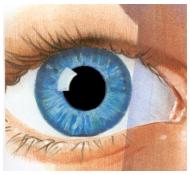
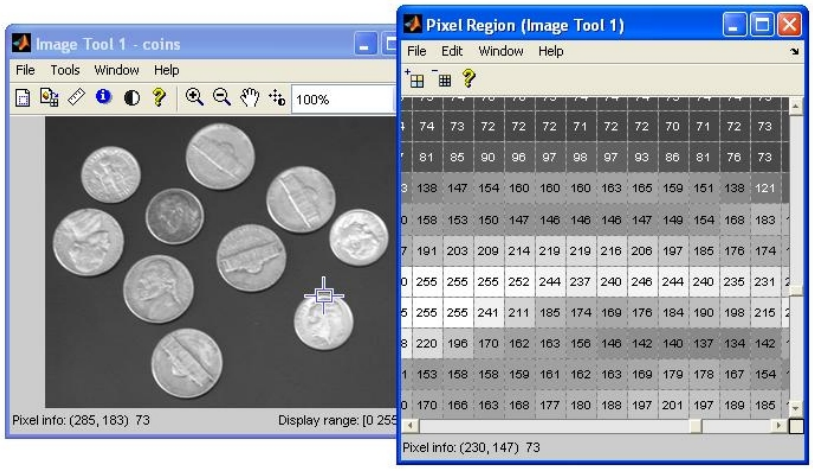
Edge Detection in Computer Vision

Analyzing intensity changes
in digital images



CS332 Visual Processing
Department of Computer Science
Wellesley College

Detecting image intensity changes



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)

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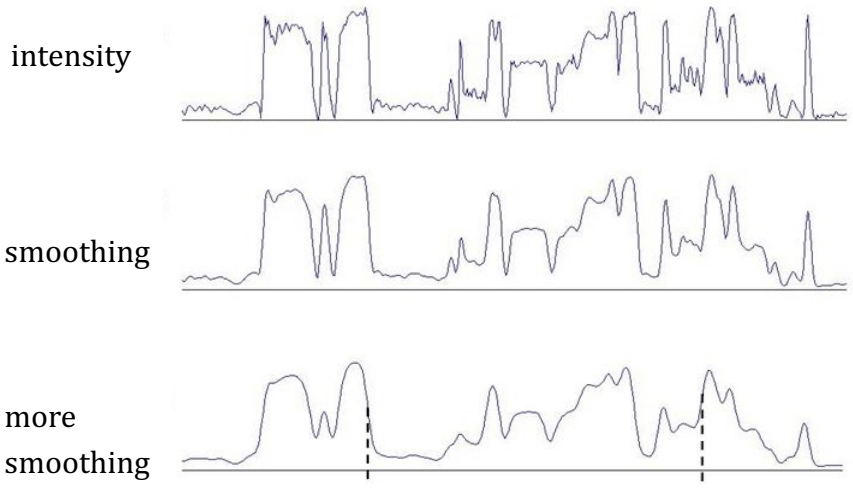
Smoothing the image intensity



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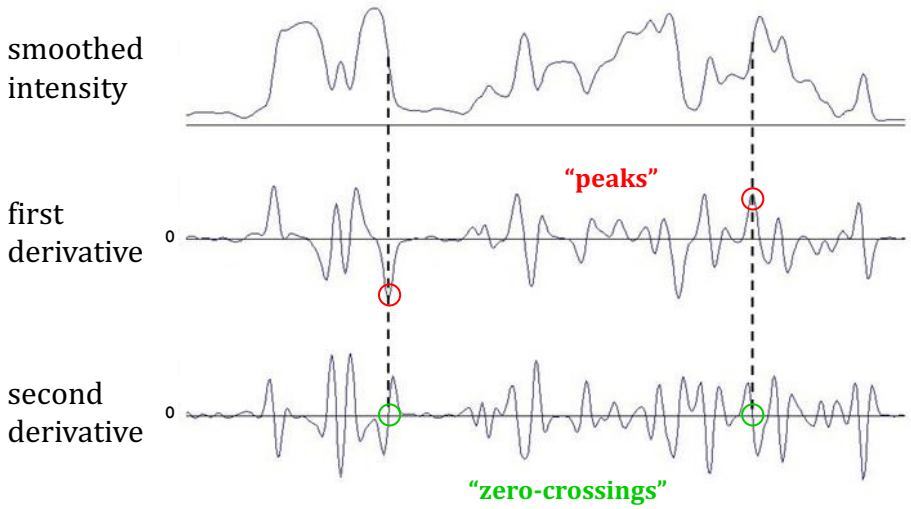
Derivatives of the smoothed intensity



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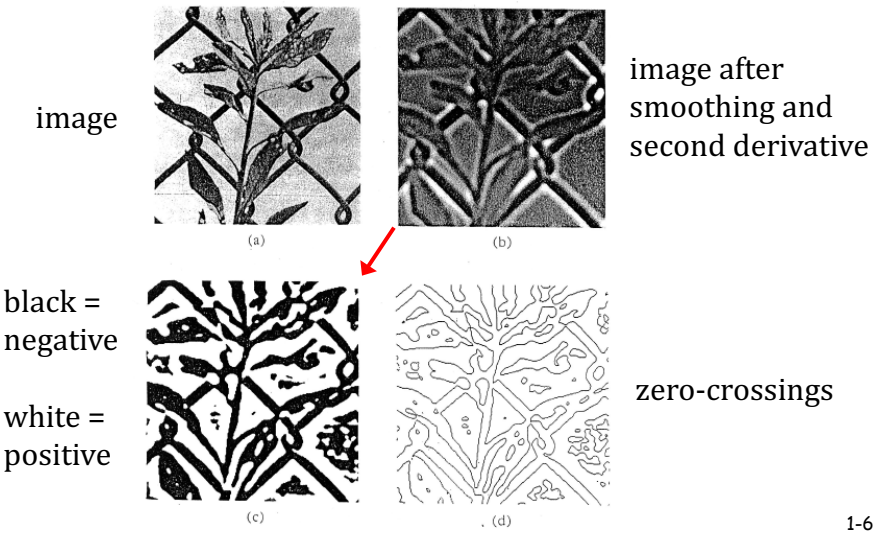
Analyzing a 2D image



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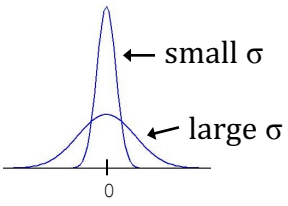
Smoothing the image intensities

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:

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



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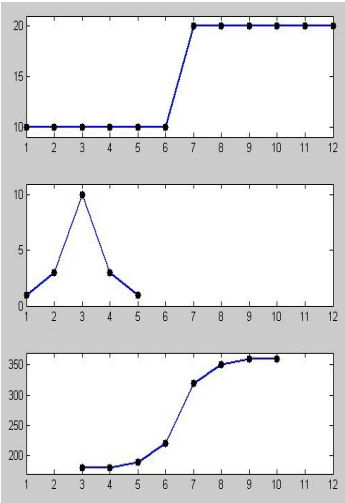
Convolution in one dimension



1	3	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)

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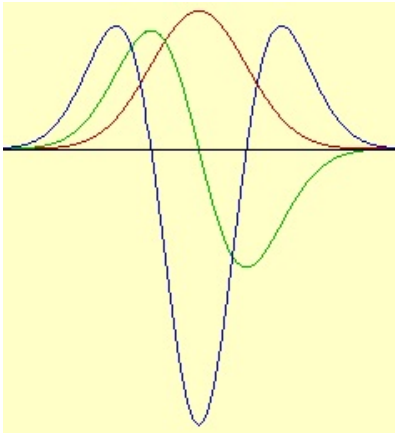
The derivative of a convolution

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

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



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Convolution in two dimensions

1	3	1
3	8	3
1	3	1

2D convolution operator

*

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

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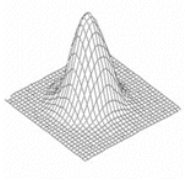
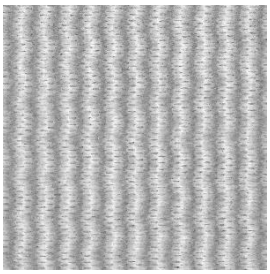
Smoothing a 2D image

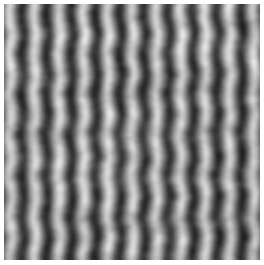
To smooth a 2D image *I(x,y)*, we convolve with a 2D Gaussian:

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





image



result of convolution

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

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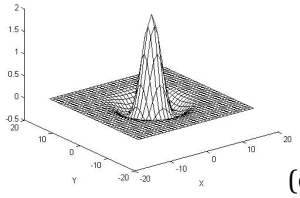
Differentiation in 2D

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:

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



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

(displayed with sign reversed)

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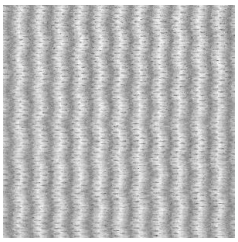
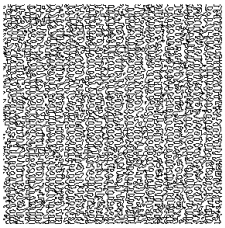
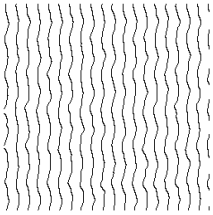
Detecting intensity changes at multiple scales



small σ   large σ

zero-crossings of convolutions of image
with $\nabla^2 G$ operators

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Computing the contrast of intensity changes

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

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

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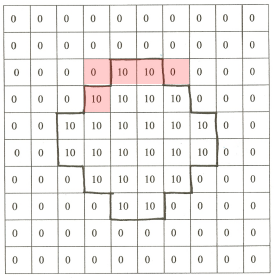
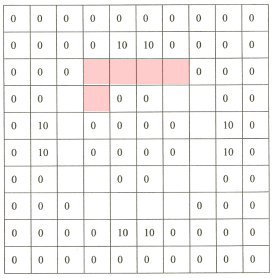
Image



Convolution operator

0	1	0
1	-4	1
0	1	0

Laplacian



Convolution result

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