Edge Detection

Edge Detection

- Edge = a point in the image where intensities are changing rapidly
- We have looked at the Sobel edge operator
  - Does digital approximation to first derivative
  - Then take magnitude of the gradient

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

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

$\frac{\partial}{\partial y}$

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

Sobel operators

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

- But this does not *identify* edge points … it simply gives a gradient magnitude at each pixel

Sobel Edge Detector Example

Original image "pout.tif"

Gradient magnitude, using Sobel masks

Threshold Edge Operator Results

- We can threshold edge magnitudes, to produce binary image

Low threshold

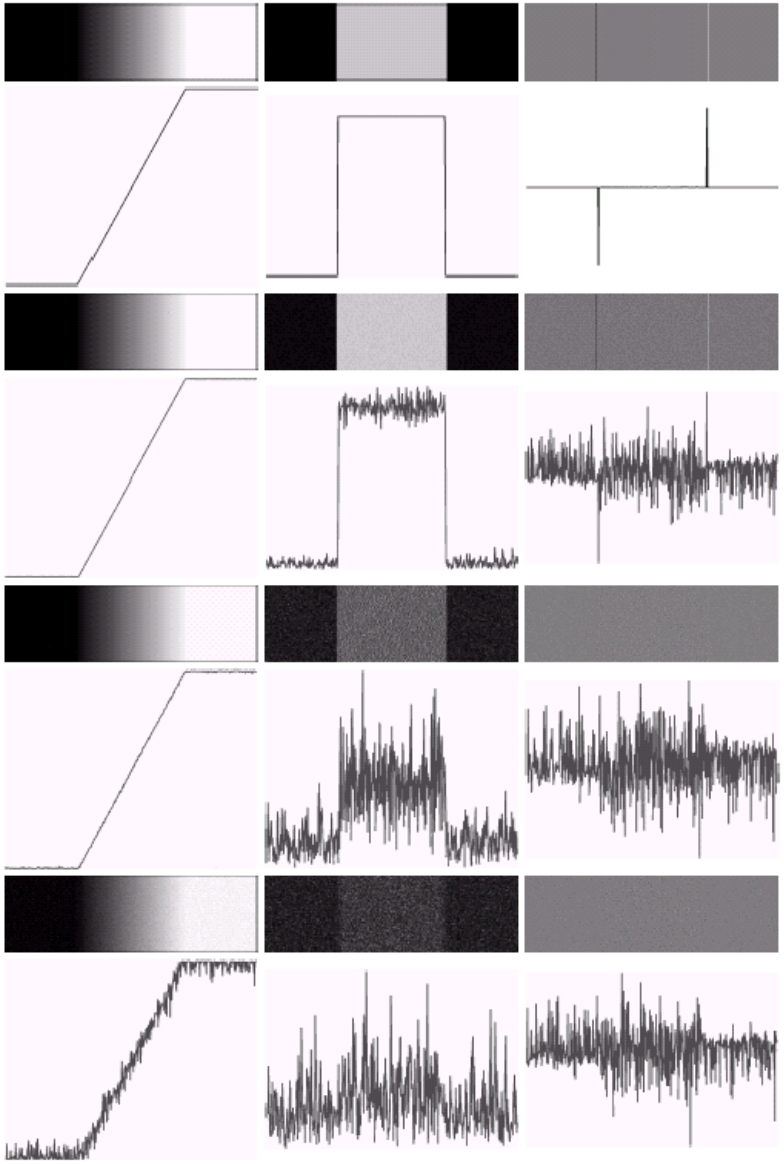
High threshold

Non-maxima suppression

- Problem – only want one response to an edge
- Solution – We take the point that is the local maximum of the gradient magnitude (in the direction of the gradient)

Derivatives amplify noise

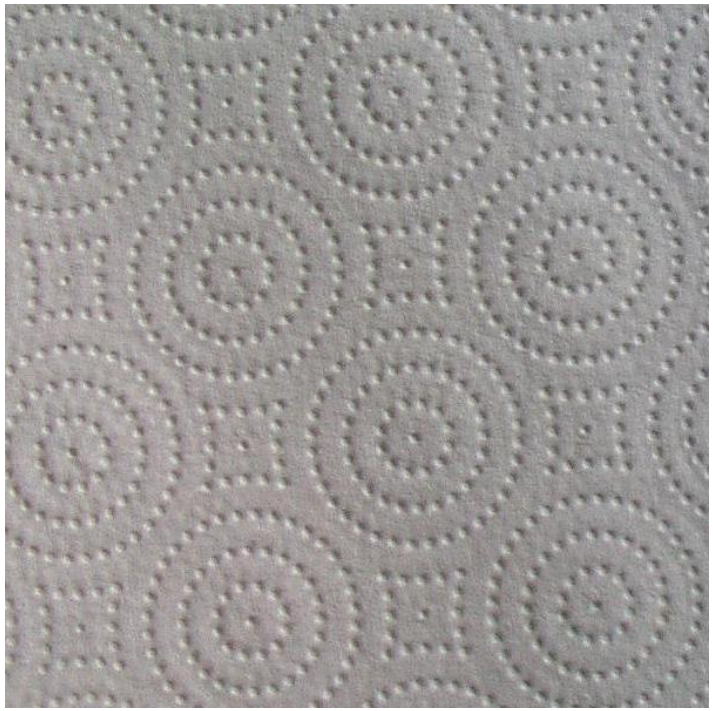
First and second derivatives of noisy ramp edge



- Even a small amount of noise greatly affects the output
- Need to smooth the image before taking derivatives

Scale Space Edge Operators

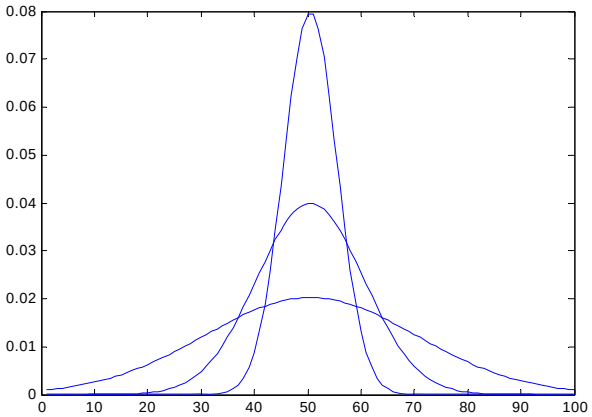
- Intensity changes occur at different scales in an image – we need operators of different sizes to detect them



Scale-Space

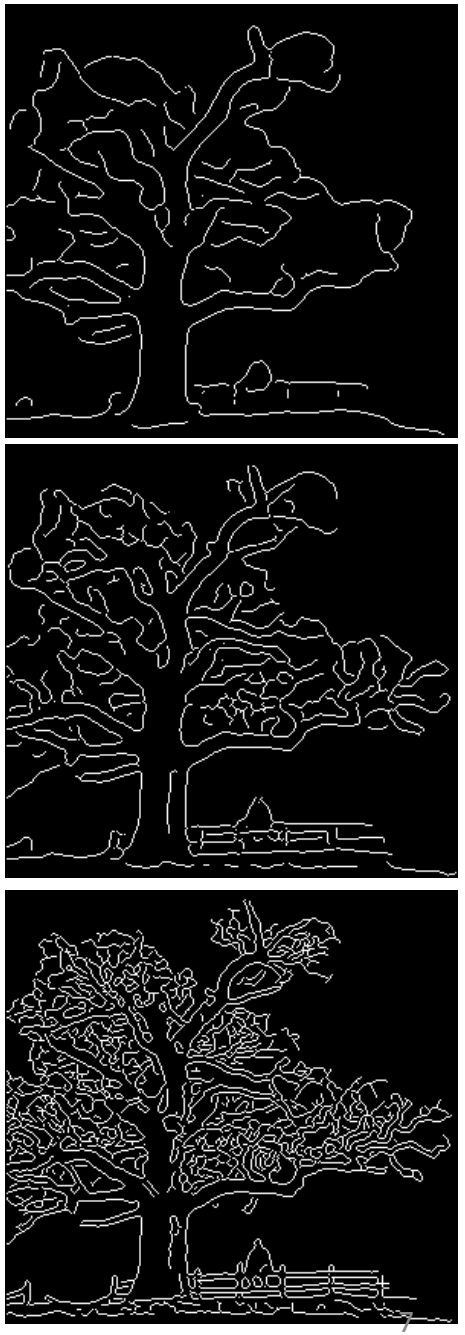
- The space of images created by applying a series of operators of different scales
- Gaussians of different sizes can be used to filter the image at different scales

$$G_\sigma(x, y) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/(2\sigma^2)}$$



- Convolving with a Gaussian blurs the image, wiping out all structure much smaller than σ

Increasing σ



Derivative of Gaussian

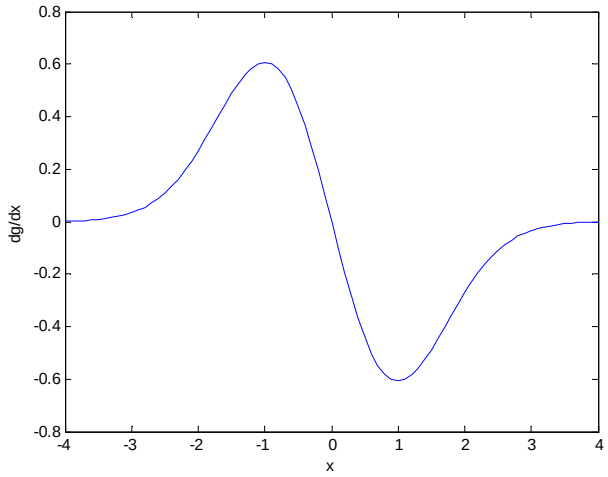
- The gradient of the smoothed image is

$$\nabla\left[G_\sigma * I\right] = \left[\nabla G_\sigma\right] * I$$

- The gradient operators are

$$\nabla G_\sigma = \begin{pmatrix} \frac{\partial G_\sigma}{\partial x} & \frac{\partial G_\sigma}{\partial y} \end{pmatrix}^T$$

$$= \begin{pmatrix} -x & -y \end{pmatrix} \frac{1}{\sigma^3} \exp\left(-\frac{x^2 + y^2}{2\sigma^2} \right)$$



- An edge point is a peak in the gradient magnitude, in the direction of the gradient

Canny Edge Operator

- We can derive the optimal edge operator to find step edges in the presence of white noise, where "optimal" means
  - Good detection (minimize the probability of detecting false edges and missing real edges)
  - Good localization (detected edges must be close to the true edges)
  - Single response (return only one point for each true edge point)

- Canny found that a very good approximation to the optimal operator is the first derivative of a Gaussian, in the direction of the gradient
  - Then suppress nonmaxima along this direction

- Algorithm:
  - Convolve image with derivative of Gaussian operators (dG/dx, (dG/dy)
  - Find the gradient direction at each pixel; quantize into one of four directions (north-south, east-west, northeast-southwest, northwest-southeast)
  - If magnitude of gradient is larger than the two neighbors along this direction, it is a candidate edge point

Edge Linking

- We want to join edge points into connected curves or lines
  - This facilitates object recognition
- Problem:
  - Some edge points along the curve may be weak, causing us to miss them
  - This would result in a broken curve
- Solution:
  - We use a high threshold to make sure we capture true edge points
  - Given these detected points, link additional edge points into contours using a lower threshold ("hysteresis")

- Algorithm
  - Find all edge points greater than t_{high}
  - From each strong edge point, follow the chains of connected edge points in both directions perpendicular to the edge normal
  - Mark all points greater than t_{low}

Matlab

- `[E,thresh]=edge(I, 'canny', thresh, sigma);`
  - thresh is [tLow tHigh]
  - sigma is std deviation of Gaussian

Image "house.jpg"

- Try
  - Varying sigma

```
for s = 0.5:0.5:5
    s
    E = edge(I, 'canny', [], s);
    imshow(E);
    pause;
end
```

  - Varying thresholds

```
for tHigh = 0.05:0.05:0.4
    tHigh
    E = edge(I, 'canny', [0.4*tHigh tHigh], 1.5);
    imshow(E);
    pause;
end
```

  - See effect of using only one threshold
    - Let thresh = [tLow tLow] – picks up too many edges
    - Let thresh = [tHigh tHigh] – misses too many edges