histogram

```
> plt.hist(kwg.ravel(),
    number of bins  256,
              range  [0,255],
  colour of the bar  facecolor='black')
```

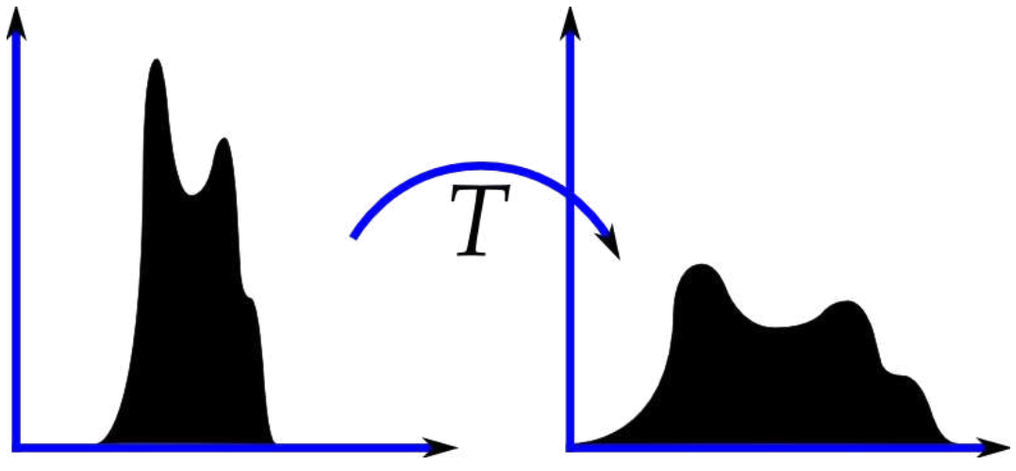


kwg.jpg



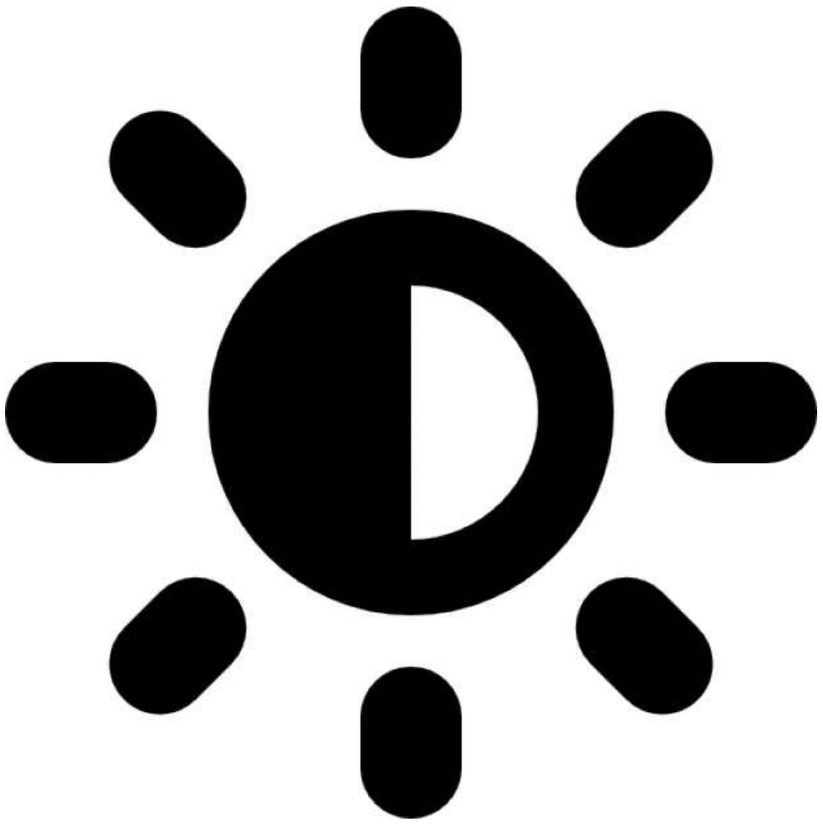
# Histogram equalization

- Histogram equalization: a method to adjust contrast in an image
- Achieved by spreading out most frequent intensity values
- Often produce unrealistic effects in photographs, but useful for scientific images
- Calculation is not computationally expensive

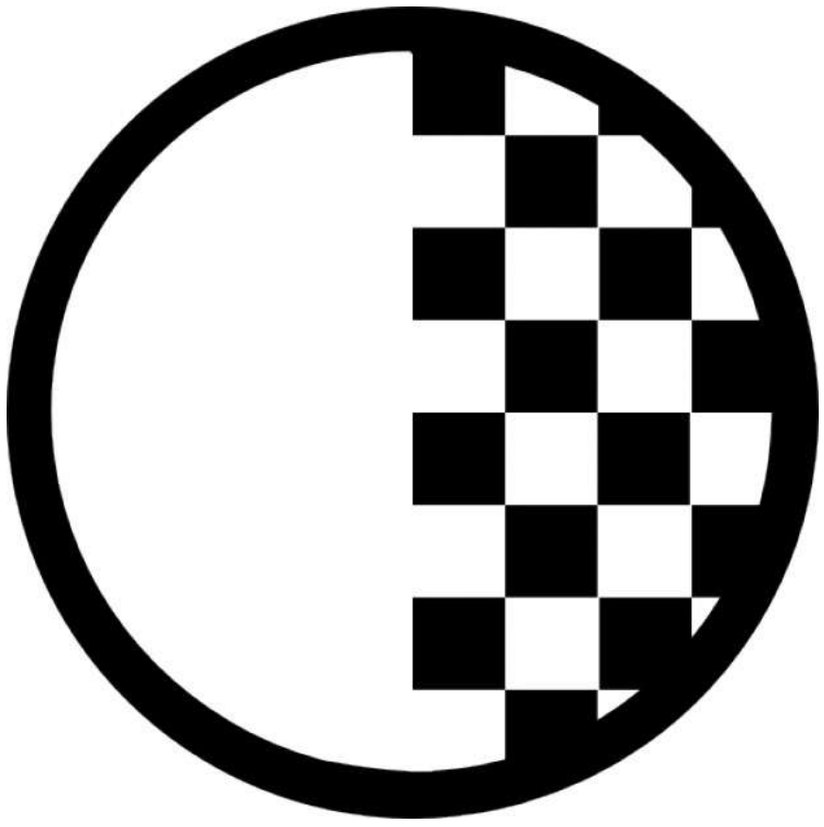



Source: https://commons.wikimedia.org/wiki/File:Histogrammspreizung.png

# Why do we need to adjust contrast?



Source: https://www.freepik.com/free-icon/brightness-and-contrast-adjustment-option_748892.htm

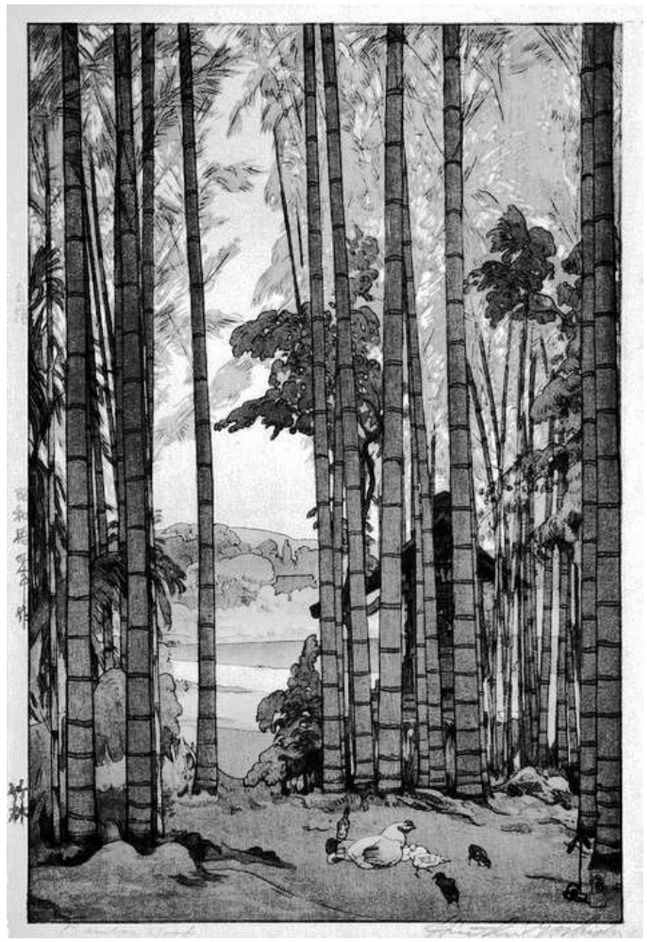


Source: https://www.freepik.com/free-icon/contrast-adjustment-symbol_736518.htm

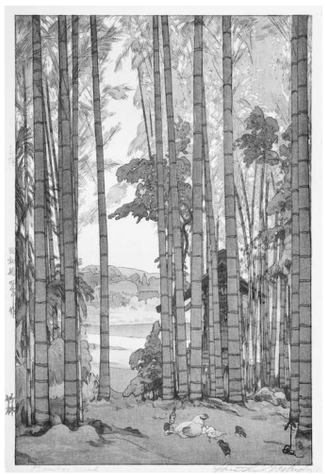
# Histogram equalization

- To perform histogram equalization, simply do

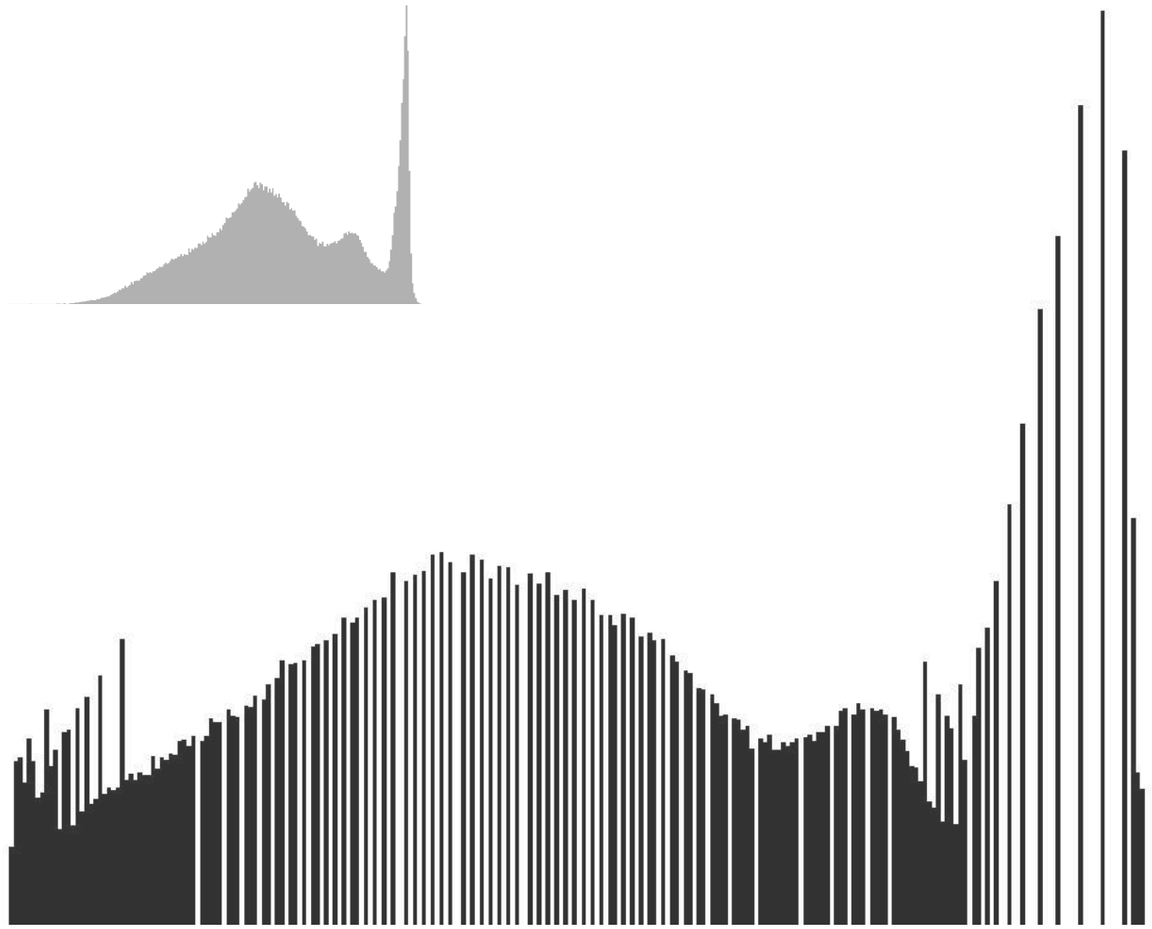
```
> heq = cv2.equalizeHist(kwg)
> plt.hist(heq.ravel(),
    number of bins 256,
             range [0,255],
colour of the bar facecolor='black')
```



heq



kwg



# Contrast limited adaptive histogram equalization (CLAHE)

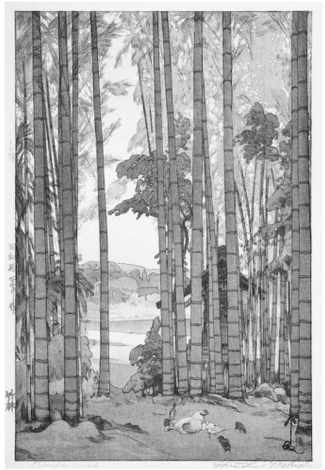
- To perform CLAHE, we do

```
> clahe  = cv2.createCLAHE()
> hcl    = clahe.apply(kwg)
> plt.hist(hcl.ravel(),
           256,
           [0,255],
           facecolor='black')
```

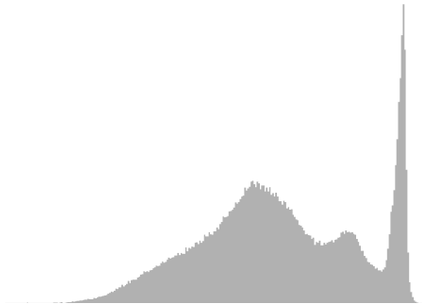
create CLAHE object

use the object to perform equalization

hcl



kwg



# Comparison

Histogram equalization

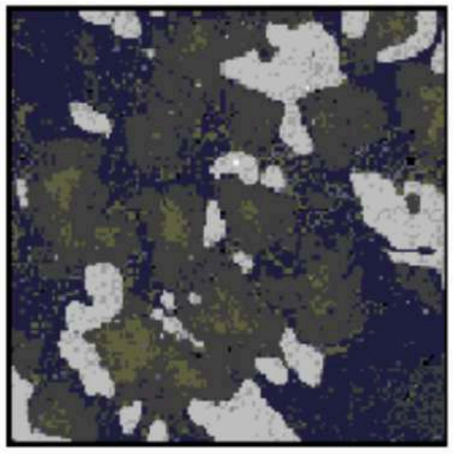
CLAHE

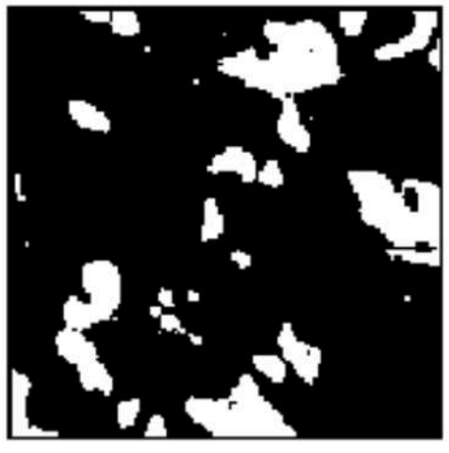
# Image thresholding

- Image thresholding: a process that converts intensity values that exceeds/below a threshold to one value, and the rest as other value(s)

- Usually we use 1 or 255 to denote the pixels/points that we want, and 0 for points/pixels to be ignored/ discarded

- This is often used to isolate region of interest





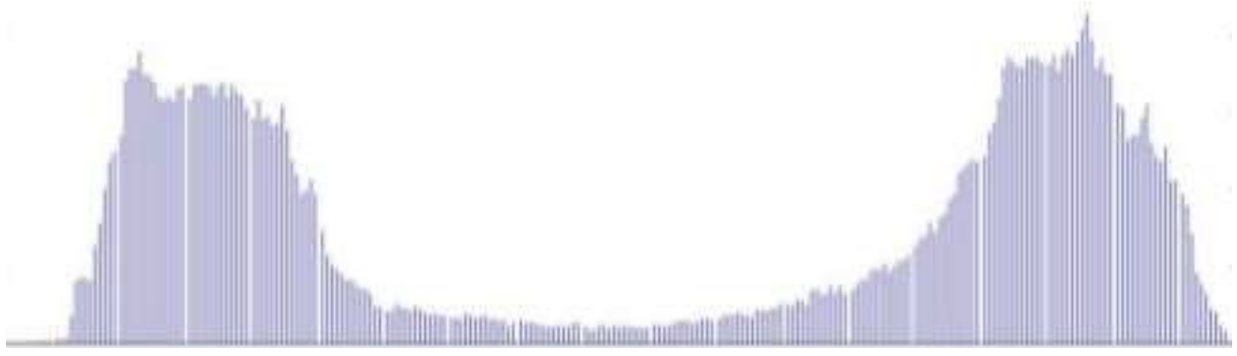
Source: http://www.ni.com/tutorial/2916/en/

# Image thresholding

- When we do thresholding, we are in fact performing segmentation using the image histogram

original image

thresholded image



Source: https://www.allaboutcircuits.com/technical-articles/image-histogram-characteristics-machine-learning-image-processing/

# Image thresholding

- Opencv provides several methods to do thresholding

```
> gr      = cv2.imread('gr.png')
> (_,thr) = cv2.threshold(gr[:, :, 0],
                          threshold value  85,
                          assigned value   255,
                          threshold style  cv2.THRESH_BINARY)
```

- Thresholding can be easily implemented in simple python; just one/two for loops will do

- But that will be slow; using opencv function gives faster implementation

gr.png

# Thresholding style

```
cv2.threshold(gr[:, :, 0],
              85,
              255,
              ThresStyle)
```