# Spatial domain Filtering

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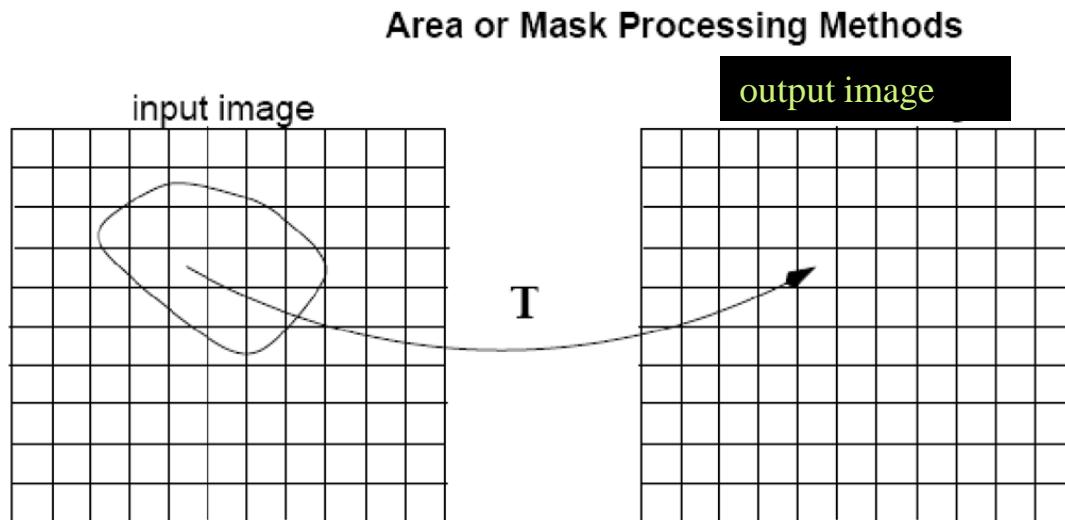
Spatial Filtering 1 (mask or area processing)

Input Image

$f(x,y)$

Smoothing or Averaging

(low pass filter)

Filtered Image

$w(s,t)\Theta f(x+s,y+t)$

Convolution

Sharpening or Gradient

(high pass filter)

Enhanced Image

$g(x,y)$

Spatial Filtering 2(mask or area processing)

- Need to define:
  - (1) Area shape and size
  - (2) Operation

Area or Mask Processing Methods

input image

output image

$$T$$
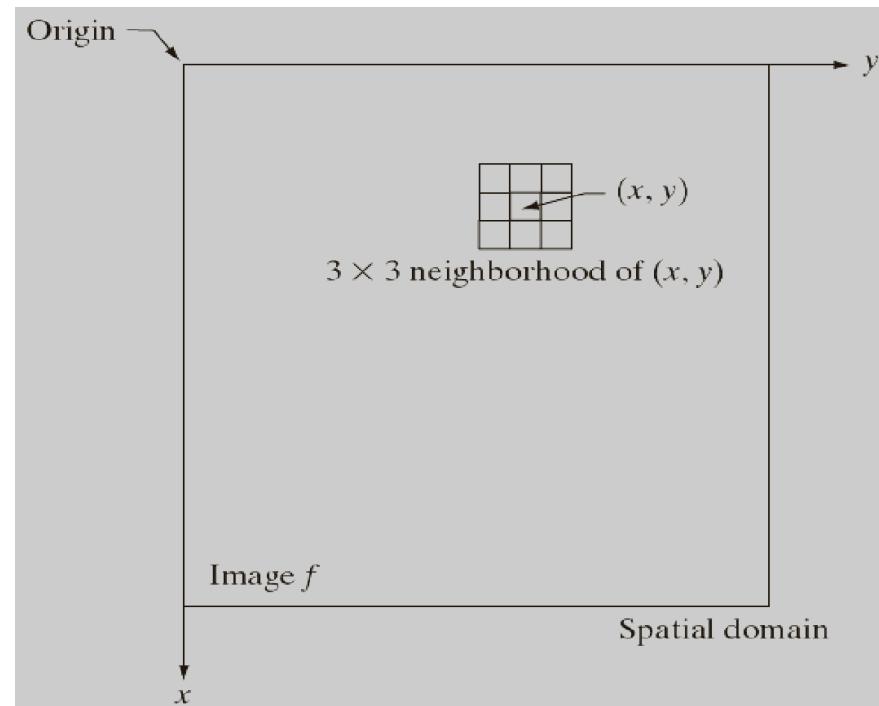
$$g(x,y) = T[f(x,y)]$$

T operates on a
neighborhood of pixels

Area Shape and Size

- Area shape is typically defined using a rectangular mask.

- Area size is determined by mask size.

  - e.g., 3x3 or 5x5

- Mask size is an

- important parameter!

Operation

- Typically linear combinations of pixel values.
 - e.g., weight pixel values and add them together.
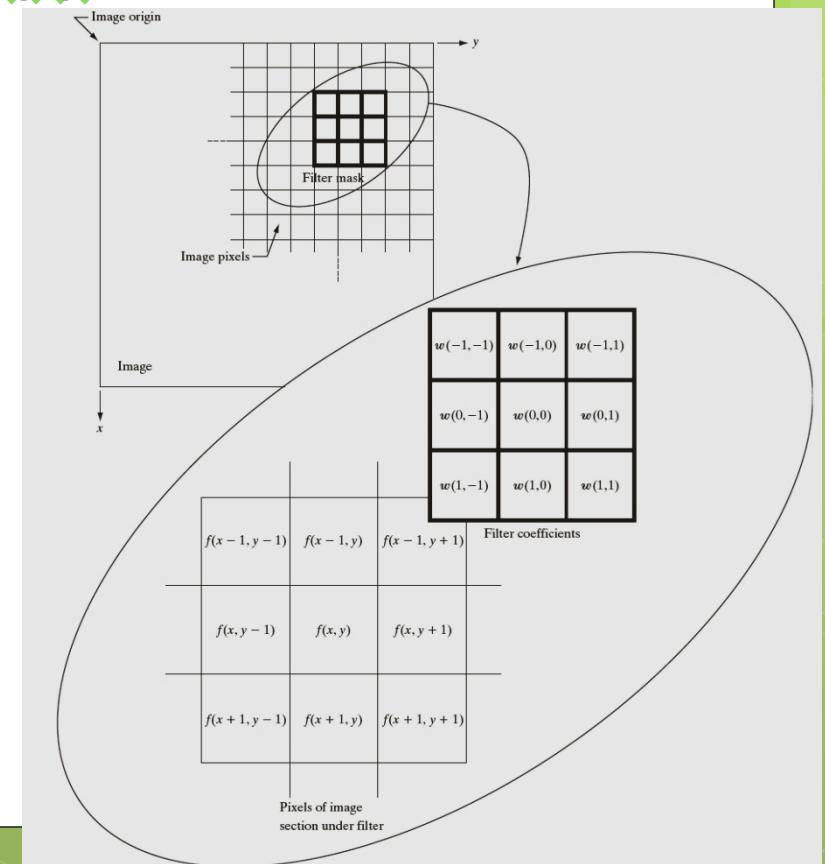
- Different results can be obtained
- using different weights.
  e.g., smoothing, sharpening,
  edge detection).
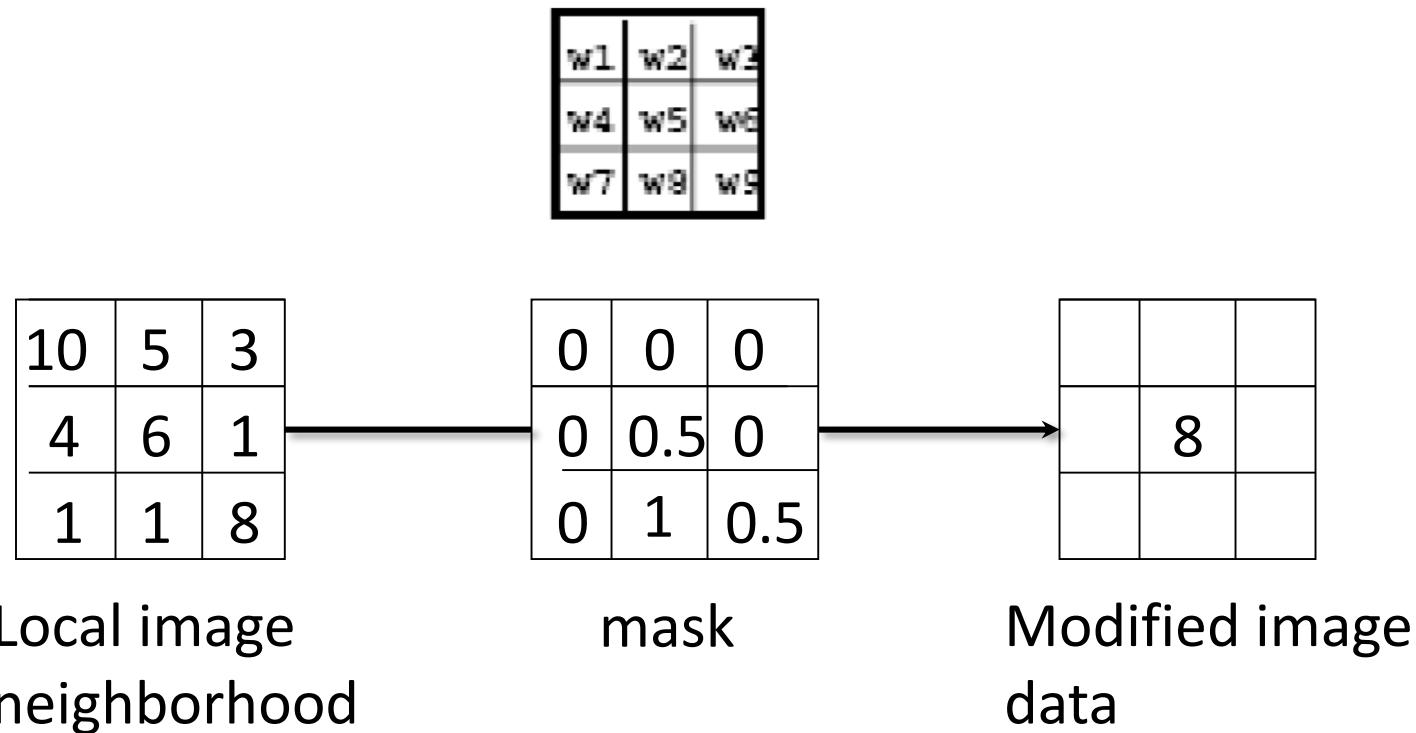
mask

Example

w1	w2	w3
w4	w5	w6
w7	w9	w9

10	5	3
4	6	1
1	1	8

0	0	0
0	0.5	0
0	1	0.5

	8	

Local image neighborhood   mask   Modified image data
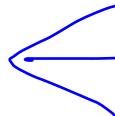
Common Linear Operations

1. Correlation كلافة
2. Convolution التقاف
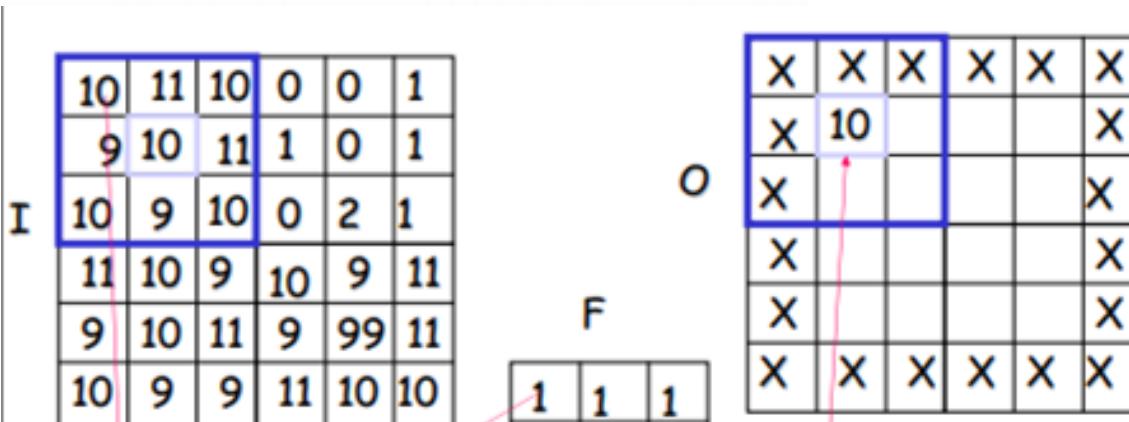
Correlation

- A filtered image is generated as the center of the mask visits every pixel in the input image.

$$I'(X, Y) = \sum_{j=-k}^{k} \sum_{i=-k}^{k} F(i,j) \, I(X+i, Y+j)$$

I

10	11	10	0	0	1
9	10	11	1	0	1
10	9	10	0	2	1
11	10	9	10	9	11
9	10	11	9	99	11
10	9	9	11	10	10

O

X	X	X	X	X	X
X	10				X
X					X
X					X
X					X
X	X	X	X	X	X

F

$1/9$

1	1	1
1	1	1
1	1	1

$1/9 \cdot (10{\times}1 + 11{\times}1 + 10{\times}1 + 9{\times}1 + 10{\times}1 + 11{\times}1 + 10{\times}1 + 9{\times}1 + 10{\times}1) =$

$1/9 \cdot (90) = 10$

Convolution

$$\frac{1}{9}\begin{array}{|c|c|c|} \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array}$$
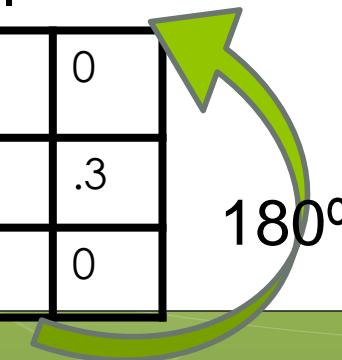
- Same as correlation, but with kernel reversed
- Represent the linear weights as an image, F
- F is called the **kernel**
- Center origin of the kernel F at each pixel location
- Multiply weights by corresponding pixels
- Set resulting value for each pixel.

Image, R, resulting from convolution of F with image H, where u,v range over kernel pixels (in 1D):

$$R_{ij} = \sum_{u,v} H_{i-u,j-v} F_{uv}$$

image

1	2	0
5	7	8
3	9	6

kernel

0	.1	0
.1	.6	.3
0	.2	0

180⁰

kernel

0	.2	0
.3	.6	.1
0	.1	0

Spatial Filtering using Correlation

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

Original image
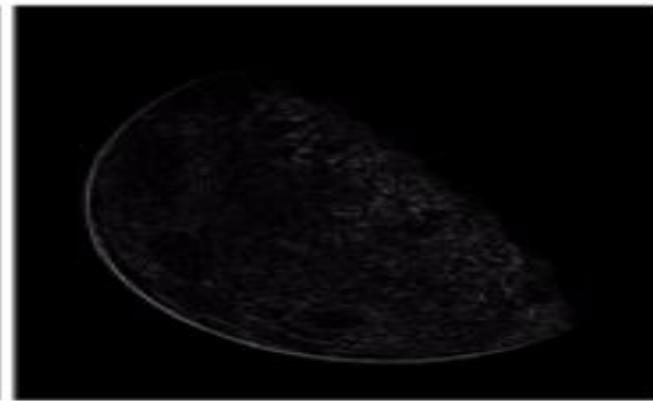
Smoothing image

$-1/9$	$-1/9$	$-1/9$
$-1/9$	$8/9$	$-1/9$
$-1/9$	$-1/9$	$-1/9$

Original image

Sharpened image

Smoothing spatial filtering
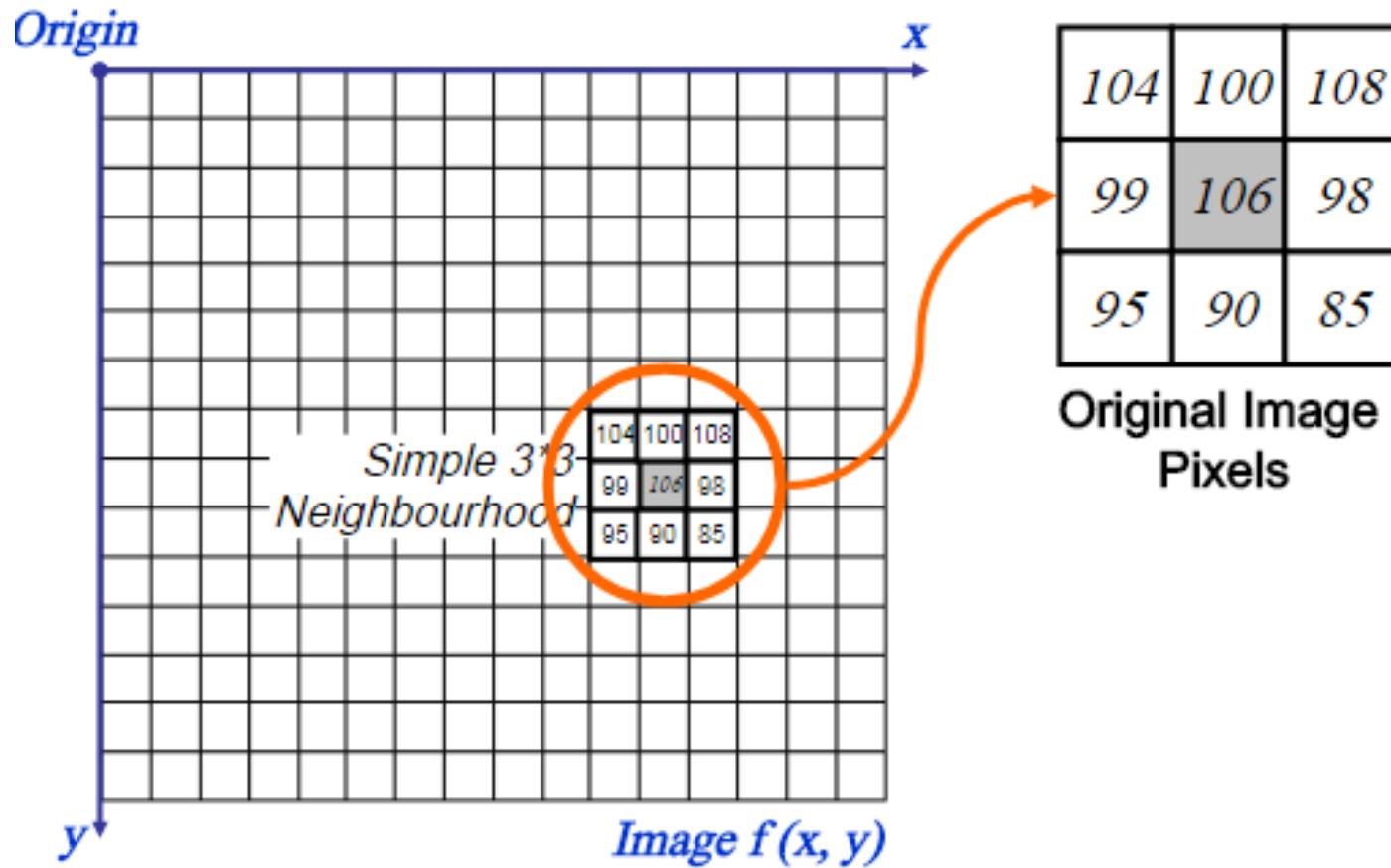
One of the simplest spatial filtering operations we can perform is a smoothing operation

- Simply average all of the pixels in a neighbourhood around a central value

- Especially useful in removing noise from images

- Also useful for highlighting gross detail
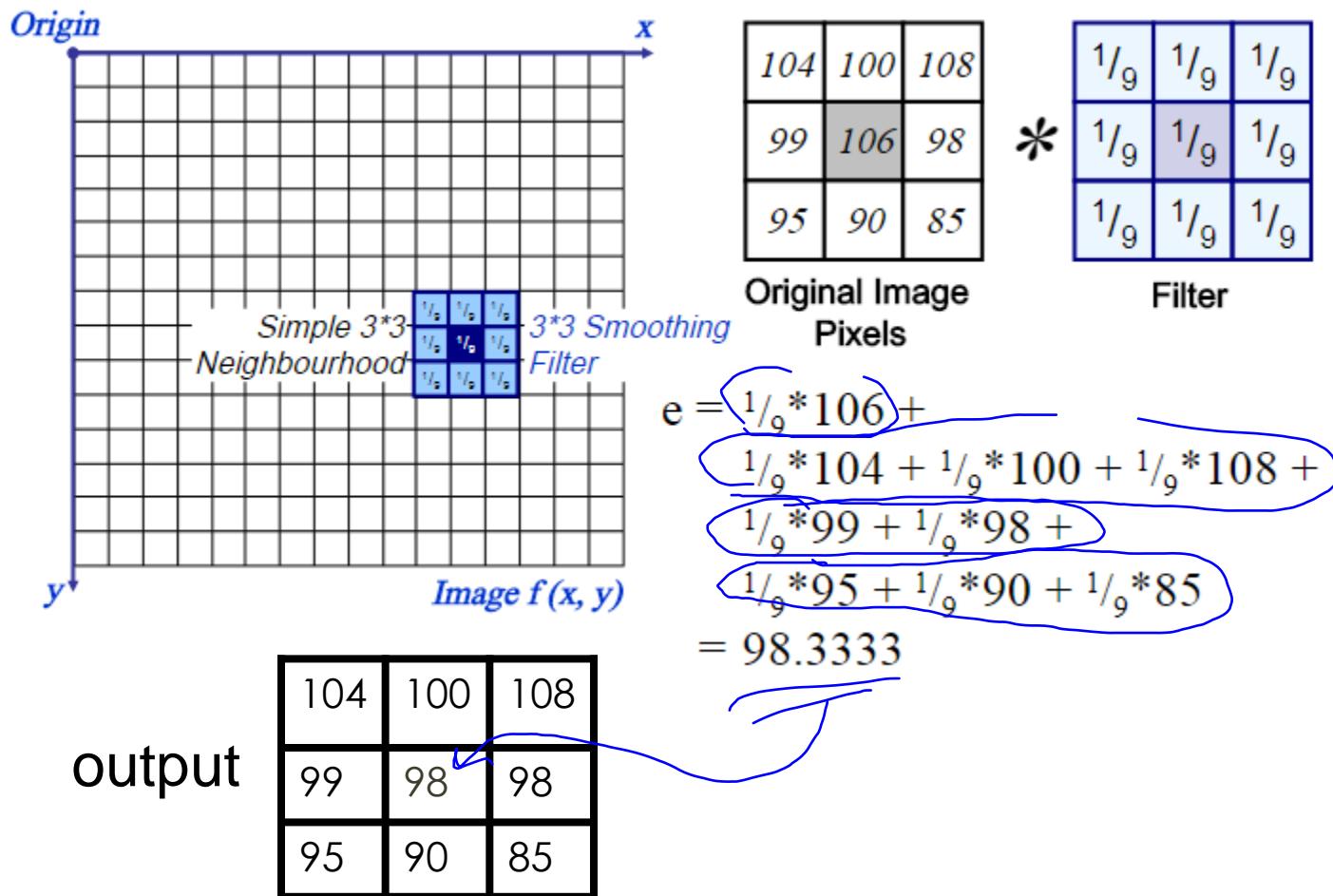
$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$

Simple averaging filter

Example of Smoothing spatial filtering

Original Image Pixels

Example of Smoothing spatial filtering

$$e = \frac{1}{9}*106 +$$
$$\frac{1}{9}*104 + \frac{1}{9}*100 + \frac{1}{9}*108 +$$
$$\frac{1}{9}*99 + \frac{1}{9}*98 +$$
$$\frac{1}{9}*95 + \frac{1}{9}*90 + \frac{1}{9}*85$$
$$= 98.3333$$

output

104	100	108
99	98	98
95	90	85

Examples of LP and HP Filters

Find the output of applying sharpening filter on the pixels (3,4) and (5,6) shown in block of image:

-1	-1	-1
-1	8	-1
-1	-1	-1
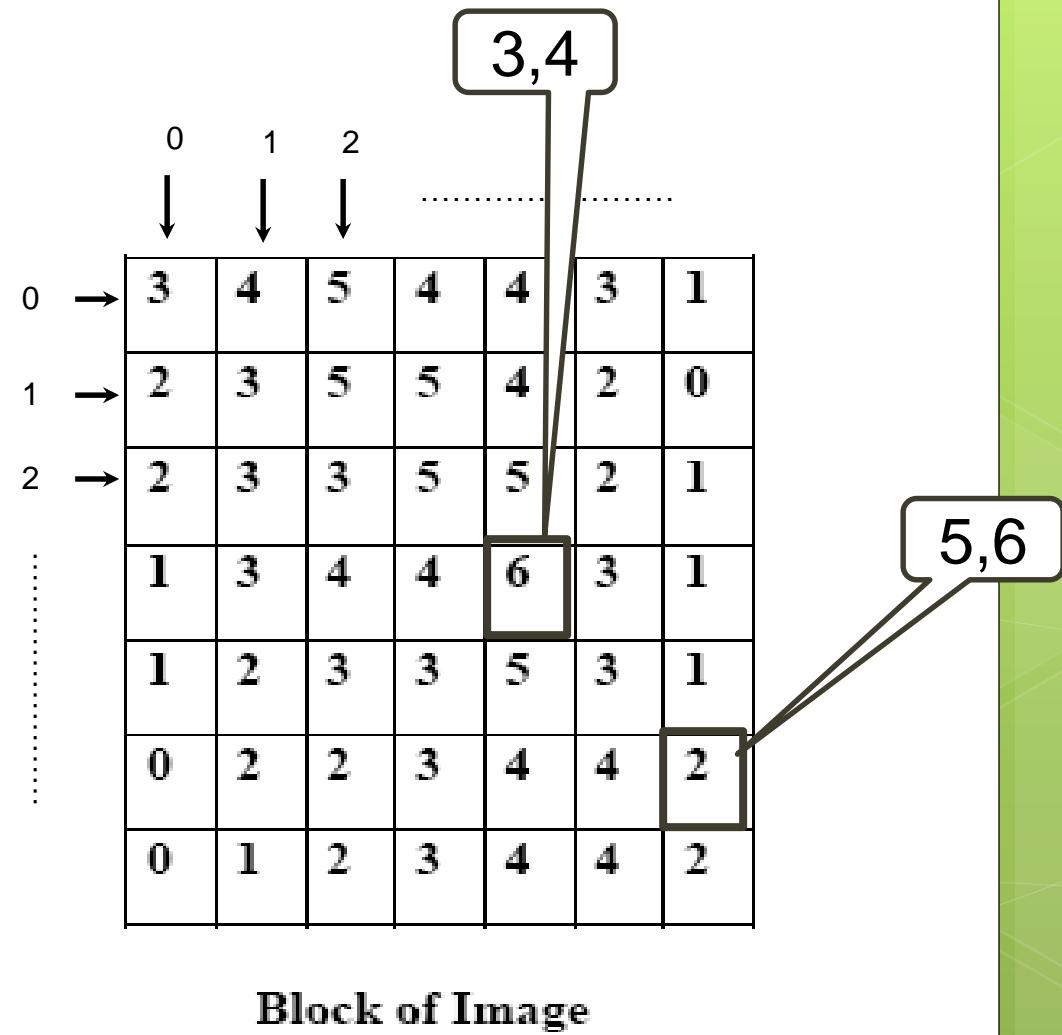
1/9

Filter

3	4	5	4	4	3	1
2	3	5	5	4	2	0
2	3	3	5	5	2	1
1	3	4	4	6	3	1
1	2	3	3	5	3	1
0	2	2	3	4	4	2
0	1	2	3	4	4	2

Block of Image

Filter

Block of Image

3,4

-1	-1	-1
-1	8	-1
-1	-1	-1

1/9

Filter

3	4	5	4	4	3	1
2	3	5	5	4	2	0
2	3	3	5	5	2	1
1	3	4	4	6	3	1
1	2	3	3	5	3	1
0	2	2	3	4	4	2
0	1	2	3	4	4	2

Block of Image

1/9 ((-1*5)+ (-1*5)+ (-1*2)+ (-1*4)+ (8*6)+(-1*3)+ (-1*3)+ (-1*5)+ (-1*3)) = ? $\frac{1}{9}(28) = 3.111$

5,6

-1	-1	-1
-1	8	-1
-1	-1	-1

1/9

Filter

3	4	5	4	4	3	1
2	3	5	5	4	2	0
2	3	3	5	5	2	1
1	3	4	4	6	3	1
1	2	3	3	5	3	1	0
0	2	2	3	4	4	2	0
0	1	2	3	4	4	2	0

Block of Image

1/9 ((-1*3)+ (-1*1)+ (-1*0)+ (-1*4)+ (8*2)+(-1*0)+ (-1*4)+ (-1*2)+ (-1*0)) = ? $\frac{1}{9}(2) = 0.222$

Discussion (Q/A)