

Spatial Operations in Image Processing

Outline

- Convolution : Linear Filtering
- Edge Detection
- Median Filters

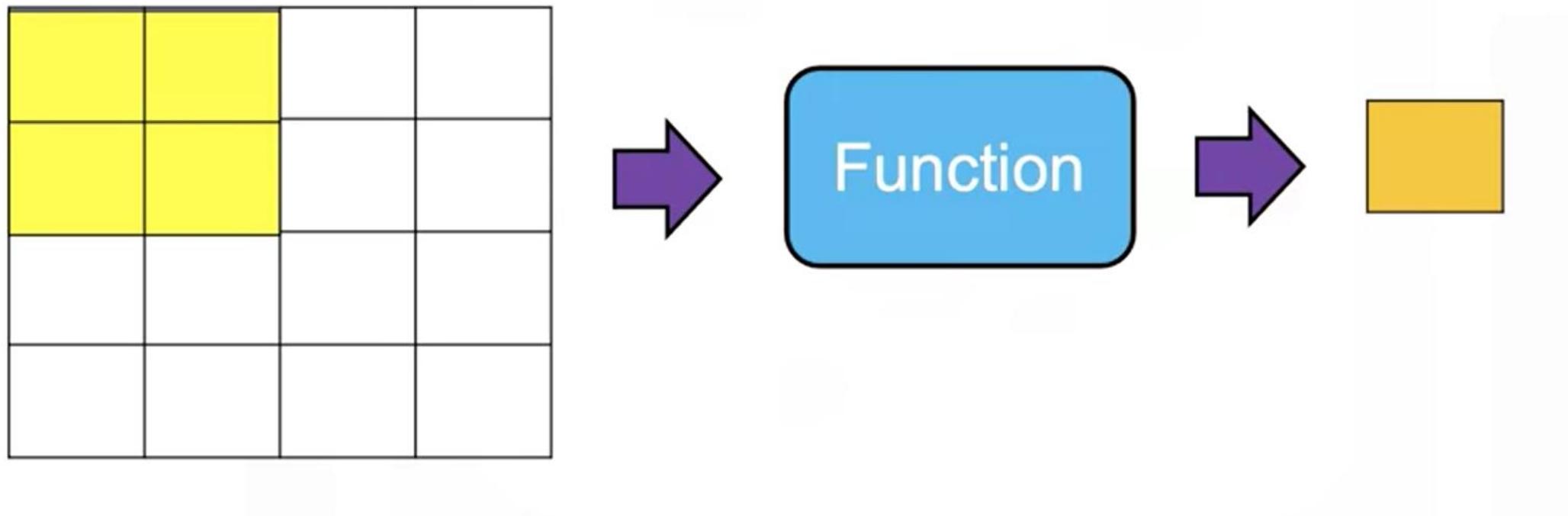
I[0,0]	I[0,1]	I[0,2]	I[0,3]	I[0,4]	I[0,5]
I[1,0]	I[1,2]	I[1,2]	I[1,3]	I[1,4]	I[1,5]
I[2,0]	I[2,2]	I[2,2]	I[2,3]	I[2,4]	I[2,5]
I[3,0]	I[3,1]	I[3,2]	I[3,3]	I[3,4]	I[3,5]
I[4,0]	I[4,1]	I[4,2]	I[4,3]	I[4,4]	I[4,5]
I[5,0]	I[5,1]	I[5,2]	I[5,3]	I[5,4]	I[5,5]

Filtering

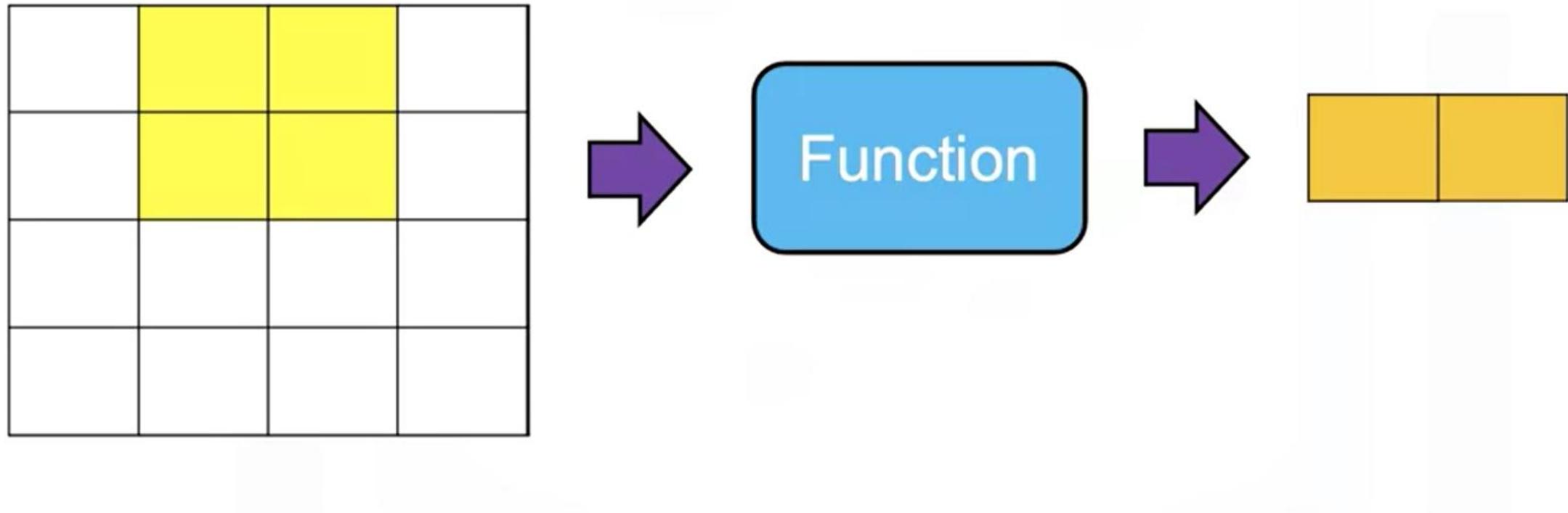
Function

Function

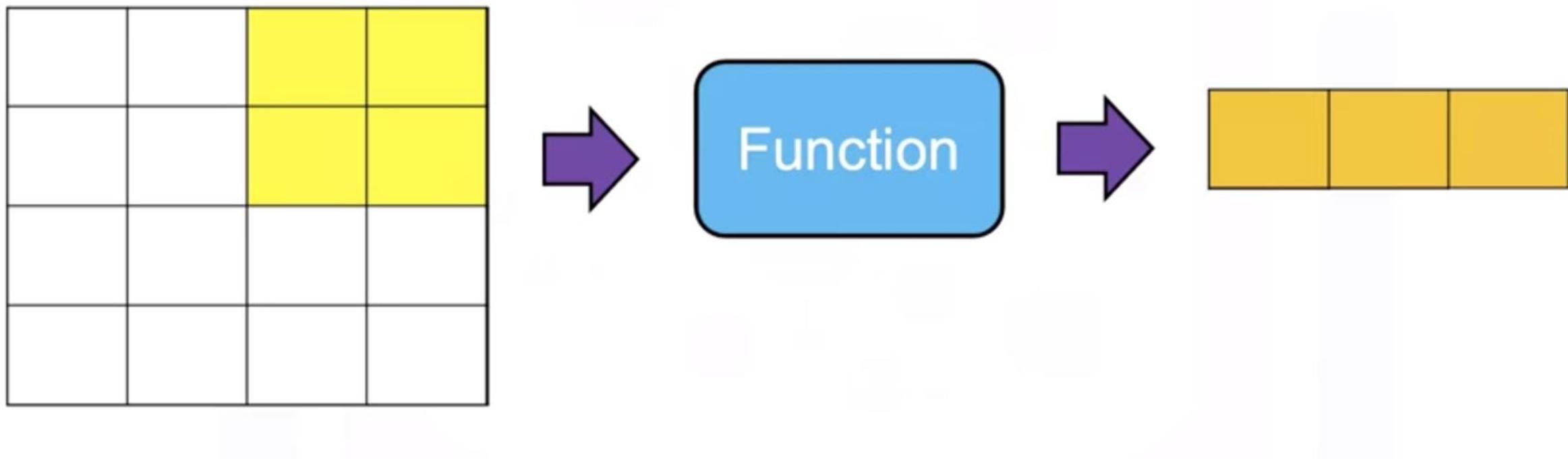
Filtering



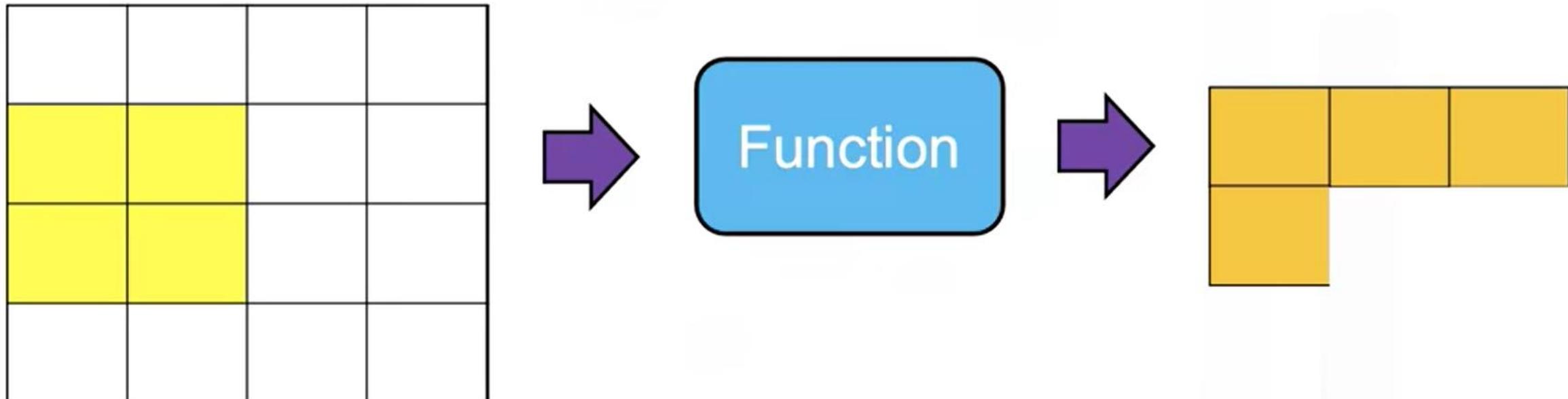
Filtering



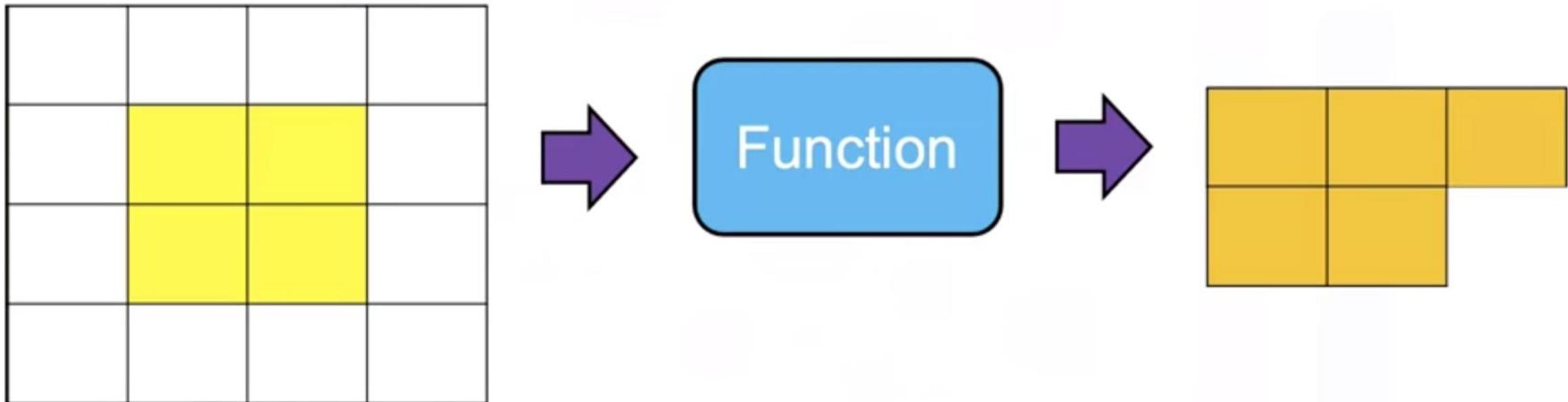
Filtering



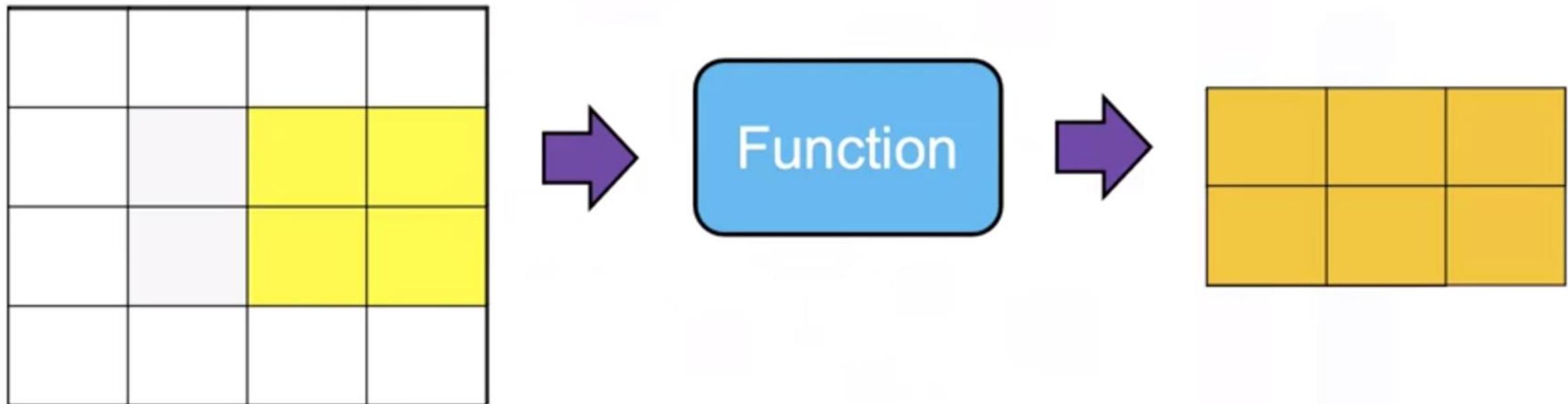
Filtering



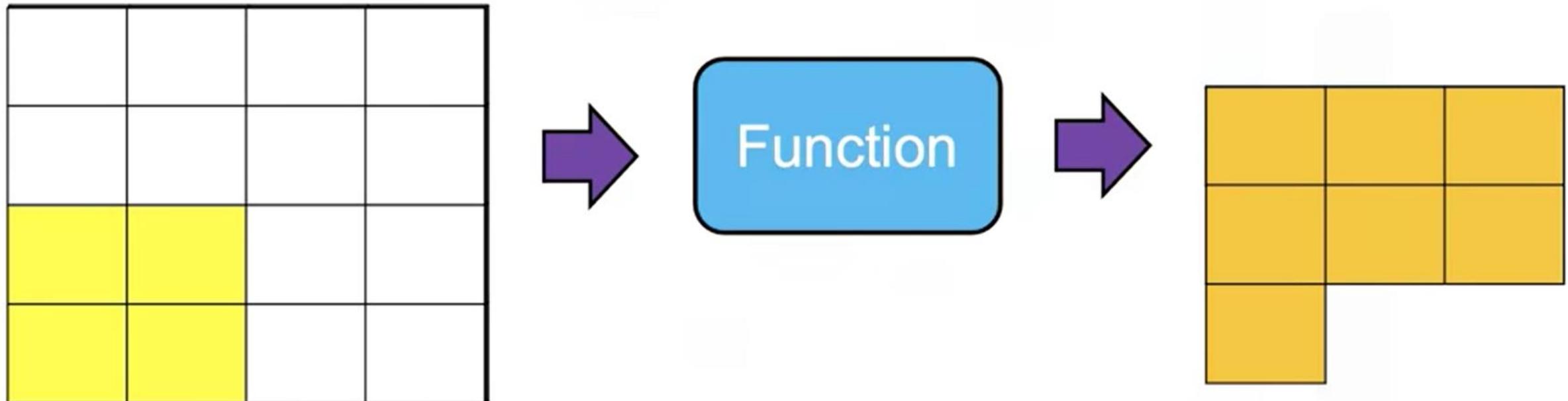
Filtering



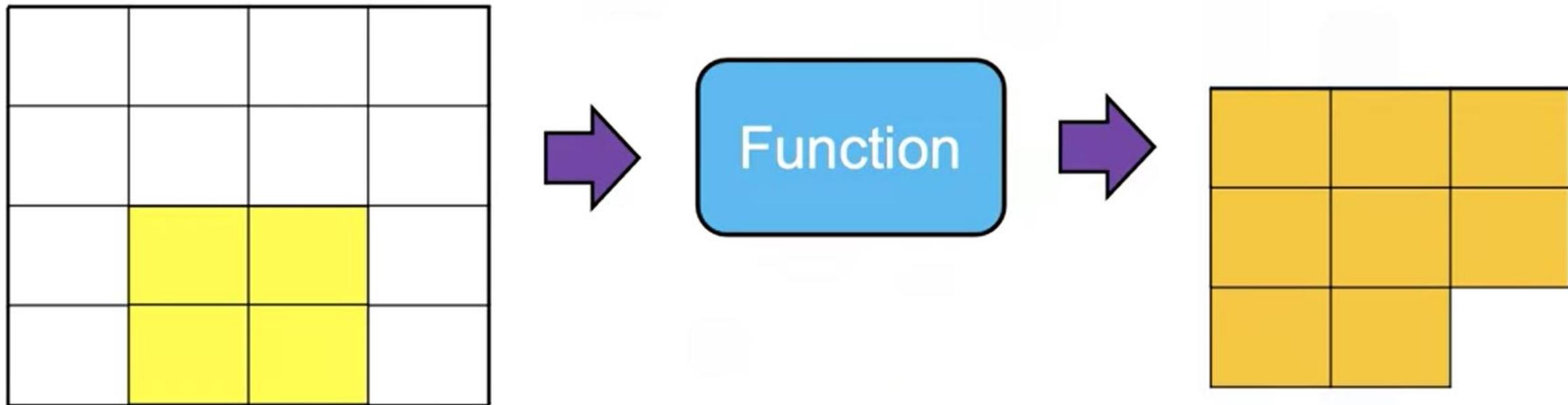
Filtering



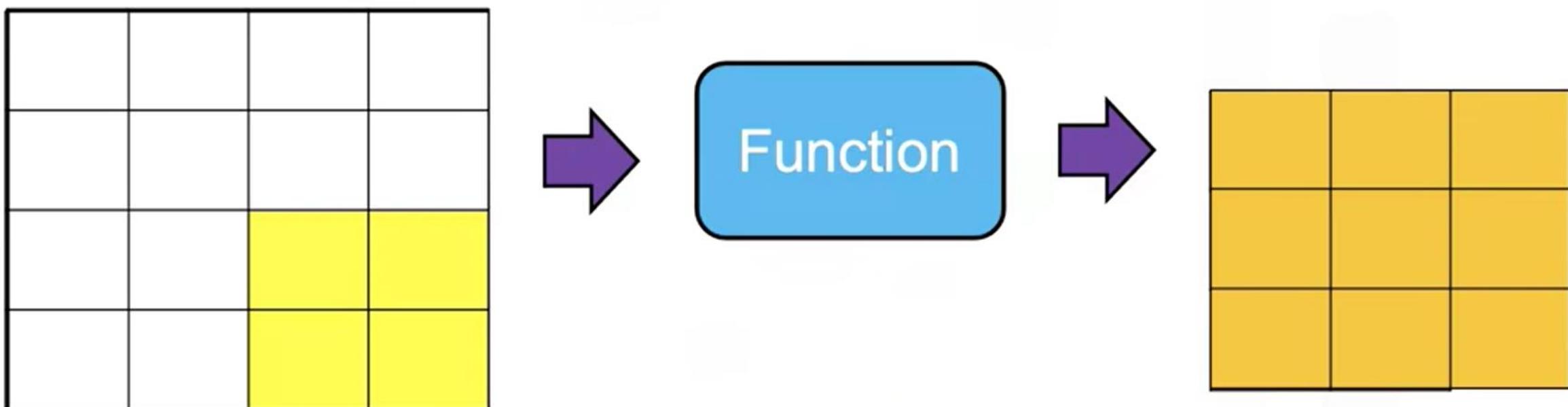
Filtering



Filtering



Filtering



Convolution: Linear Filtering

Convolution là gì? (Tích chập là gì?)

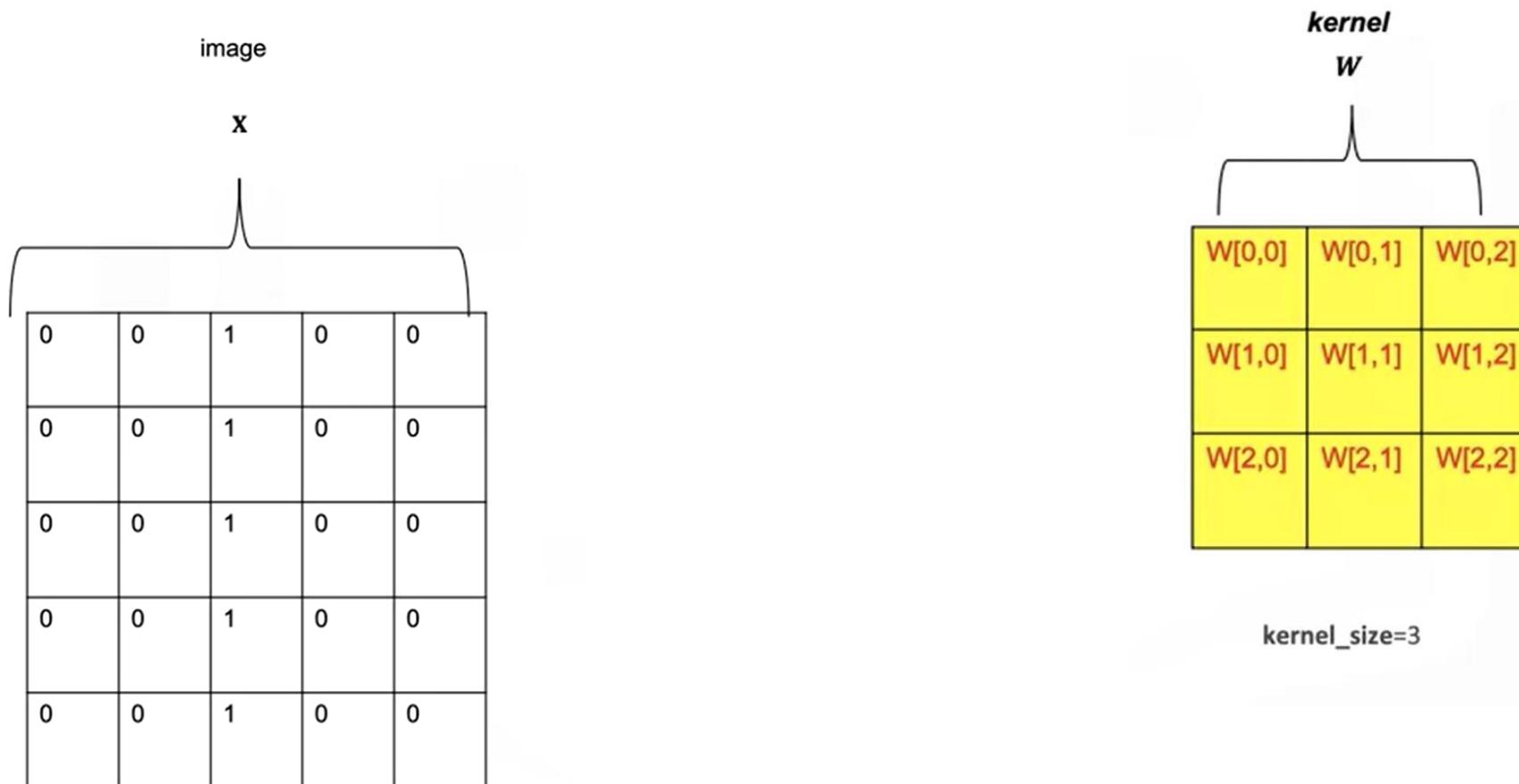
- Input: ảnh X
- Output: ảnh Z
- W: kernel hay còn gọi là bộ lọc (filter)
- Toán tử * là toán tử tích chập

$$\mathbf{z} = \mathbf{w}\mathbf{x}$$

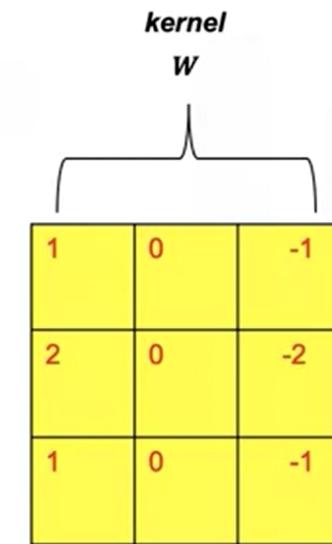
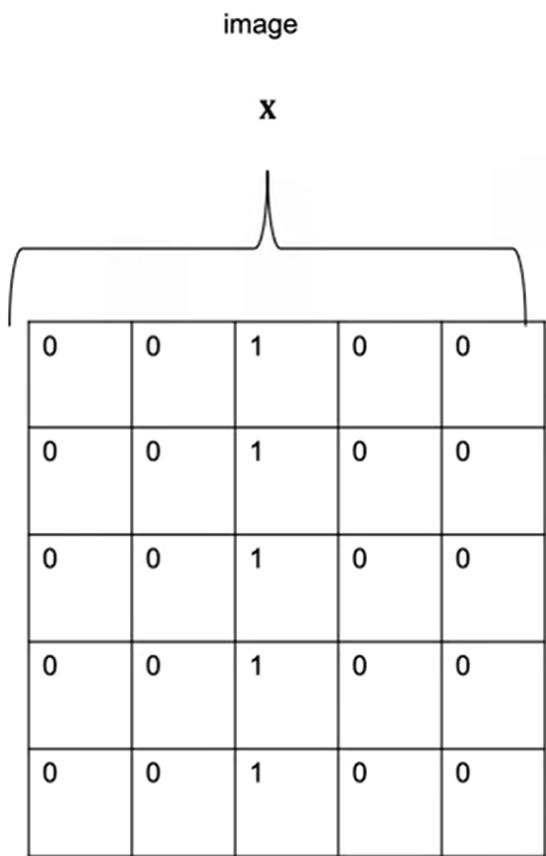
$$\mathbf{z} = \mathbf{W} * \mathbf{X}$$

kernel

Convolution



Convolution



Convolution – demo

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

Convolution – demo

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

$$0x1+0x0+1x-1$$

Convolution - demo

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

$$0x1+0x0+1x-1$$

+

$$0x2+0x0+1x-2$$

Convolution - demo

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

$$0x1+0x0+1x-1$$

+

$$0x2+0x0+1x-2$$

+

$$0x1+0x0+1x-1$$

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

$$0x1+0x0+1x-1$$

+

$$0x2+0x0+1x-2$$

+

$$0x1+0x0+1x-1$$

-1

+

-2

+

-1

4

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

Z

-4

$$0x1 + 0x0 + 1x-1$$

+

$$0x2 + 0x0 + 1x-2$$

+

$$0x1 + 0x0 + 1x-1$$

-1

+

-2

+

-1

4

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

$$0 \times 1 + 1 \times 0 + 0 \times -1$$

Z

-4

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

$$0 \times 1 + 1 \times 0 + 0 \times -1$$

-4

Z

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

$$0 \times 1 + 1 \times 0 + 0 \times -1$$

+

$$0 \times 2 + 1 \times 0 + 0 \times -2$$

-4

Z

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

$$0x1 + 1x0 + 0x-1$$

+

$$0x2 + 1x0 + 0x-2$$

+

$$0x1 + 0x0 + 0x-1$$

-4

Z

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

$$\begin{array}{l} 0x1+1x0+0x-1 \\ + \\ 0x2+1x0+0x-2 \\ + \\ 0x1+0x0+0x-1 \end{array} \quad \begin{array}{|c|c|} \hline 0 & \\ \hline + & \\ \hline 0 & \\ \hline + & \\ \hline 0 & \\ \hline 0 & \\ \hline \end{array}$$

Z

-4	0
----	---

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

Z

-4	0
----	---

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

Z

-4	0	4
----	---	---

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

Z

-4	0	4
-4		

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

0	0	1	0	0
0	0	1	0	0
0	0	2	1	0
0	0	1	0	0
0	0	1	0	0

Z

-4	0	4
-4	0	

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

0	0	1	0	0
0	0	1	1	0
0	0	1	2	0
0	0	1	1	0
0	0	1	0	0

Z

-4	0	4
-4	0	4

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

Z

-4	0	4
-4	0	4
-4		

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

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

Z

-4	0	4
-4	0	4
-4	0	

$$\mathbf{Z} = \mathbf{W} * \mathbf{X}$$

X

0	0	1	0	0
0	0	1	0	0
0	0	1	1	0
0	0	1	2	0
0	0	1	1	0

Z

-4	0	4
-4	0	4
-4	0	4

Convolution

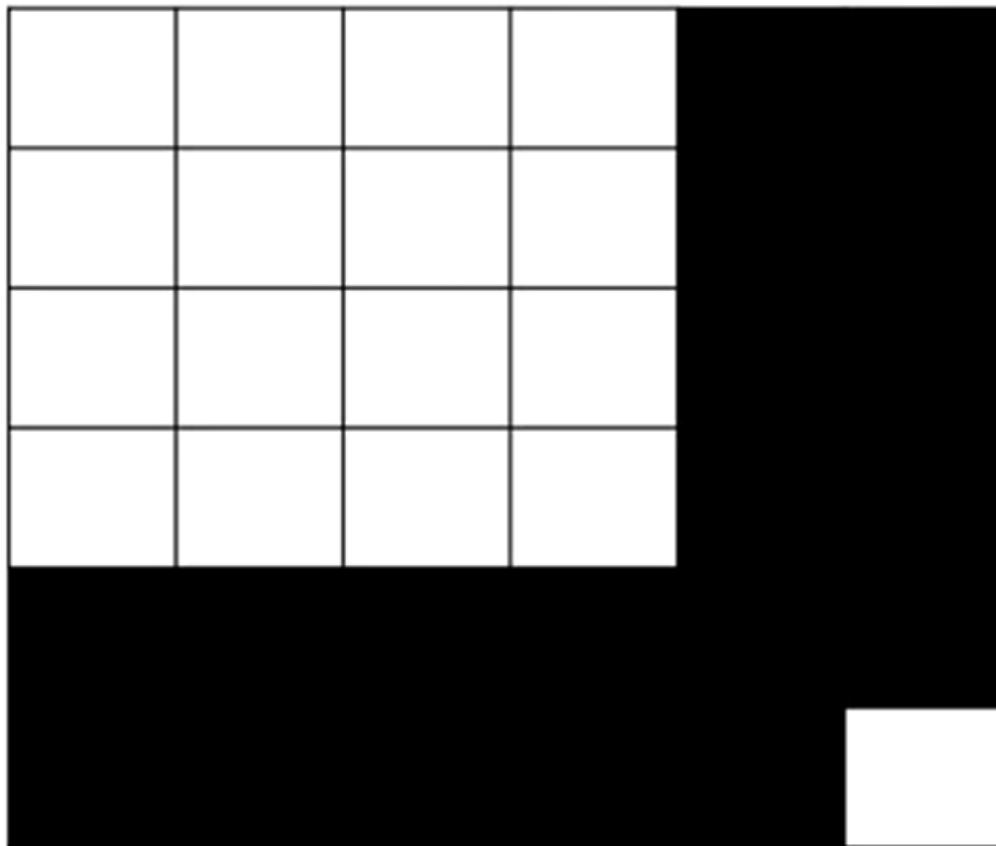
0	0	0	0	0	0
0					0
0					0
0					0
0					0
0	0	0	0	0	0

Convolution

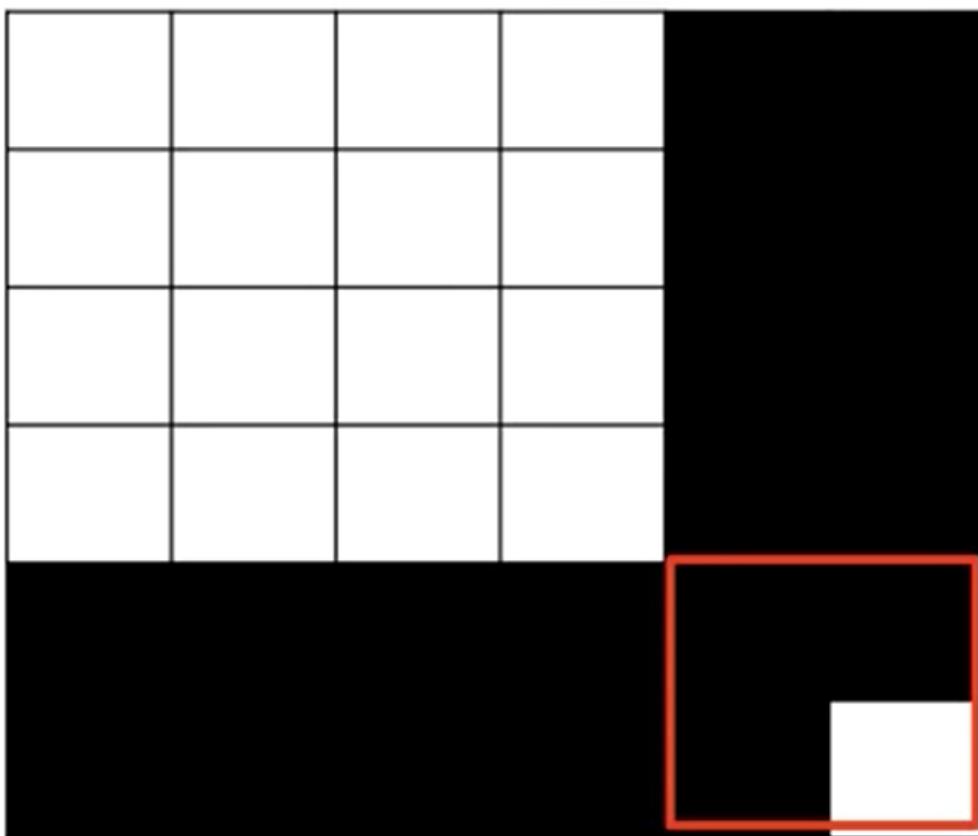
12	12	8	4	2	2
12	12	8	4	2	2
2	2	2	4	4	4
3	3	4	2	3	3
4	4	20	3	4	4
4	4	20	3	4	4

Low pass filter

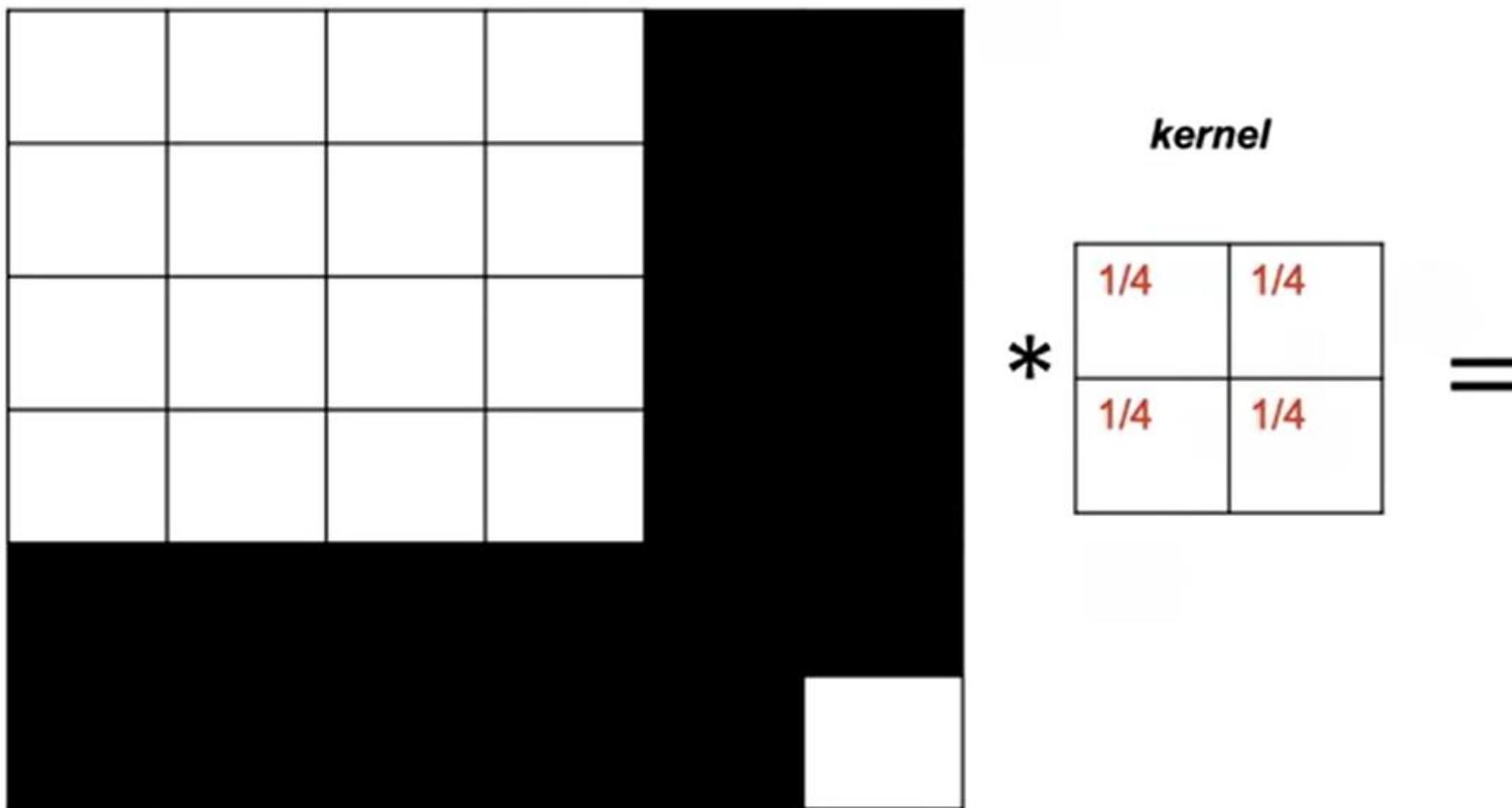
Mean filtering



Mean filtering



Mean filtering



Mean filtering

255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
0	0	0	0	0	0
0	0	0	0	0	255

kernel

$$\begin{matrix} * & \begin{matrix} 1/4 & 1/4 \\ 1/4 & 1/4 \end{matrix} & = \end{matrix}$$

Mean filtering

255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
0	0	0	0	0	0
0	0	0	0	0	255

$$\begin{matrix} & \text{kernel} \\ * & \begin{array}{|c|c|} \hline 1/4 & 1/4 \\ \hline 1/4 & 1/4 \\ \hline \end{array} \end{matrix} =$$

Mean filtering

$$\begin{array}{|c|c|c|c|c|c|} \hline 255 & 255 & 255 & 255 & 0 & 0 \\ \hline 255 & 255 & 255 & 255 & 0 & 0 \\ \hline 255 & 255 & 255 & 255 & 0 & 0 \\ \hline 255 & 255 & 255 & 255 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & 255 \\ \hline \end{array} * \begin{array}{|c|c|} \hline \textit{kernel} & \\ \hline 1/4 & 1/4 \\ \hline 1/4 & 1/4 \\ \hline \end{array} = \begin{array}{|c|c|c|c|c|c|} \hline 255 & 255 & 255 & & & \\ \hline 255 & 255 & 255 & & & \\ \hline 255 & 255 & 255 & & & \\ \hline & & & & & \\ \hline \end{array}$$

Mean filtering

255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
0	0	0	0	0	0
0	0	0	0	0	255

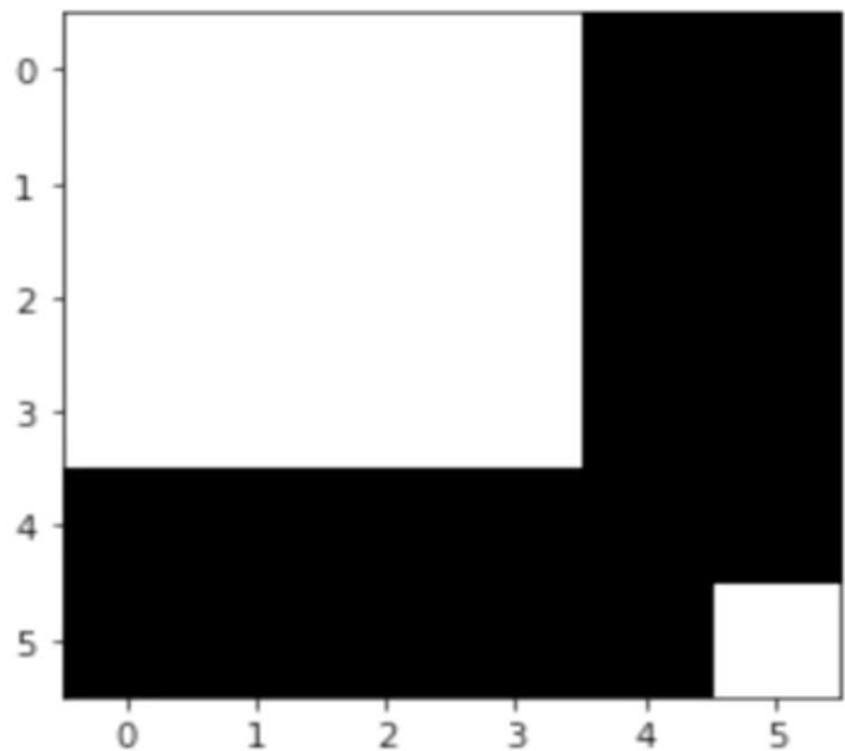
$$\begin{matrix} & \text{kernel} \\ * & \begin{array}{|c|c|} \hline 1/4 & 1/4 \\ \hline 1/4 & 1/4 \\ \hline \end{array} \end{matrix} =$$

255	255	255	255	128	
255	255	255	255	128	
255	255	255	255	128	
255	255	255	255	128	

Mean filtering

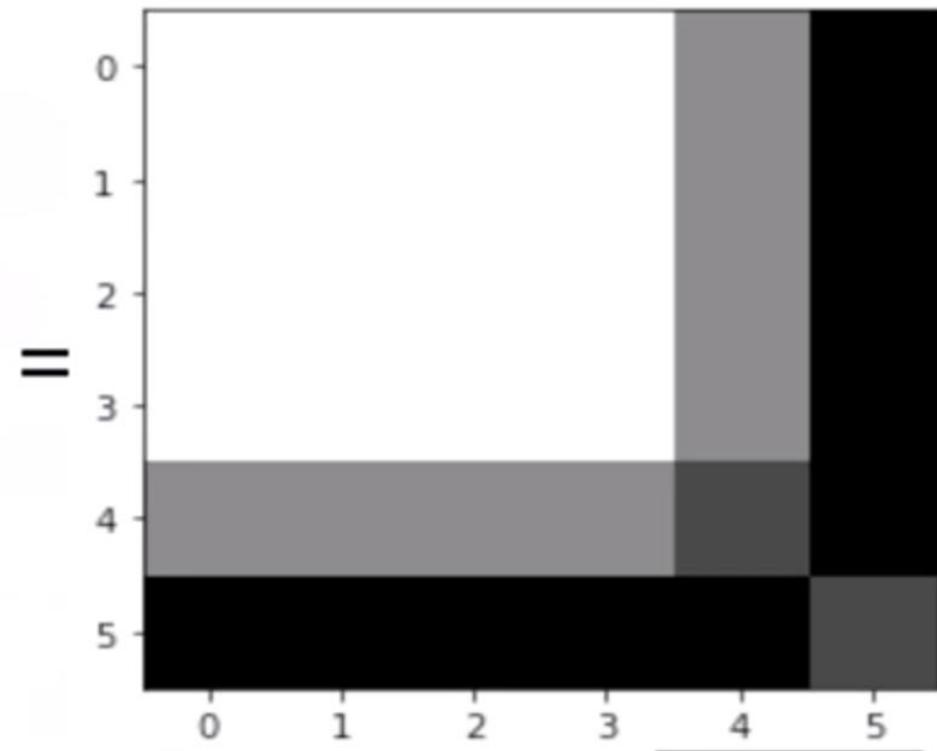
$$\begin{array}{|c|c|c|c|c|c|} \hline 255 & 255 & 255 & 255 & 0 & 0 \\ \hline 255 & 255 & 255 & 255 & 0 & 0 \\ \hline 255 & 255 & 255 & 255 & 0 & 0 \\ \hline 255 & 255 & 255 & 255 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & 255 \\ \hline \end{array} * \begin{array}{c} \textit{kernel} \\ \hline \begin{array}{|c|c|} \hline 1/4 & 1/4 \\ \hline 1/4 & 1/4 \\ \hline \end{array} \end{array} = \begin{array}{|c|c|c|c|c|c|} \hline 255 & 255 & 255 & 255 & 128 & 0 \\ \hline 255 & 255 & 255 & 255 & 128 & 0 \\ \hline 255 & 255 & 255 & 255 & 128 & 0 \\ \hline 255 & 255 & 255 & 255 & 128 & 0 \\ \hline 128 & 128 & 128 & 128 & 64 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & 64 \\ \hline \end{array}$$

Mean filtering



kernel

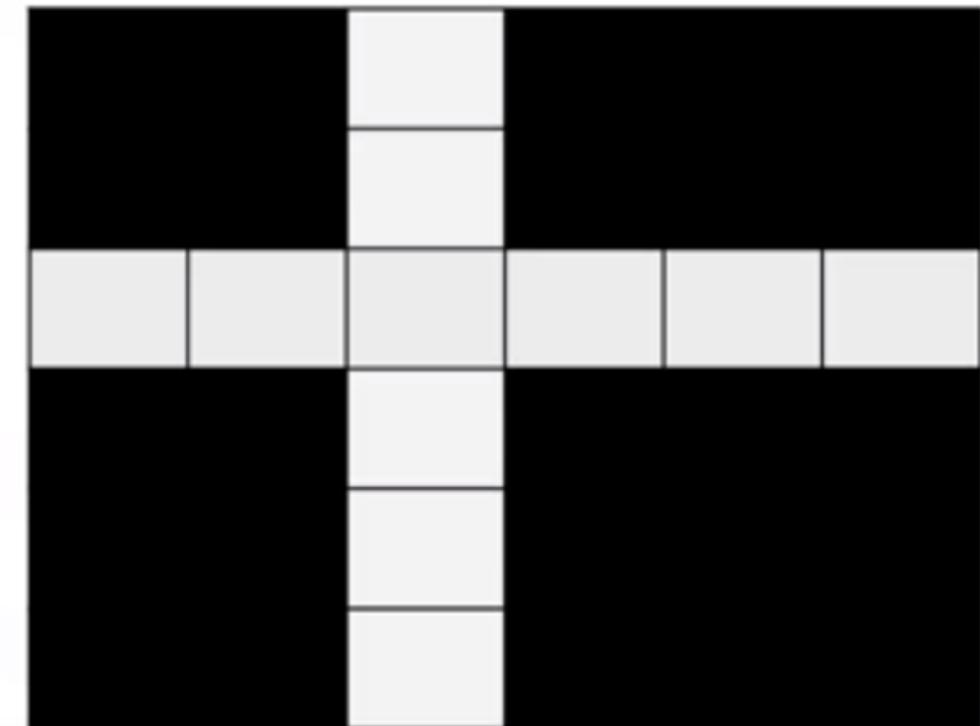
$$\begin{array}{|c|c|} \hline 1/4 & 1/4 \\ \hline 1/4 & 1/4 \\ \hline \end{array}$$



Edge detection

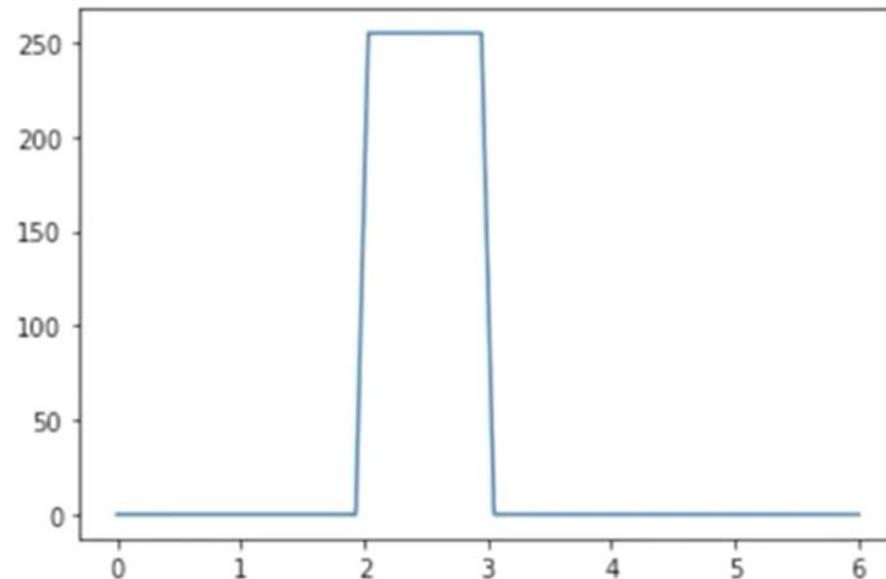
Edge detection

- Cạnh trong ảnh số là nơi độ sáng của hình ảnh thay đổi mạnh.
- Phát hiện cạnh là bước quan trọng trong nhiều thuật toán về Computer vision.



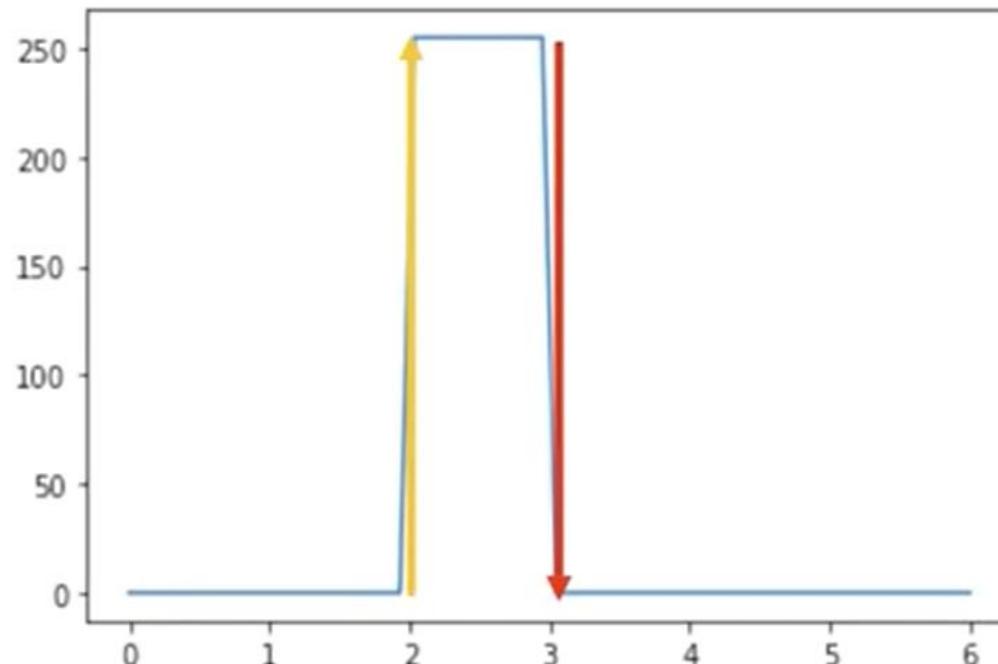
Edge detection

0	0	255	0	0	0
0	0	255	0	0	0
255	255	255	255	255	255
0	0	255	0	0	0
0	0	255	0	0	0
0	0	255	0	0	0



0	0	255	0	0	0
0	0	255	0	0	0
255	255	255	255	255	255
0	0	255	0	0	0
0	0	255	0	0	0
0	0	255	0	0	0

- Biểu đồ dòng đầu tiên của ảnh. Trục hoành là chỉ số cột và trục tung là giá trị cường độ



0	0	255	0	0	0
0	0	255	0	0	0
255	255	255	255	255	255
0	0	255	0	0	0
0	0	255	0	0	0
0	0	255	0	0	0

0	1	2	3	4	5
0	0	255	0	0	0
0	0	255	0	0	0
255	255	255	255	255	255
0	0	255	0	0	0
0	0	255	0	0	0
0	0	255	0	0	0

$$I[i, j + 1] - I[i, j]$$

0	1	2	3	4	5
0	0	255	0	0	0
0	0	255	0	0	0
255	255	255	255	255	255
0	0	255	0	0	0
0	0	255	0	0	0
0	0	255	0	0	0

$$I[i, j + 1] - I[i, j]$$

$$\frac{\partial I}{\partial x}$$

i	$I[i, 2]$	$I[i, 1]$	$I[i, j + 1] - I[i, j]$
0	255	0	255
1	255	0	255
2	255	255	0
3	255	0	255
4	255	0	255
6	255	0	255

0	1	2	3	4	5
0	0	255	0	0	0
0	0	255	0	0	0
255	255	255	255	255	255
0	0	255	0	0	0
0	0	255	0	0	0
0	0	255	0	0	0

$$I[i, j + 1] - I[i, j]$$

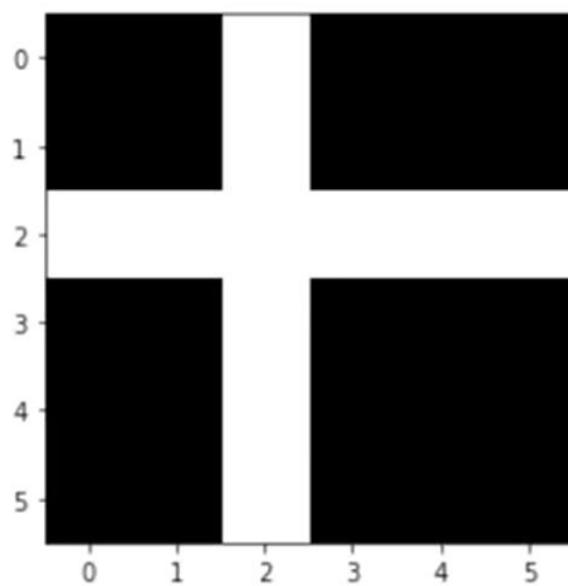
$$\frac{\partial I}{\partial x}$$

i	$I[i, 2]$	$I[i, 1]$	$I[i, j + 1] - I[i, j]$
0	255	0	255
1	255	0	255
2	255	255	0
3	255	0	255
4	255	0	255
6	255	0	255

0	1	2	3	4	5
0	0	255	0	0	0
0	0	255	0	0	0
255	255	255	255	255	255
0	0	255	0	0	0
0	0	255	0	0	0
0	0	255	0	0	0

i	$I[i, 3]$	$I[i, 2]$	$I[i, j + 1] - I[i, j]$
0	0	255	-255
1	0	255	-255
2	255	255	0
3	0	255	-255
4	0	255	-255
6	0	255	-255

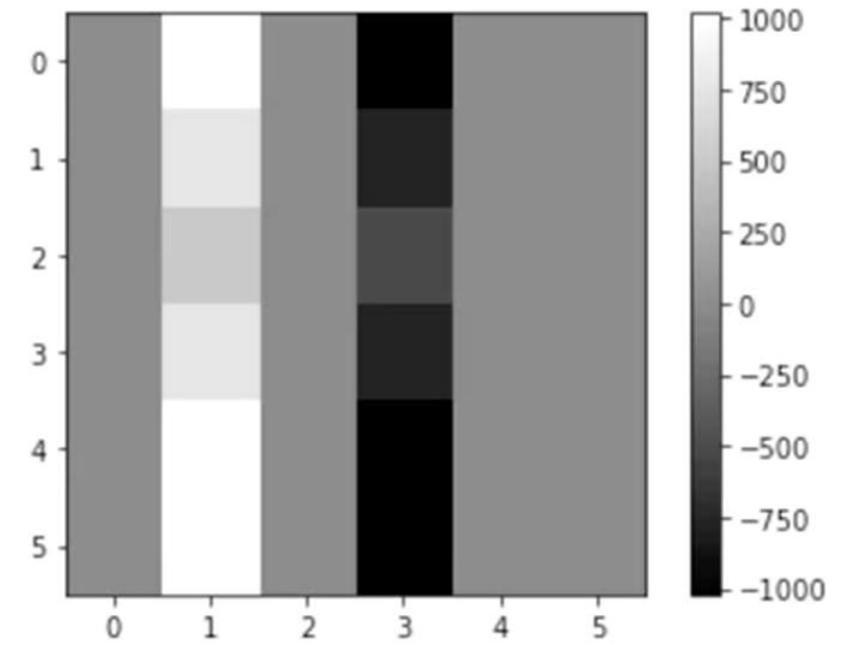
Horizontal Derivative Approximations



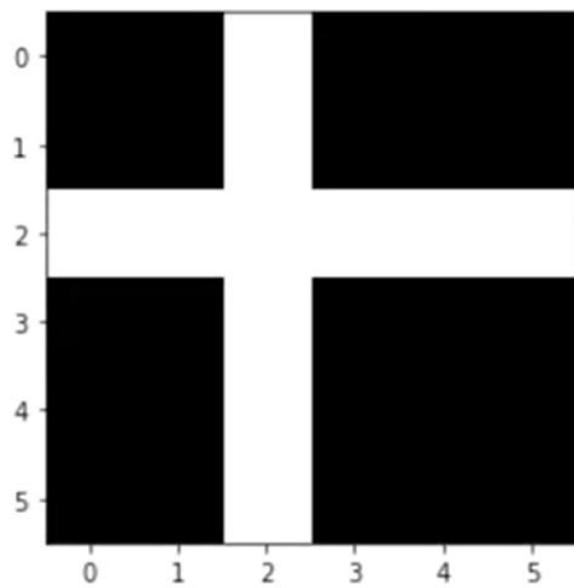
*

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

=



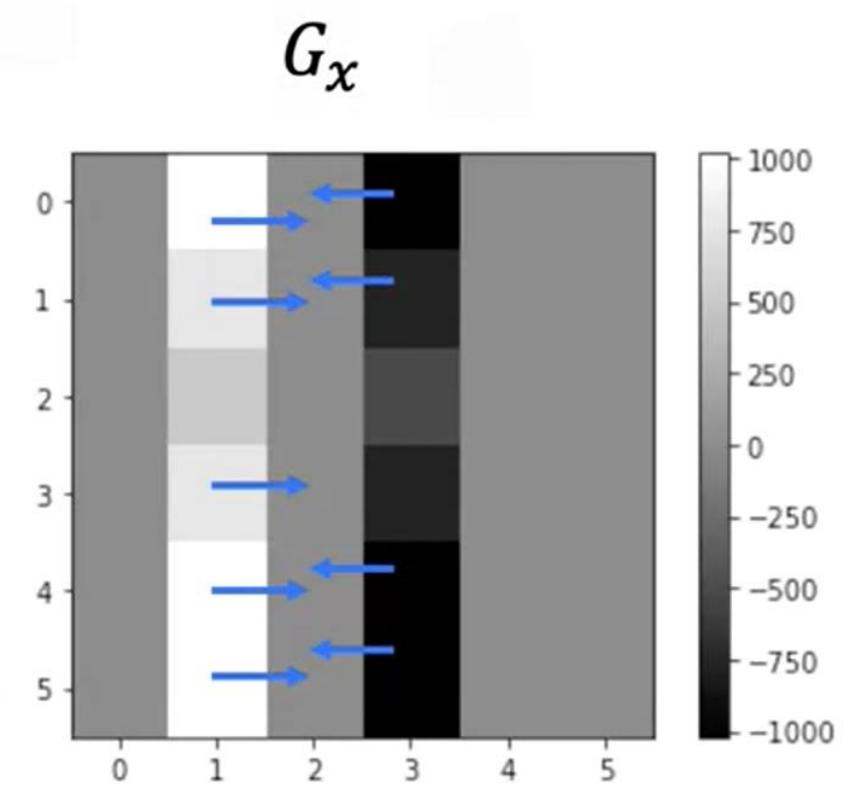
G_x



*

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

=



Median Filter

Median filter (lọc trung vị)

255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
0	0	0	0	0	0
0	0	0	0	0	255



		255		

Median filter

255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
0	0	0	0	0	0
0	0	0	0	0	255



255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
0	0	0	0	0	0
0	0	0	0	0	0

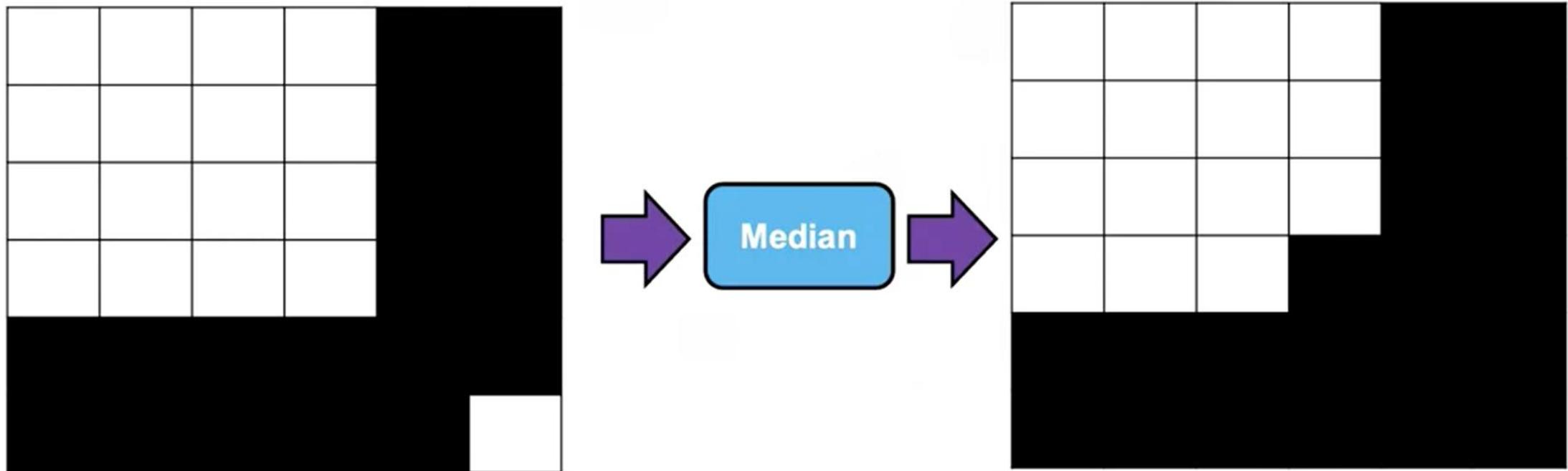
Median filter

255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
0	0	0	0	0	0
0	0	0	0	0	255



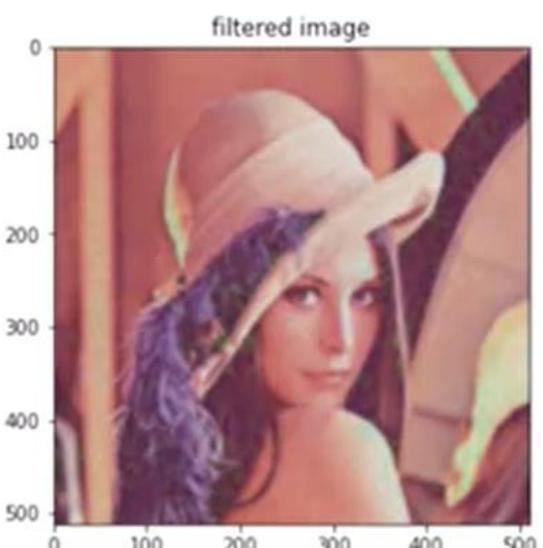
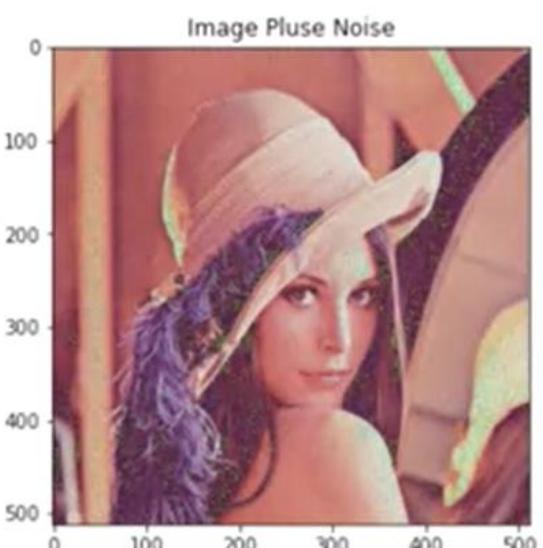
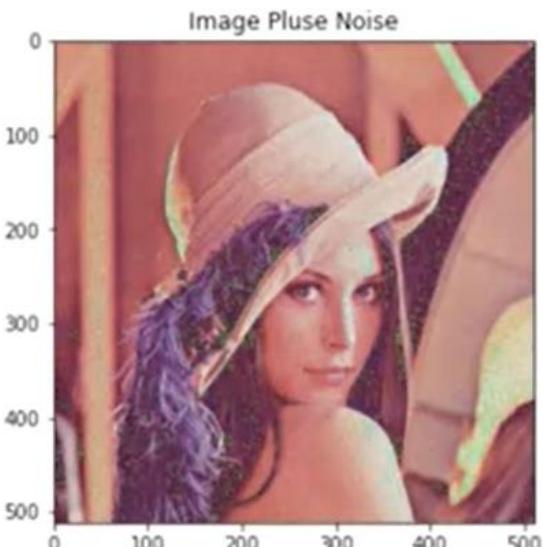
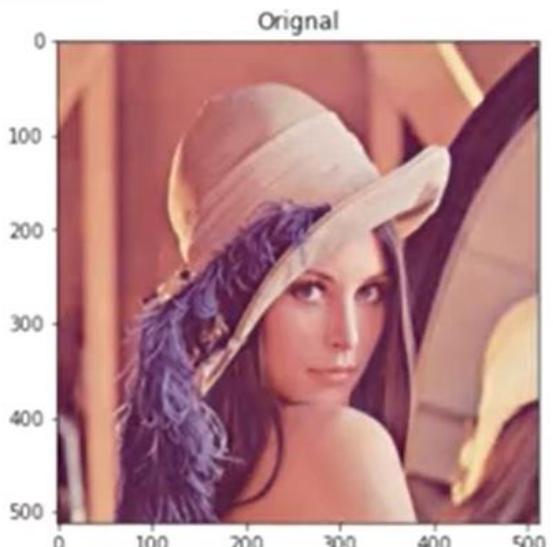
255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	255	0	0
255	255	255	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

Median filter



Filter with OpenCV

```
new_image= image+Noise  
  
kernel = np.ones((6,6))/36  
  
image_filtered=cv2.filter2D(src=new_image ,ddepth=-1,kernel=kernel)
```



```
kernel = np.array([[-1,-1,-1],  
                  [-1, 9,-1],  
                  [-1,-1,-1]])
```

```
image_filtered=cv2.filter2D(src=image,ddepth=-1,kernel=kernel)
```



```
img_gray = cv2.imread('barbara.png', cv2.IMREAD_GRAYSCALE)
```

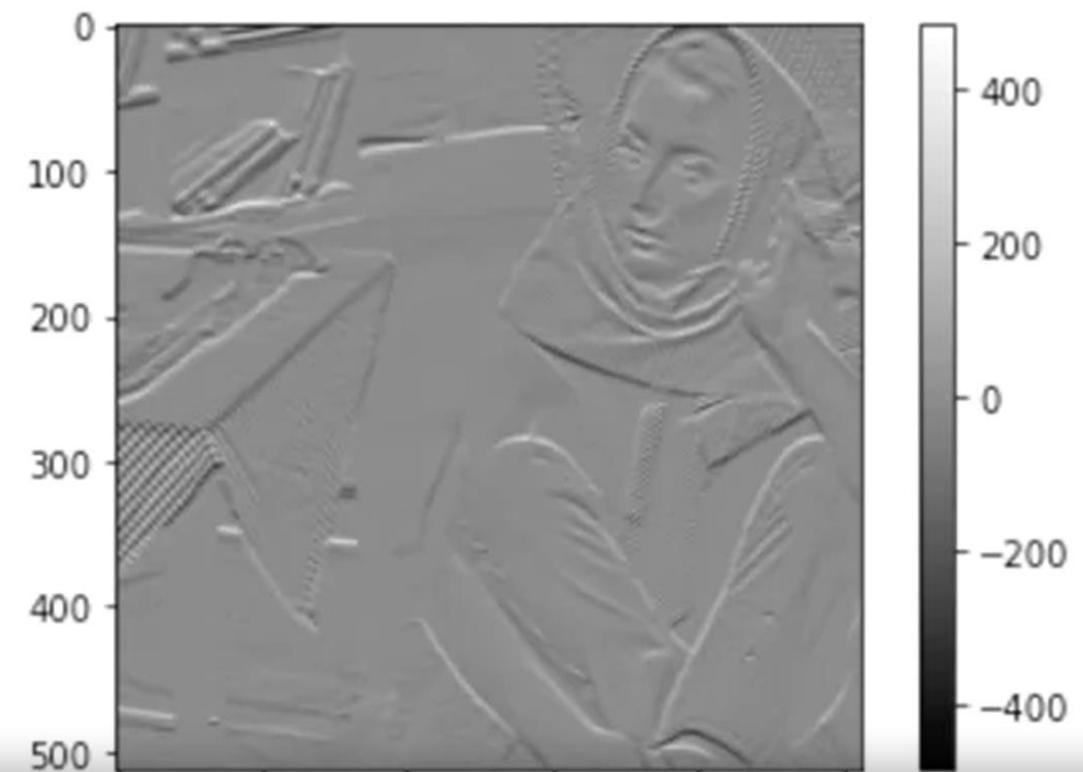
```
img_gray=cv2.GaussianBlur(img_gray,(3,3),sigmaX=0.1,sigmaY=0.1)
```



```
ddepth = cv2.CV_16S
```

```
grad_x = cv2.Sobel(src=img_gray, ddepth=ddepth, dx=1, dy=0, ksize=3)
```

```
grad_y = cv2.Sobel(src=img_gray, ddepth=ddepth, dx=0, dy=1, ksize=3)
```



```
abs_grad_x = cv2.convertScaleAbs(grad_x)  
abs_grad_y = cv2.convertScaleAbs(grad_y)
```

```
grad = cv2.addWeighted(abs_grad_x, 0.5, abs_grad_y, 0.5, 0)
```

