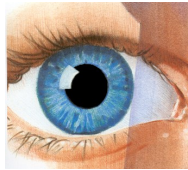


# Edge Detection in Computer Vision

Analyzing intensity changes  
in digital images



**CS332 Visual Processing**  
Department of Computer Science  
Wellesley College

## Detecting image intensity changes

The screenshot shows two windows from an image processing application. The main window, titled "Image Tool 1 - coins", displays a collection of coins on a dark background. A small white box highlights a specific coin. The status bar at the bottom of this window shows "Pixel info: (285, 183) 73" and "Display range: [0 255]".

The "Pixel Region (Image Tool 1)" window is overlaid on the main window, showing a grid of pixel intensity values. The grid is 10 columns wide and 10 rows high. The status bar at the bottom of this window shows "Pixel info: (230, 147) 73".

73	74	76	76	73	74	74	73	74	73		
74	73	72	72	72	71	72	72	70	71	72	73
81	85	90	96	97	98	97	93	86	81	76	73
138	147	154	160	160	160	163	165	159	151	138	121
158	153	150	147	146	146	146	147	149	154	168	183
191	203	209	214	219	219	216	206	197	185	176	174
255	255	255	252	244	237	240	246	244	240	235	231
255	255	241	211	185	174	169	176	184	190	198	215
220	196	170	162	163	156	146	142	140	137	134	142
153	158	158	159	161	162	163	169	170	178	167	154
170	166	163	168	177	180	188	197	201	197	188	185

1-2

## Detecting intensity changes

### Smooth the image intensities

- reduces effect of noise
- sets resolution or scale of analysis

### Differentiate the smoothed intensities

- transforms image into a representation that facilitates detection of intensity changes

### Detect and describe features in the transformed image

(e.g. peaks or zero-crossings)

1-3

## Smoothing the image intensity

intensity



smoothing

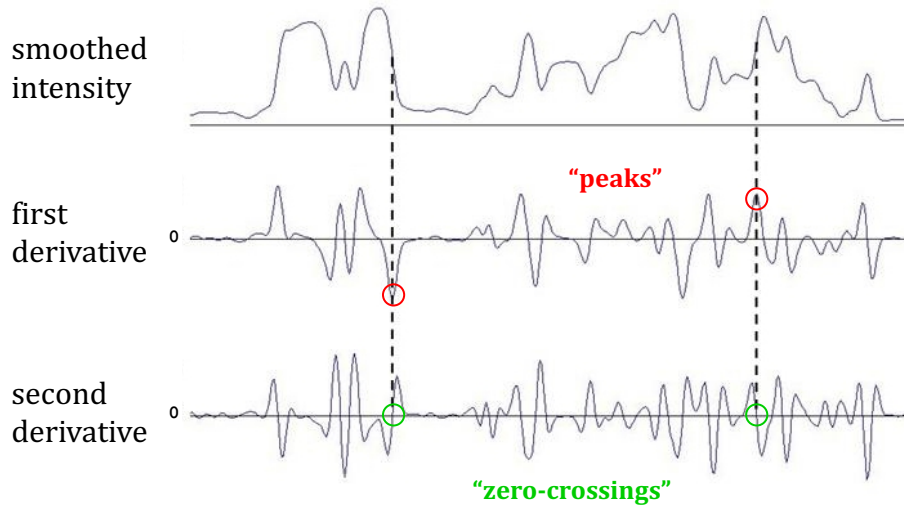


more  
smoothing



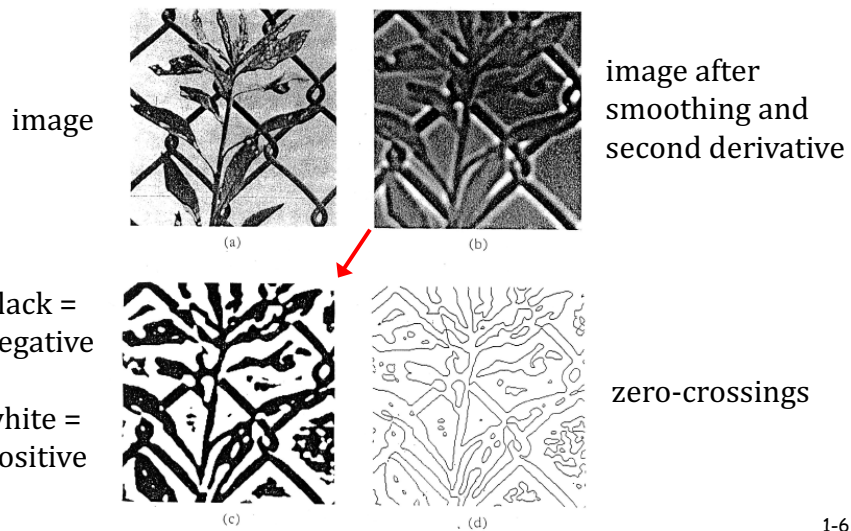
1-4

## Derivatives of the smoothed intensity



1-5

## Analyzing a 2D image



1-6

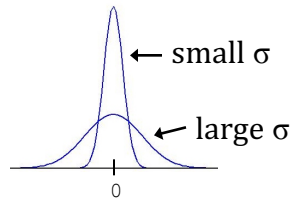
## Smoothing the image intensities

**Strategy 1:** compute the *average* intensity in a neighborhood around each image position

**Strategy 2:** compute a *weighted average* of the intensity values in a neighborhood around each image position

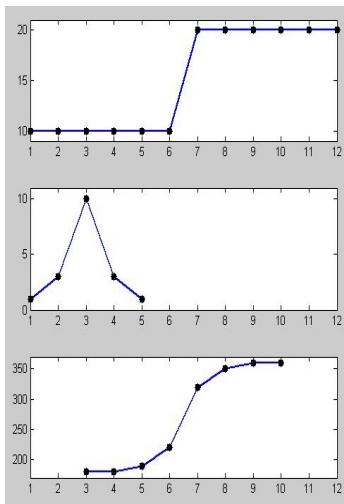
- use a smooth function that weighs nearby intensities more heavily
- *Gaussian function* works well -- in one dimension:

$$G(x) = \left(\frac{1}{\sigma}\right) e^{\left(\frac{-x^2}{2\sigma^2}\right)}$$



1-7

## Convolution in one dimension



1	3	10	3	1	10	10	10	10	10	20	20	20	20	20	20
---	---	----	---	---	----	----	----	----	----	----	----	----	----	----	----

↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑  
intensity  
I(x)

convolution operator  
G(x)

1	3	10	3	1
---	---	----	---	---

convolution result

0	0	180	180	190	220	320	350	360	360	0	0
---	---	-----	-----	-----	-----	-----	-----	-----	-----	---	---

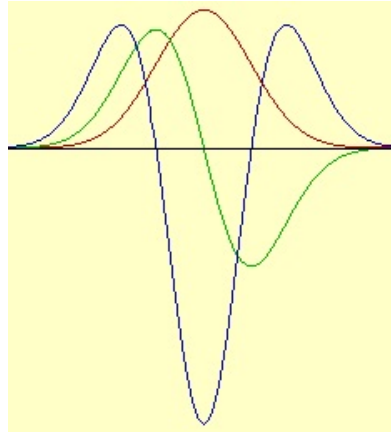
↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑  
G(x) \* I(x)

1-8

## The derivative of a convolution

$$\frac{d}{dx} (G(x) * I(x)) = \left( \frac{d}{dx} G(x) \right) * I(x)$$

$$\frac{d}{dx} \left( \frac{d}{dx} G(x) * I(x) \right) = \left( \frac{d^2}{dx^2} G(x) \right) * I(x)$$



1-9

## Convolution in two dimensions

1	3	1
3	8	3
1	3	1

2D  
convolution  
operator

\*

1	1	1	8	8	8
1	3	1	8	8	8
1	3	1	8	8	8
1	1	1	8	8	8
1	1	1	8	8	8
1	1	1	8	8	8

image

=

convolution result

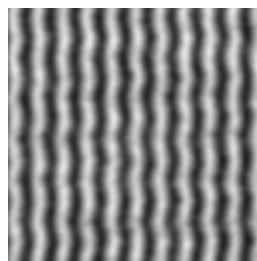
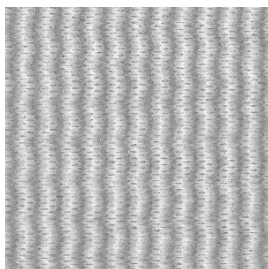
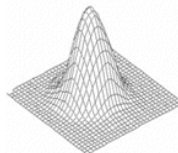
	24				

1-10

## Smoothing a 2D image

To smooth a 2D image  $I(x,y)$ , we convolve with a 2D Gaussian:

$$G(x,y) = \left( \frac{1}{\sigma^2} \right) e^{\left( \frac{-(x^2+y^2)}{2\sigma^2} \right)}$$



result of  
convolution

$$G(x,y) * I(x,y)$$

image

1-11

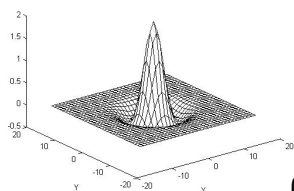
## Differentiation in 2D

To differentiate the smoothed image, we will use the *Laplacian* operator:

$$\nabla^2 = \left( \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \right)$$

We can again combine the smoothing and derivative operations:

$$\nabla^2 [G(x,y) * I(x,y)] = [\nabla^2 G(x,y)] * I(x,y)$$

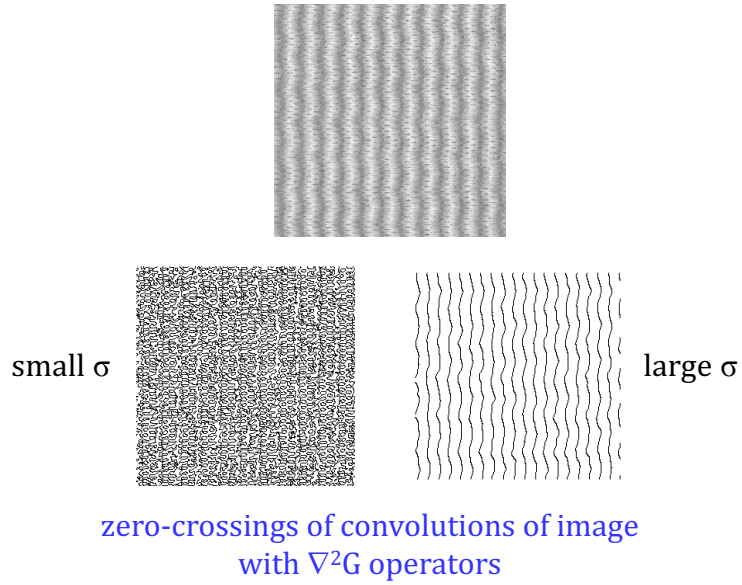


$$\nabla^2 G = \frac{1}{\sigma^2} \left( \frac{r^2}{\sigma^2} - 2 \right) e^{-\frac{r^2}{2\sigma^2}} \quad r^2 = x^2 + y^2$$

(displayed with sign reversed)

1-12

## Detecting intensity changes at multiple scales



1-13

## Computing the contrast of intensity changes



$$L = [\nabla^2 G(x,y)] * I(x,y)$$



$$slope = \sqrt{\left(\frac{\partial L}{\partial x}\right)^2 + \left(\frac{\partial L}{\partial y}\right)^2}$$

1-14

Image

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	10	10	10	0	0	0
0	0	0	10	10	10	10	0	0	0
0	0	10	10	10	10	10	10	0	0
0	0	10	10	10	10	10	10	0	0
0	0	0	10	10	10	10	0	0	0
0	0	0	0	10	10	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Convolution operator

0	1	0
1	-4	1
0	1	0

Laplacian

0	0	0	0	0	0	0	0	0	0
0	0	0	0	10	10	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	10	0	0	0	0	0	0	10	0
0	10	0	0	0	0	0	0	10	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	10	10	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Convolution result