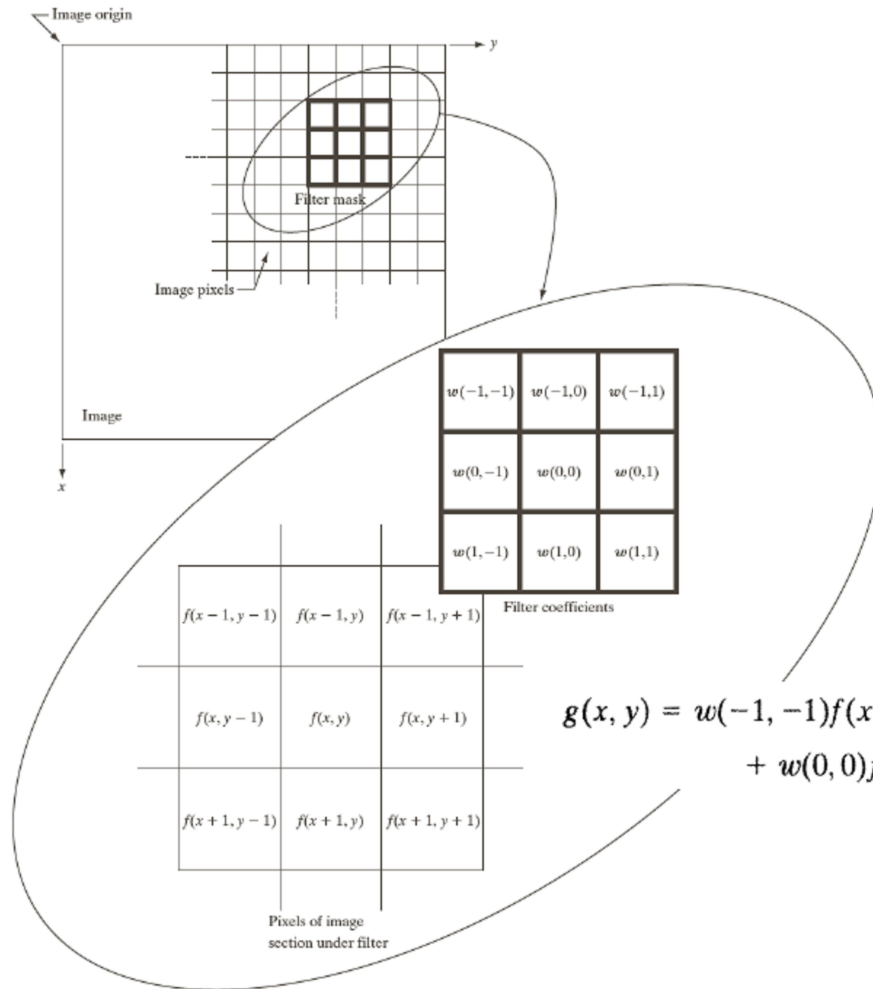


Lecture 13

Spatial Filtering

$$g(x, y) = \sum_{s=-a}^a \sum_{t=-b}^b w(s, t) f(x + s, y + t)$$



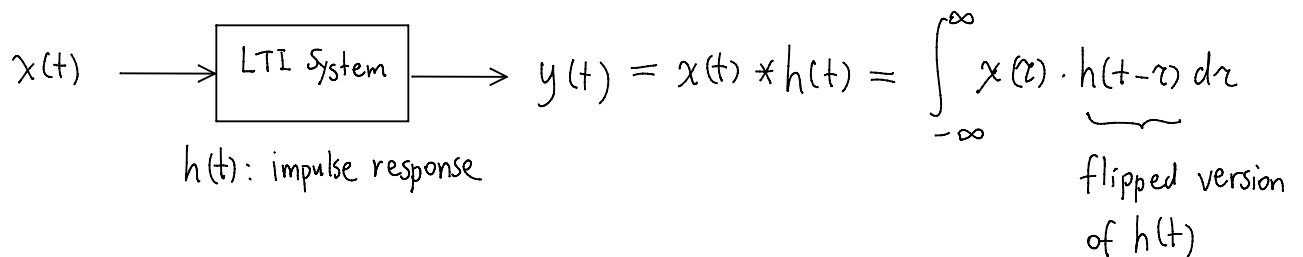
$$g(x, y) = w(-1, -1)f(x - 1, y - 1) + w(-1, 0)f(x - 1, y) + \dots + w(0, 0)f(x, y) + \dots + w(1, 1)f(x + 1, y + 1)$$

Correlation:

$$w(x, y) \star f(x, y) = \sum_{s=-a}^a \sum_{t=-b}^b w(s, t) f(x + s, y + t)$$

Convolution:

$$w(x, y) \star f(x, y) = \sum_{s=-a}^a \sum_{t=-b}^b w(s, t) f(x - s, y - t)$$



```
>> x = [0 0 0 1 0 0 0 0];
>> w = [1 2 3 2 8];
>> conv(x, w)
```

ans =

Columns 1 through 11

0 0 0 1 2 3 2 8 0 0 0

Column 12

0

- Implement correlation using convolution

```
>> conv(x, flip(w))
```

ans =

0 0 0 8 2 3 2 1 0 0 0 0

```
>> conv(x, w, 'same')
```

ans =

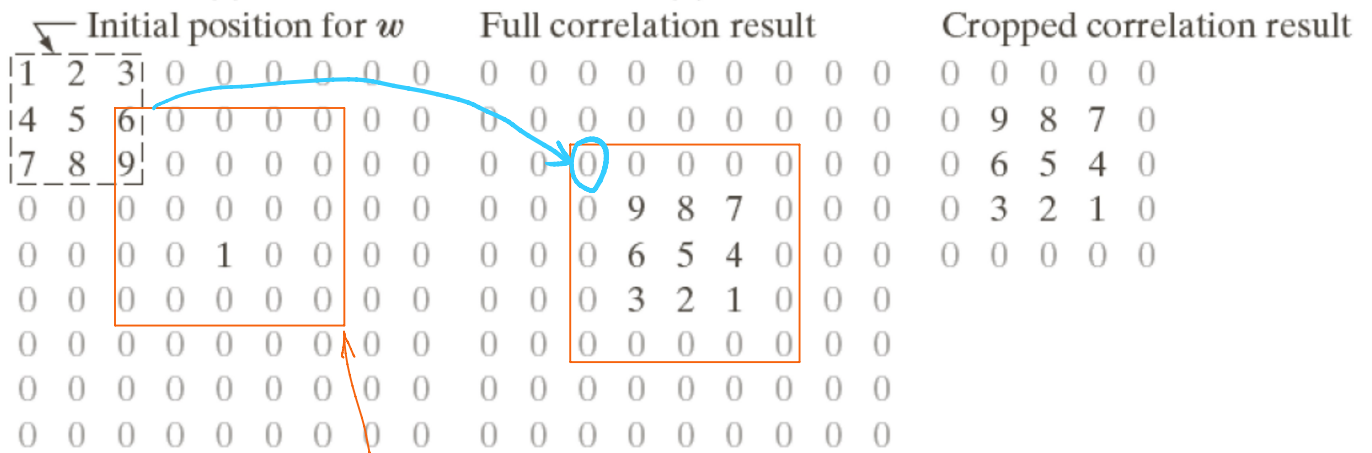
0 1 2 3 2 8 0 0

Cropped convolution result

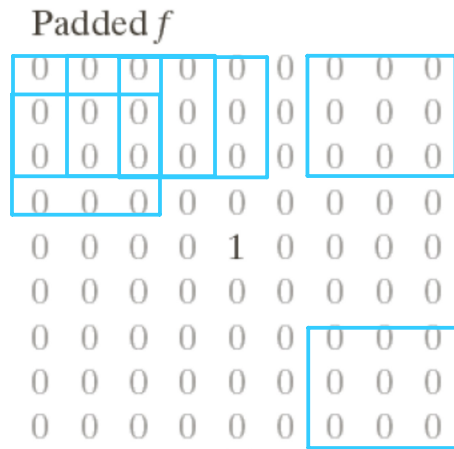
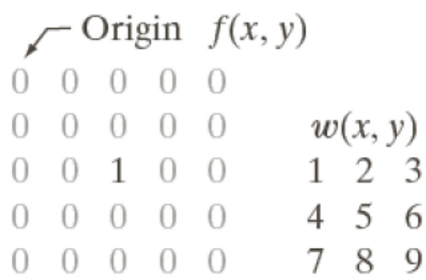
0 1 2 3 2 8 0 0

Full correlation result

0 0 0 8 2 3 2 1 0 0 0 0

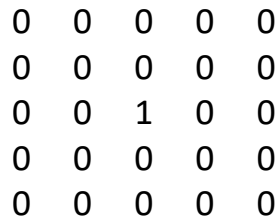


Original image



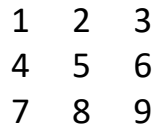
```
>> f = zeros(5,5);
>> f(3, 3) = 1;
>> f
```

f =



```
>> w = reshape(1:9, 3, 3)'
```

w =



```
>> conv2(f, w, 'same')
```

```
ans =
```

```
0 0 0 0 0
0 1 2 3 0
0 4 5 6 0
0 7 8 9 0
0 0 0 0 0
```

- Implement correlation using convolution

```
w =
```

```
1 2 3
4 5 6
7 8 9
```

```
>> w1 = flip(w, 1)
```

```
w1 =
```

```
7 8 9
4 5 6
1 2 3
```

```
>> w2 = flip(w1, 2)
```

```
w2 =
```

```
9 8 7
6 5 4
3 2 1
```

Rotated w

```
9 8 7 0 0 0 0 0 0
6 5 4 0 0 0 0 0 0
3 2 1 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0
0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
```

```
>> conv2(f, w2, 'same')
```

```
ans =
```

```
0 0 0 0 0
0 9 8 7 0
0 6 5 4 0
0 3 2 1 0
0 0 0 0 0
```

Same result
as using
filter2

```
>> filter2(w, f)
```

```
ans =
```

```
0 0 0 0 0
0 9 8 7 0
0 6 5 4 0
0 3 2 1 0
0 0 0 0 0
```

Boundary Padding Options

```
>> A = [1 2; 3 4]
```

A =

```
1 2
3 4
```

```
>> padarray(A, [2 2]) % Zero Padding
```

ans =

```
0 0 0 0 0 0
0 0 0 0 0 0
0 0 1 2 0 0
0 0 3 4 0 0
0 0 0 0 0 0
0 0 0 0 0 0
```

```
>> padarray(A, [2 2], 'symmetric')
```

ans =

```
4 3 3 4 4 3
2 1 1 2 2 1
2 1 1 2 2 1
4 3 3 4 4 3
4 3 3 4 4 3
2 1 1 2 2 1
```

```
>> padarray(A, [2 2], 'replicate')
```

ans =

```
1 1 1 2 2 2
1 1 1 2 2 2
1 1 1 2 2 2
3 3 3 4 4 4
3 3 3 4 4 4
3 3 3 4 4 4
```

```
>> padarray(A, [2 2], 'circular')
```

ans =

```
1 2 1 2 1 2
3 4 3 4 3 4
1 2 1 2 1 2
3 4 3 4 3 4
1 2 1 2 1 2
3 4 3 4 3 4
```

```
>> I = imread('Fig0335(a)(ckt_board_saltpep_prob_pt05).tif');  
>> imshow(I)  
>> h = ones(3,3)/9
```

h =

```
0.1111 0.1111 0.1111  
0.1111 0.1111 0.1111  
0.1111 0.1111 0.1111
```

```
>> J = imfilter(I, h, 'symmetric');  
>> figure; imshowpair(I, J, 'montage');
```

