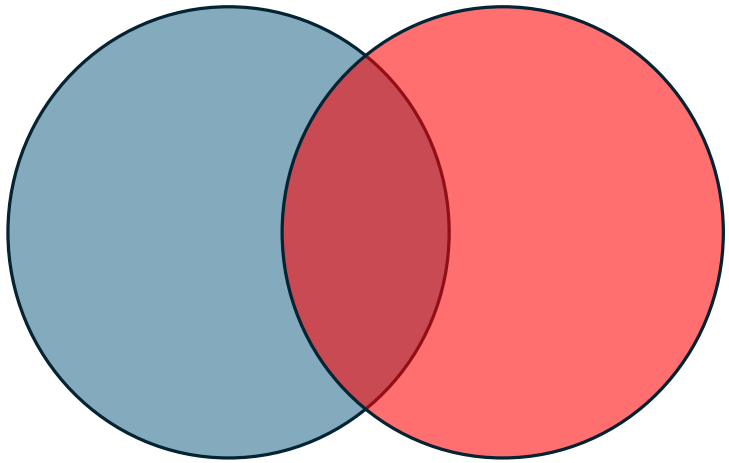
Lecture 2
Operations on Images

ECE 1390/2390

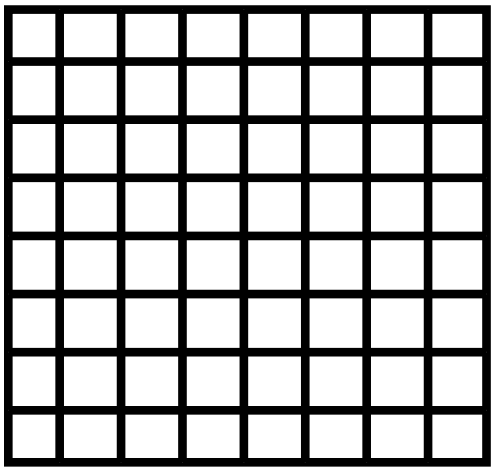
Learning Objectives:

- Mathematical operations
- Bitwise/Logical operations
- Dealing with overflow
- Masking and thresholding



An image is a matrix of information
(tensor for color images)

X



Math based operations

$$Y = a * X$$

$$Y = fn(X)$$

$$Y = H * X * H'$$

Morphological operations

E.g. Dilate/Erode

```
For (i=0; i<n; i++)
        do something at {i}
end
```

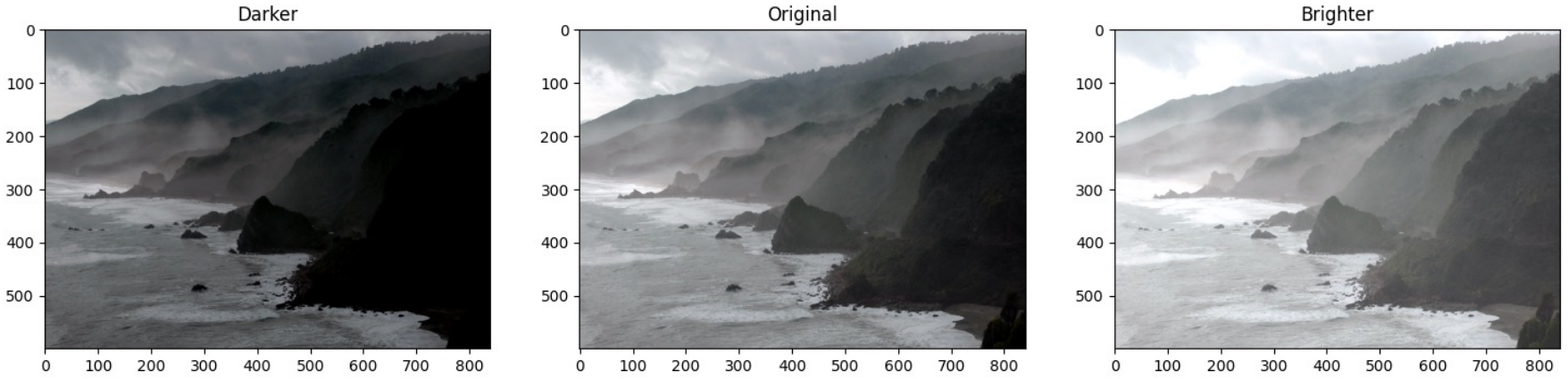
Brightness

$$Y = X + a$$

Changing the brightness of an image means adding/subtracting a scalar from the image

From Lecture1/04_Image_Enhancement.ipnb

```
matrix = np.ones(img_rgb.shape, dtype="uint8") * 50

img_rgb_brighter = cv2.add(img_rgb, matrix)

img_rgb_darker = cv2.subtract(img_rgb, matrix)
```



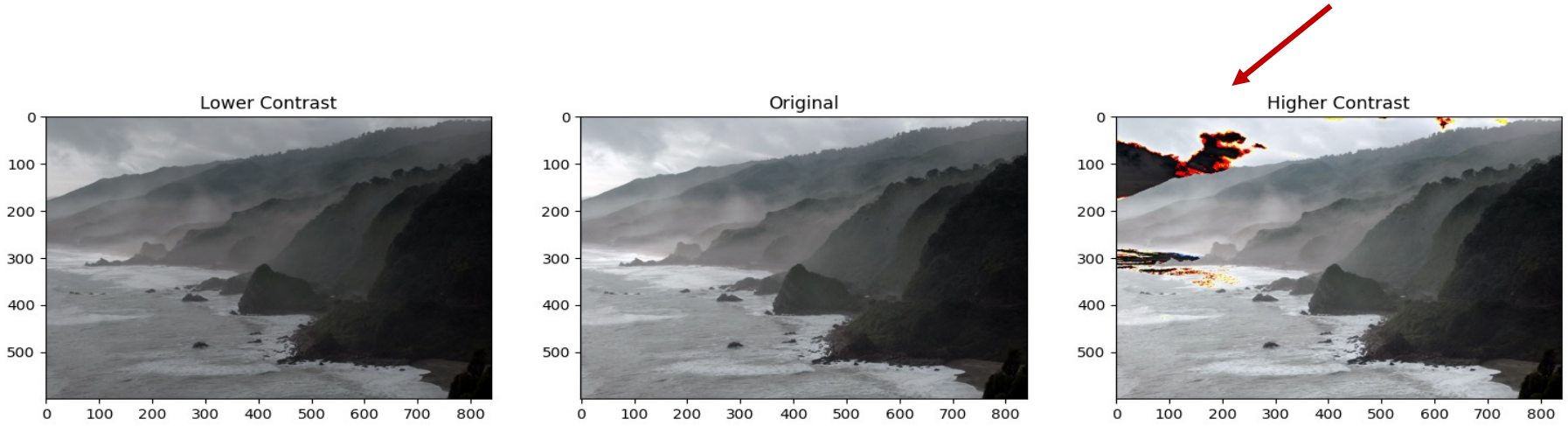
Contrast

$$Y = a * X$$

Contrast is the range of values in the image. Multiplying by a scalar changes the contrast

From Lecture1/04_Image_Enhancement.ipnb

```
matrix_low_contrast = np.ones(img_rgb.shape) * 0.8
matrix_high_contast = np.ones(img_rgb.shape) * 1.2

img_rgb_darker = np.uint8(cv2.multiply(np.float64(img_rgb),
matrix_low_contrast))

img_rgb_brighter = np.uint8(cv2.multiply(np.float64(img_rgb),
matrix_high_contast))
```



Clipping

Python:

[1]:
```
import numpy as np
import cv2
```

[2]:
```
a=np.array(250,dtype=np.uint8)
b=np.array(10,dtype=np.uint8)
```

[3]:
```
# In openCV
cv2.add(a,b)
```

[3]:
```
array([[255]], dtype=uint8)
```

OpenCV clips at 255

[4]:
```
# Directly as NP array
a+b
```

[4]:
```
4
```

numpy rolls over (260 -> 255, 0, 1, 2, 3, 4)

[5]:
```
a+10
```

[5]:
```
260
```

np + scalar => converts type

Clipping

Python:

a = [100 150 200 250] → convert to uint16
b = [10 10. 10. 10] → convert to uint16

a + b = [110 160 210 260] (uint16)

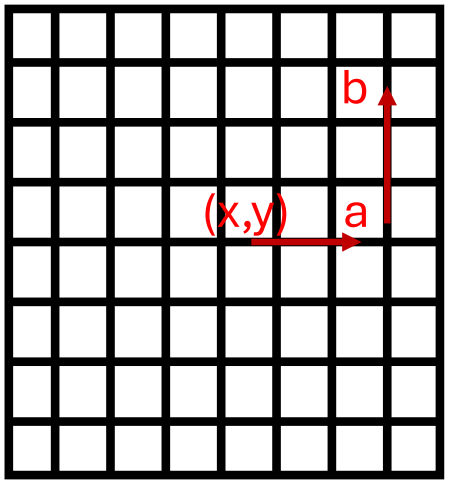
Normalize

= [110 160 210 260] * 255 /260

= [107 157 206 255]

Point Spread Function

General



$$h(x, a, y, b)$$

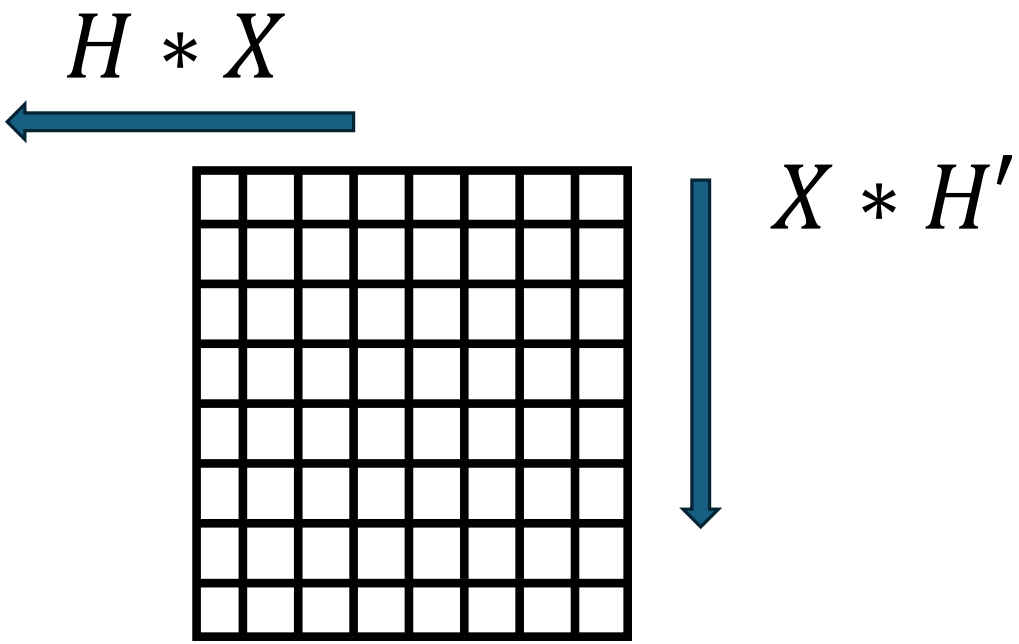
Operation varies depending on which position (x,y) in the image

Shift invariant

$$h(a - x, b - y)$$

Operation is independent of the position (x,y) in the image

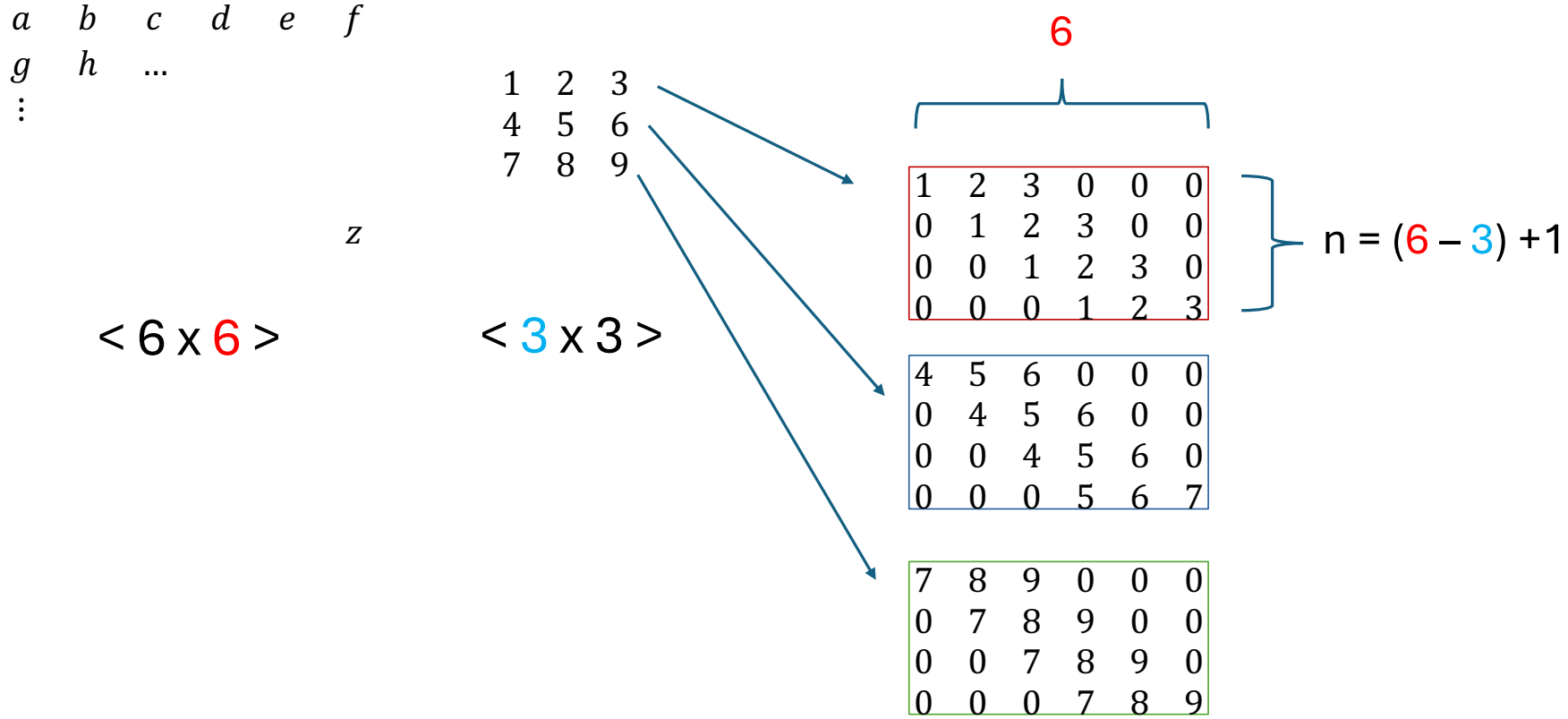
$$Y = H * X * H'$$



Out = kron(kron(H,X), H')

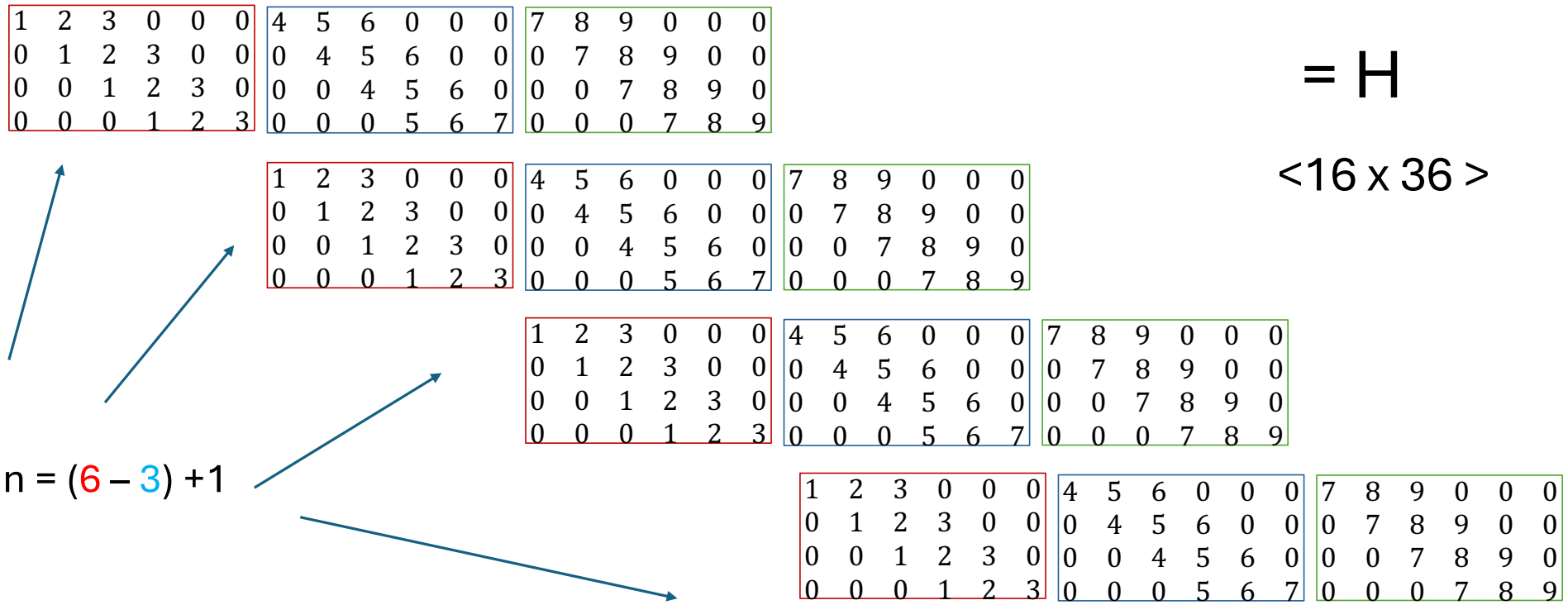
Out = np.convolution(np.convolution(X,H,axis=0), H,axis=1)

2D convolution as a matrix operation



Construction of “H” matrix

2D convolution as a matrix operation



2D convolution as a matrix operation

$a \quad b \quad c \quad d \quad e \quad f$
$g \quad h \quad \ldots$

<16 x 36 > <36 x 1 >

< 6 x 6 >

$$H * g' = x$$

$$reshape(x) \rightarrow < 4\ x\ 4 >$$

a
b
c
d
e
f
g
$\vdots$

= g’

2D convolution as a matrix operation

In MATLAB: conv2(B,A,'valid')

H = kron(eye(N),reshape(A',1,[])
g = reshape(B',1,[])
x = reshape(H*g' , N, N)

$$< 6\ x\ 6 > * < 3\ x\ 3 > = < 4\ x\ 4 >$$

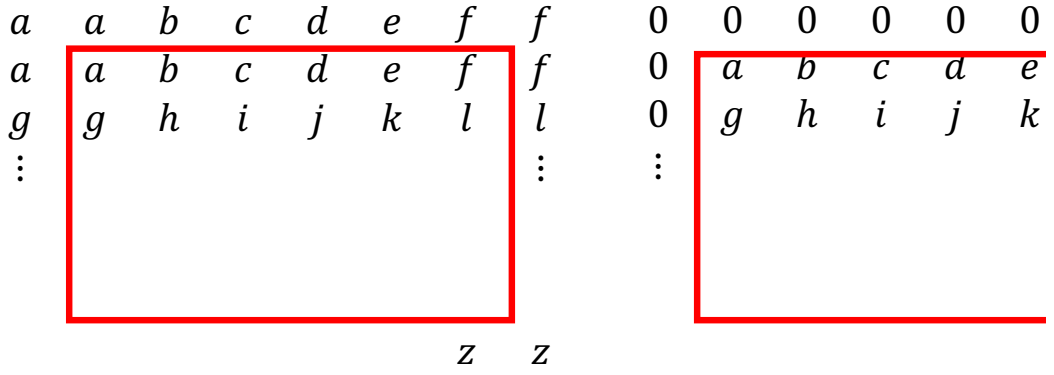
N = (6 – 3) +1

If you want the same size output as input image:

N=6

= (8 – 3)

need to pad the image from <6x6> to <8x8>



2D convolution as a matrix operation

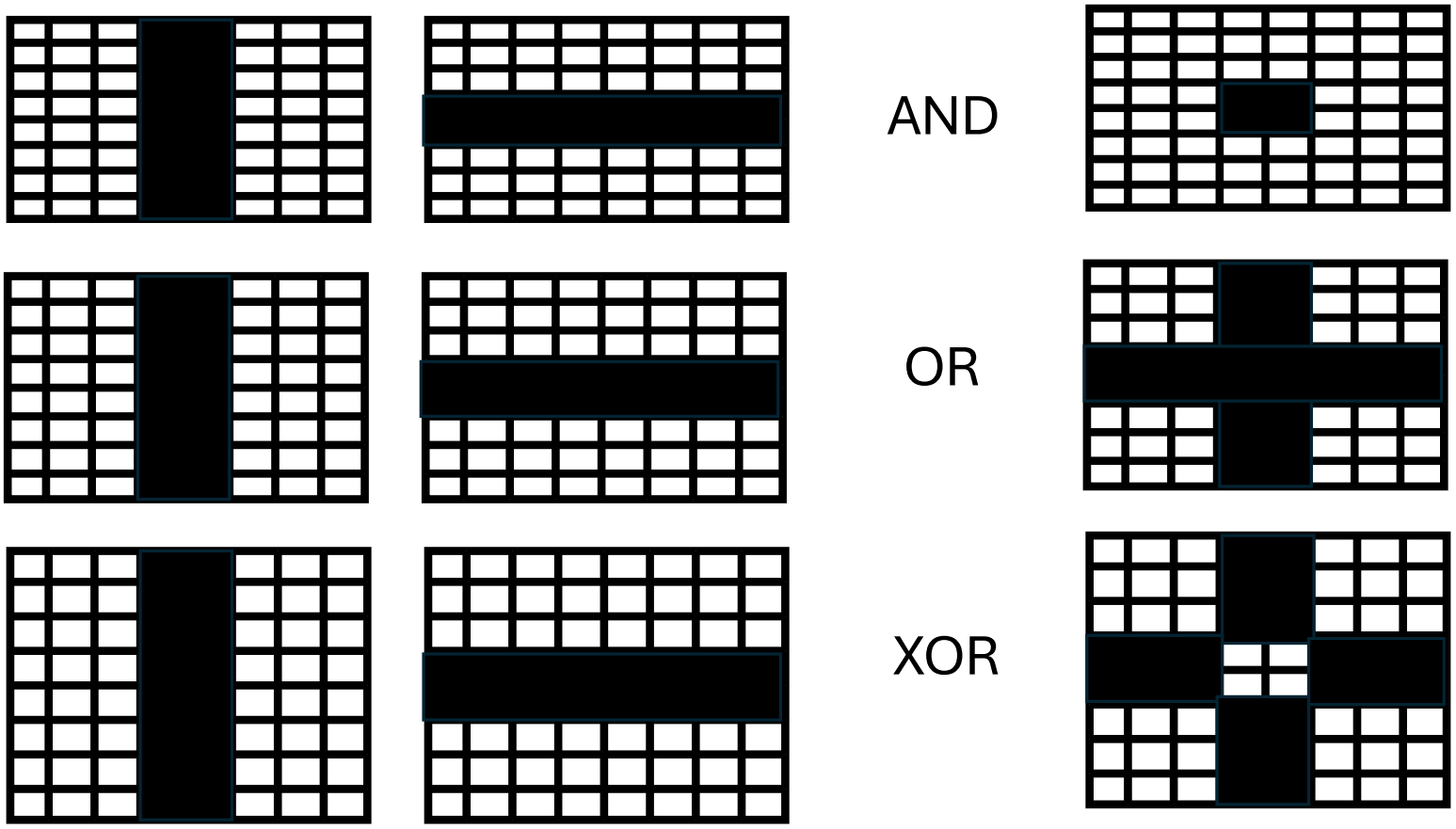
```
kernel= np.ones((3,3))/9

img_smooth = cv2.filter2D(img,-1,kernel)
```

Depth

-1 : gives output image data type as input

cv2.CV_8U = 0	uint8
cv2.CV_8S = 1	int8
cv2.CV_16U = 2	uint16
cv2.CV_16S = 3	int16
cv2.CV_32S = 4	int32
cv2.CV_32F = 5	float32
cv2.CV_64F = 6	float64

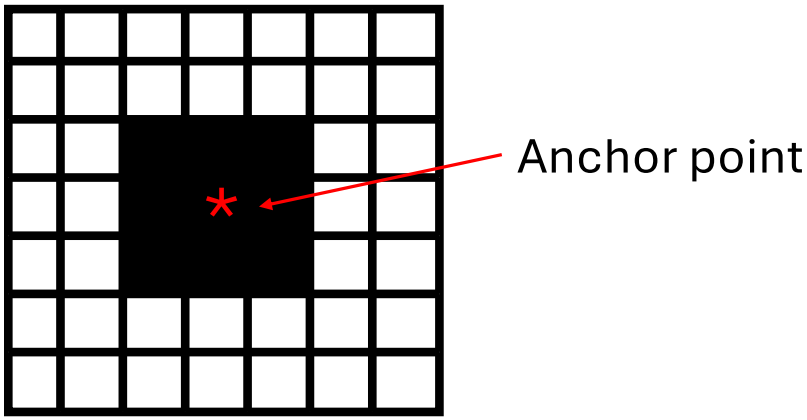
Boolean (Bit-wise) operations



Morphological Operations
Erosion/Dilation

Kernel is Boolean (mask)

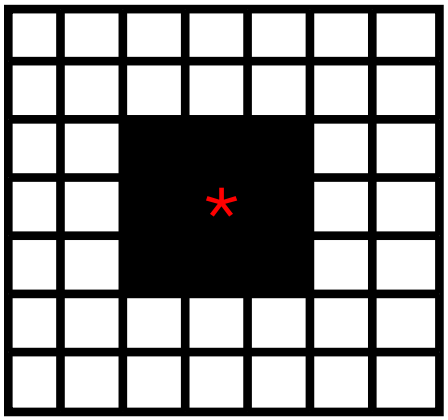
Structure/Kernel



Erosion/Dilation

Anchor point

Structure/Kernel



For {i,j} in image:

move kernel anchor to {i,j}

list = find (kernel ==true)

newVal{i,j} = fcn (image[list])

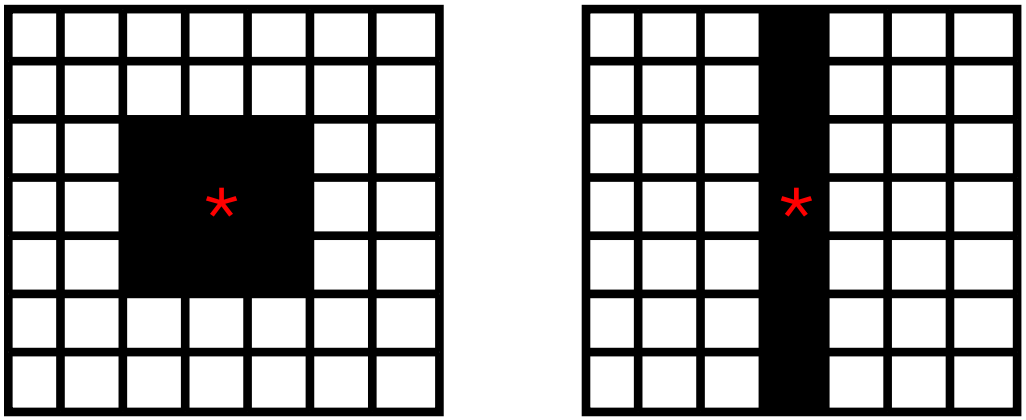
Dilation - MAX (image[list])

Erosion - MIN (image[list])

Denoising - MEDIAN (image[list])

Smoothing - MEAN (image[list])

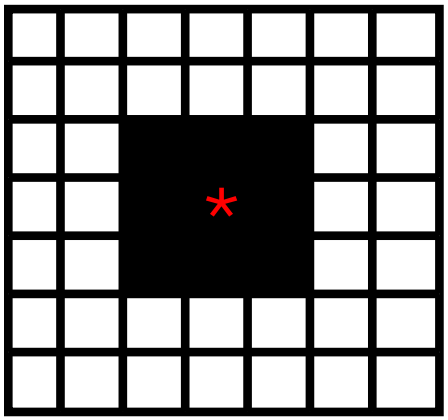
Erosion/Dilation



Convolutional (Filtering) Operations

Anchor point

Structure/Kernel



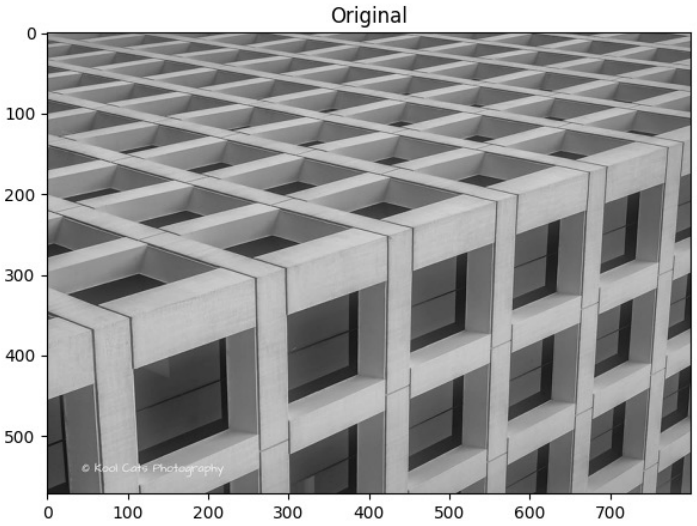
For {i,j} in image:

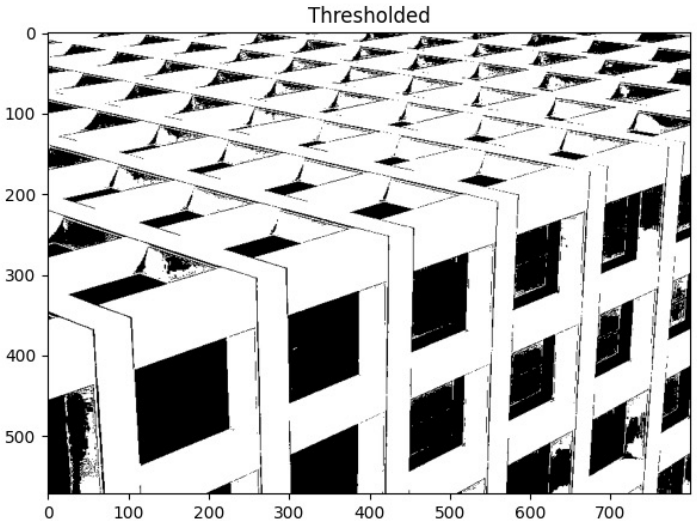
move kernel anchor to {i,j}

newVal{i,j} = sum(image .* kernel)

Thresholding

thres, img_out = cv2.threshold(img, thres, replacement value, type)





Thresholding

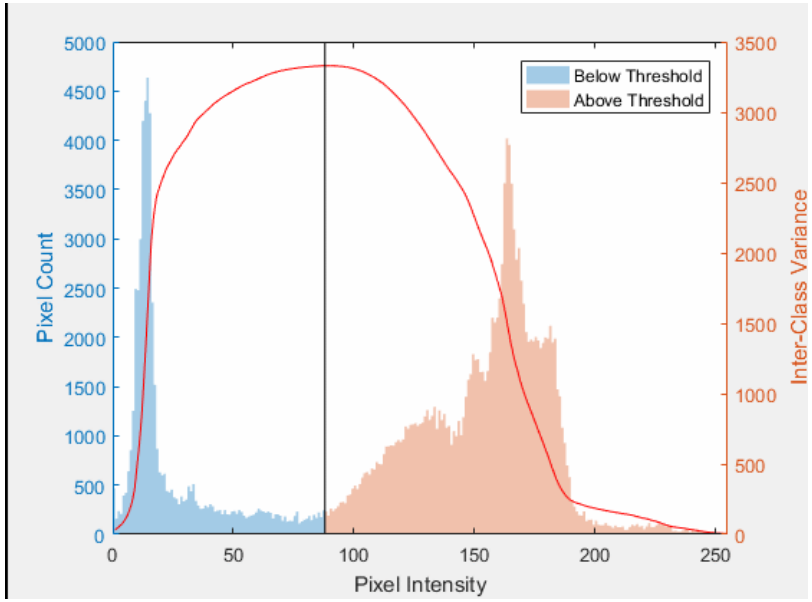
thres, img_out = cv2.threshold(img, thres, replacement value, type)

Types:

• **THRESH_BINARY**	**If x > thresh; x= rep_value; else x=0**
• **THRESH_BINARY_INV**	**If x > thresh; x= 0; else x= rep_value**
• **THRESH_TRUNC**	**If x > thresh; x= x ; else x= thresh**
• **THRESH_TOZERO**	**If x > thresh; x= x; else x= 0**
• **THRESH_TOZERO_INV**	**If x > thresh; x= 0; else x= x**

Otsu's thresholding

- Nobuyuki Otsu (1979). "A threshold selection method from gray-level histograms". *IEEE Transactions on Systems, Man, and Cybernetics*. **9** (1): 62–66.



Variance values above thresh

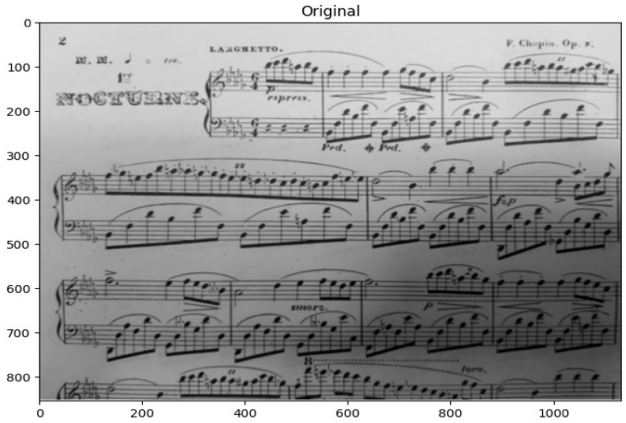
Variance values below thresh

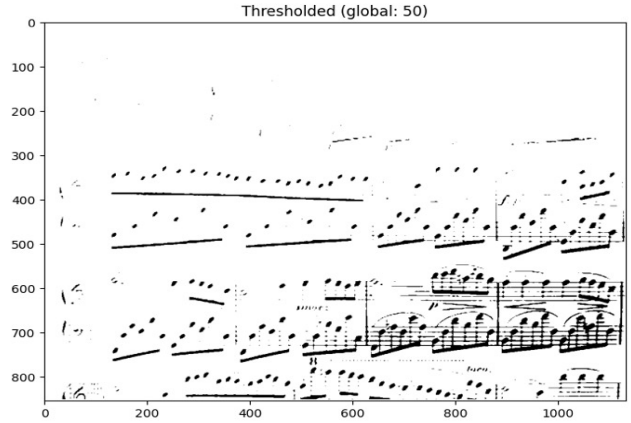
$$\sigma^2 = w_0 \cdot {\sigma_0}^2 + w_1 \cdot {\sigma_1}^2$$

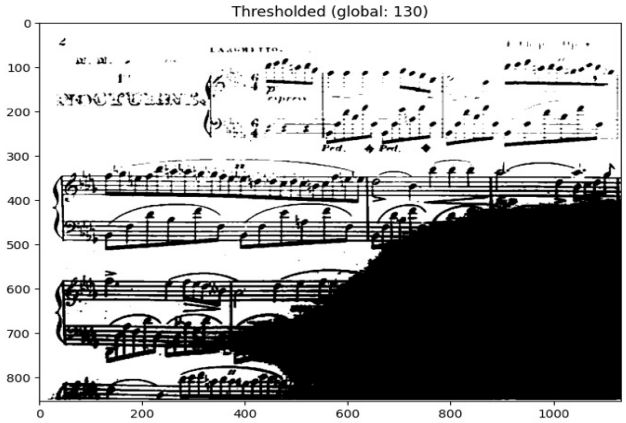
Probability of values below thresh

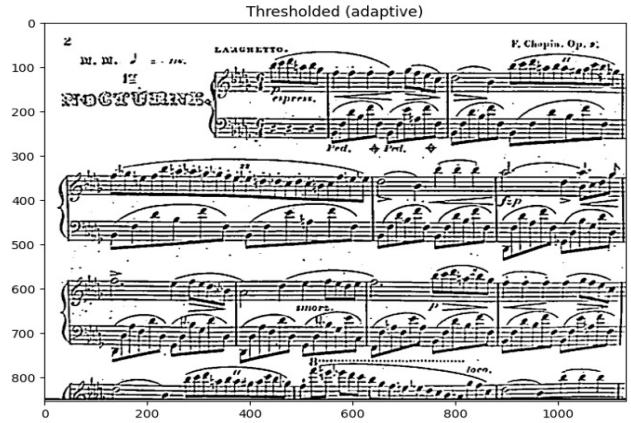
Probability of values above thresh

Adaptive thresholding



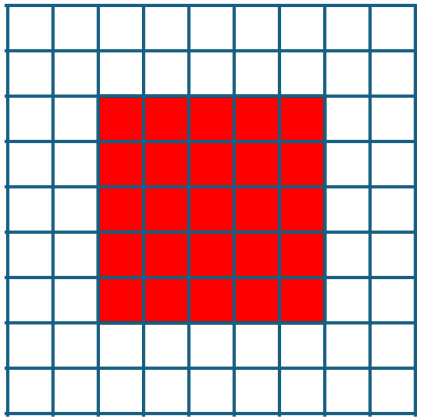






Adaptive thresholding

$$thres\{i,j\} = \left(\frac{1}{n*m}\sum_{i=1}^{n}\sum_{j=1}^{m} x[i,j]\right) - C$$



$$\text{thes\{i,j\}} = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} G[i,j]}\sum_{i=1}^{n}\sum_{j=1}^{m} G[i,j]*x[i,j]\right) - C$$