Edge Detection

Winter in Kraków photographed by Marcin Ryczek

CS194: Image Manipulation, Comp. Vision, and Comp. Photo
Alexei Efros, UC Berkeley, Spring 2020

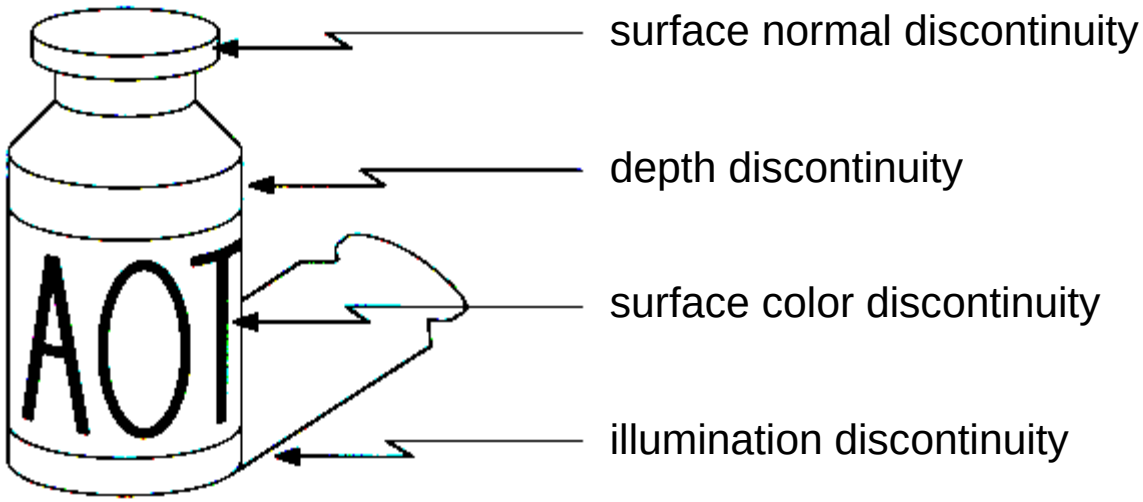
Edge detection

- **Goal:** Identify sudden changes (discontinuities) in an image
  - Intuitively, most semantic and shape information from the image can be encoded in the edges
  - More compact than pixels
- **Ideal:** artist's line drawing (but artist is also using object-level knowledge)

Source: D. Lowe

Origin of edges

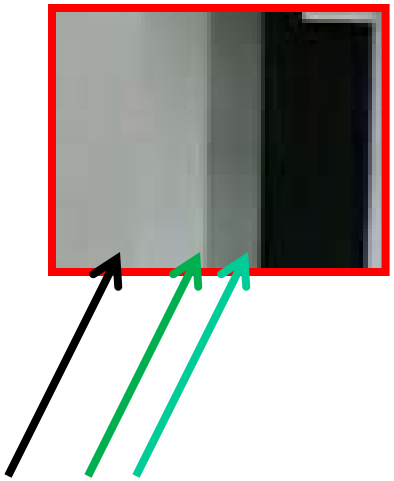
Edges are caused by a variety of factors:



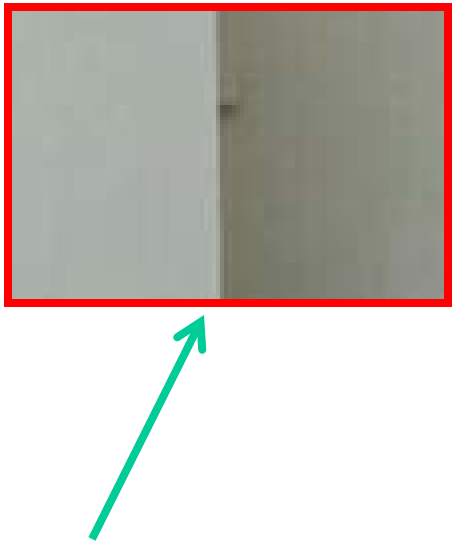
Source: Steve Seitz

Closeup of edges

Closeup of edges



Closeup of edges

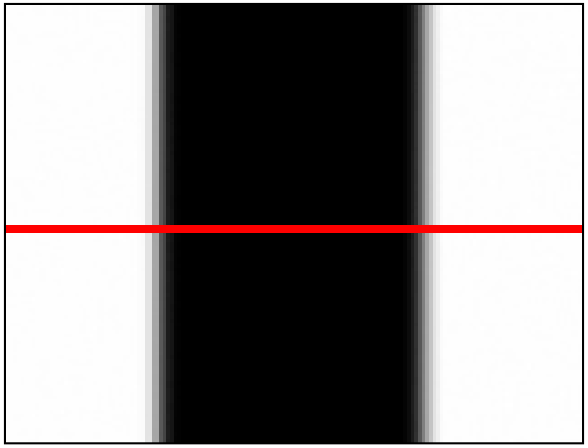


Closeup of edges

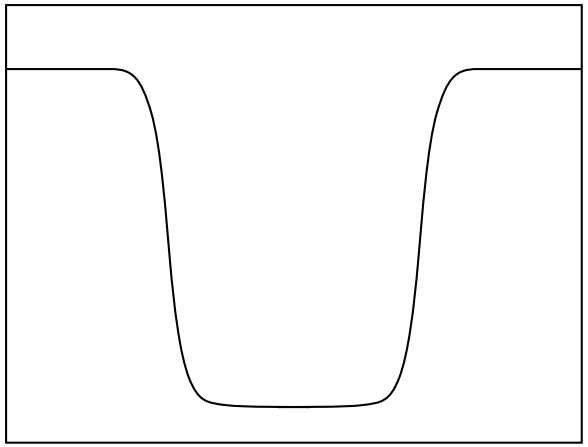
Characterizing edges

- An edge is a place of rapid change in the image intensity function

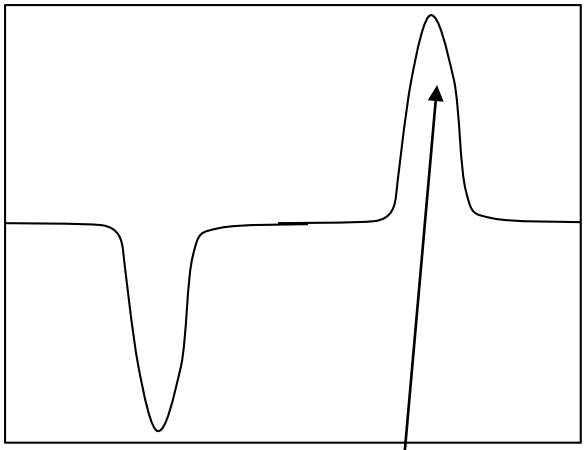
image



intensity function
(along horizontal scanline)



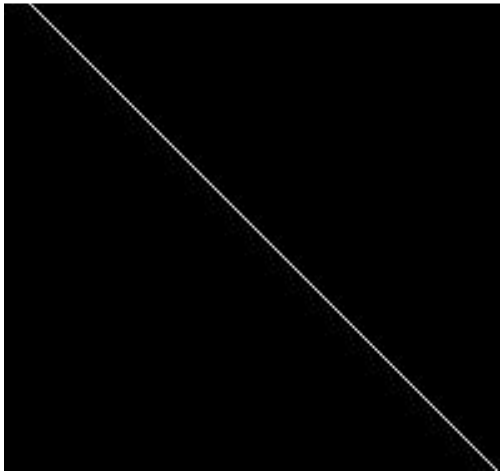
first derivative



edges correspond to
extrema of derivative

There is ALWAYS a tradeoff between smoothing and good edge localization!

Image with Edge



Edge Location

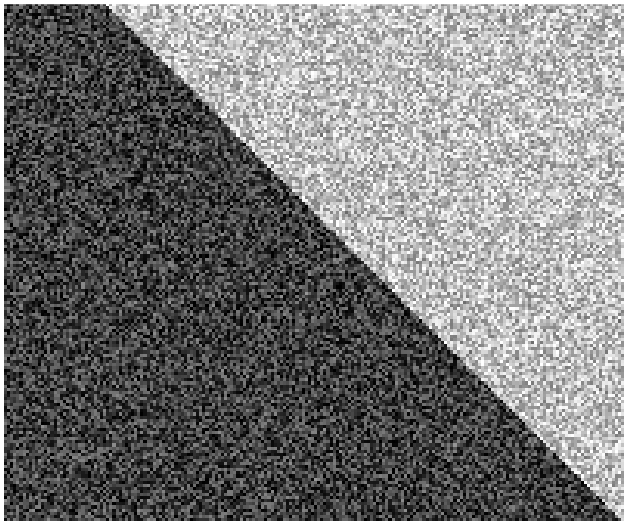
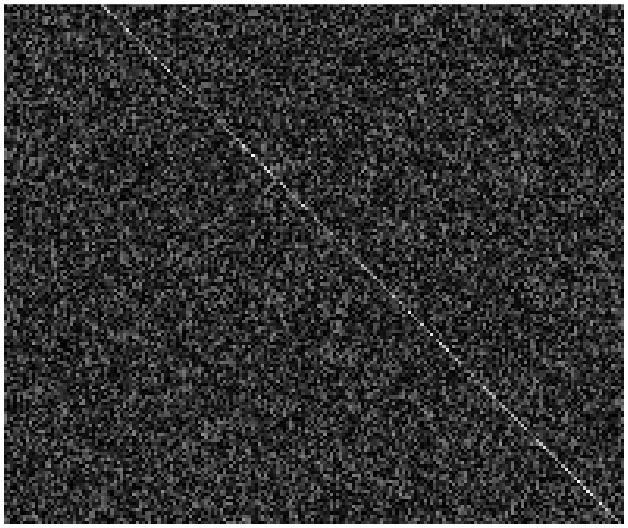
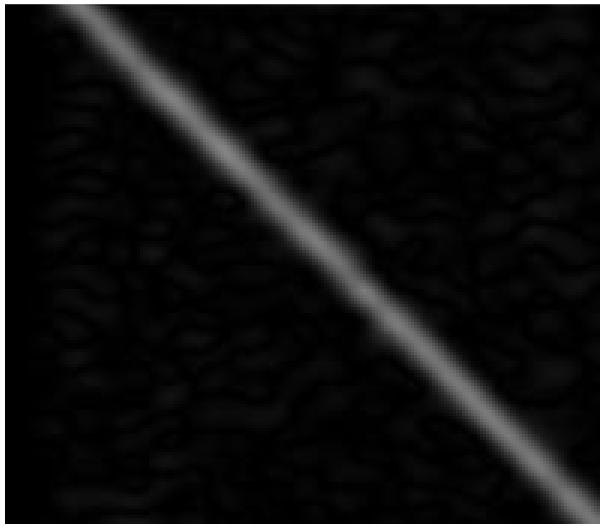


Image + Noise



Derivatives detect edge *and* noise



Smoothed derivative removes noise, but blurs edge

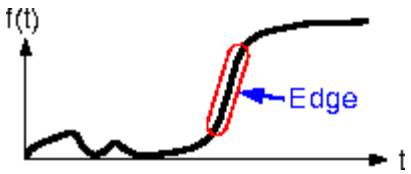
The Canny edge detector

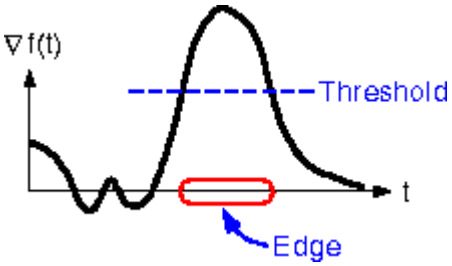
norm of the gradient

The Canny edge detector

thresholding

The Canny edge detector

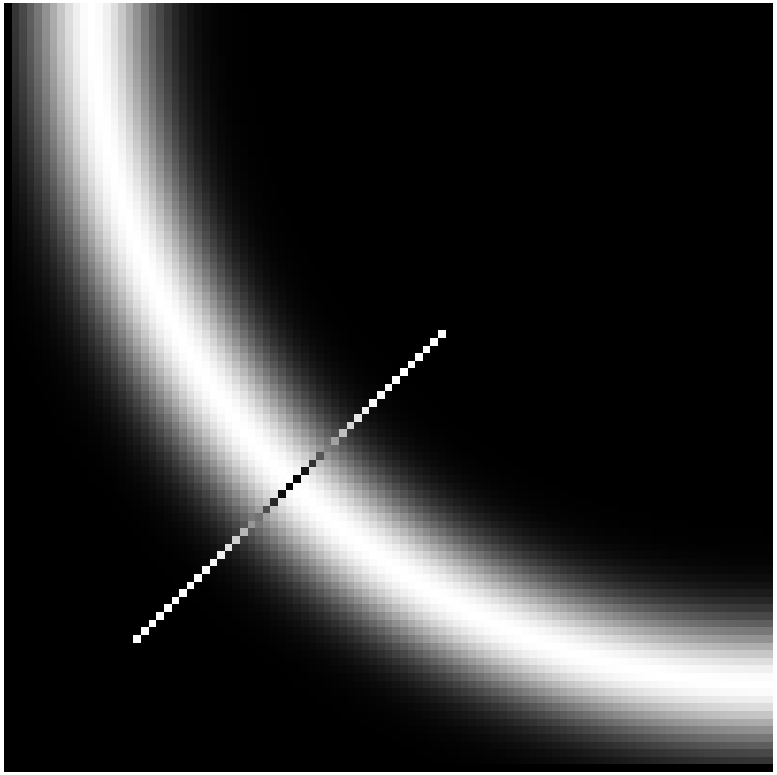




How to turn these thick regions of the gradient into curves?

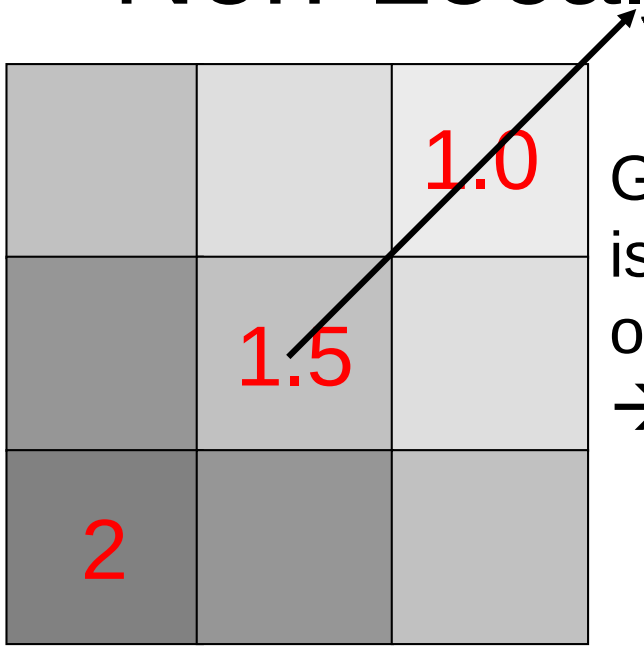
thresholding

Non-maximum suppression

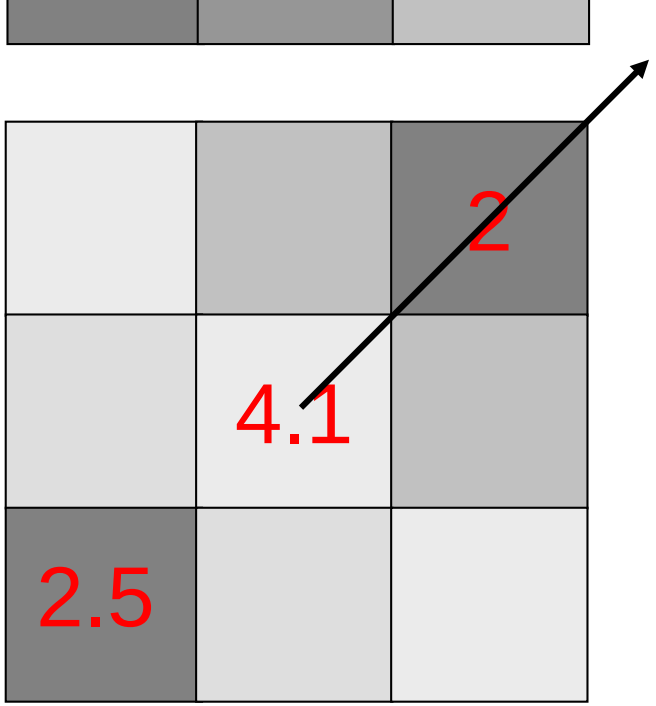


Check if pixel is local maximum along gradient direction, select single max across width of the edge

Non-Local Maxima Suppression

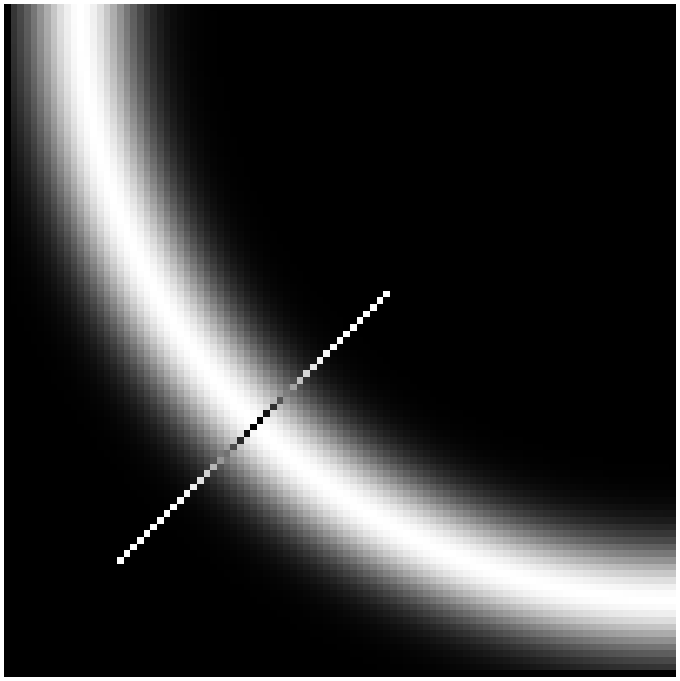


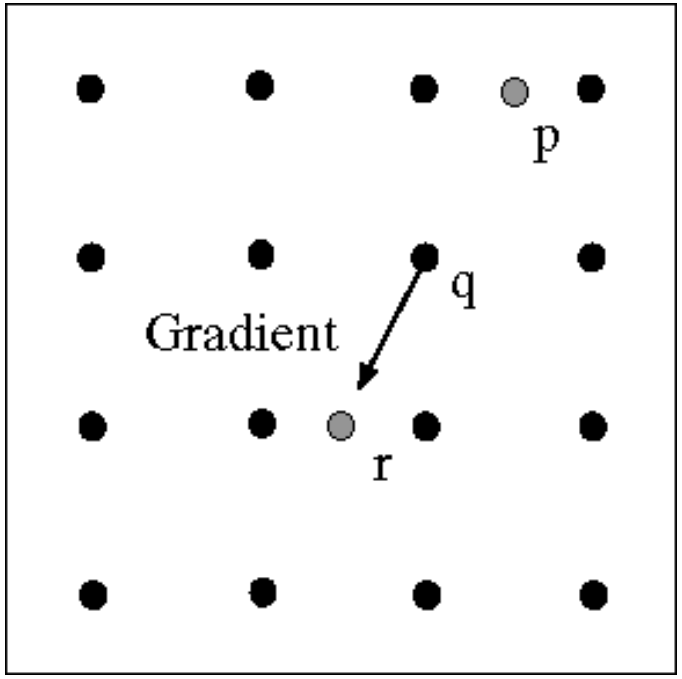
Gradient magnitude at center pixel is lower than the gradient magnitude of a neighbor *in the direction of the gradient*
→ Discard center pixel (set magnitude to 0)



Gradient magnitude at center pixel is greater than gradient magnitude of all the neighbors *in the direction of the gradient*
→ Keep center pixel unchanged

Non-maximum suppression





requires checking interpolated pixels p and r

The Canny edge detector

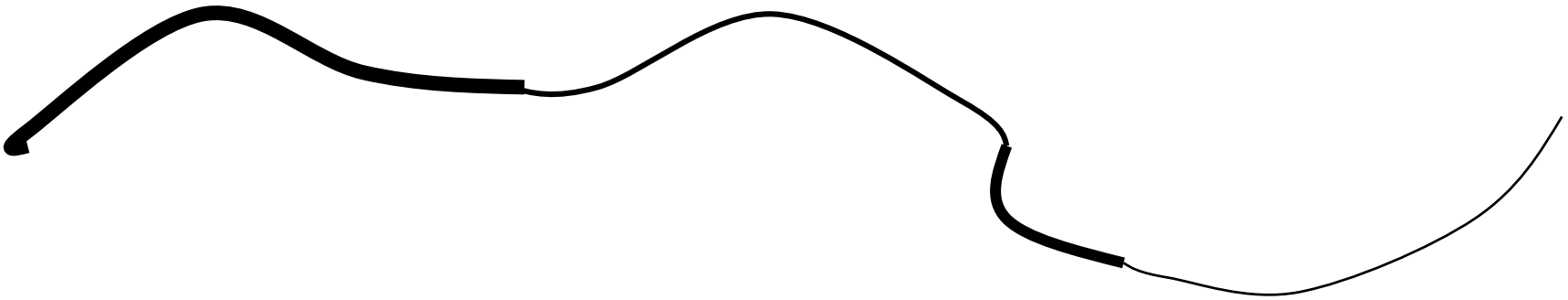
Problem: pixels along this edge didn't survive the thresholding

thinning

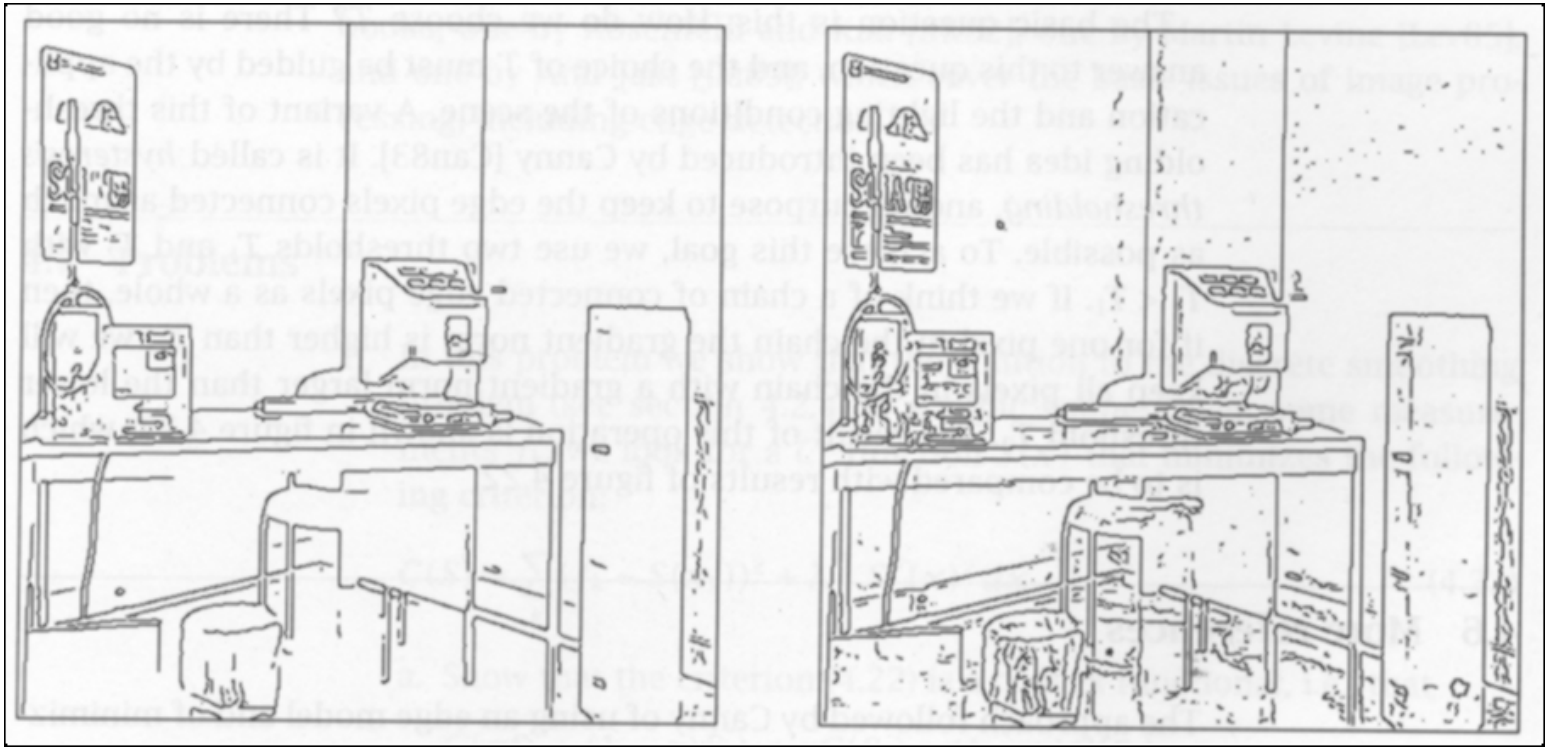
(non-maximum suppression)

Hysteresis thresholding

Use a high threshold to start edge curves, and a low threshold to continue them.



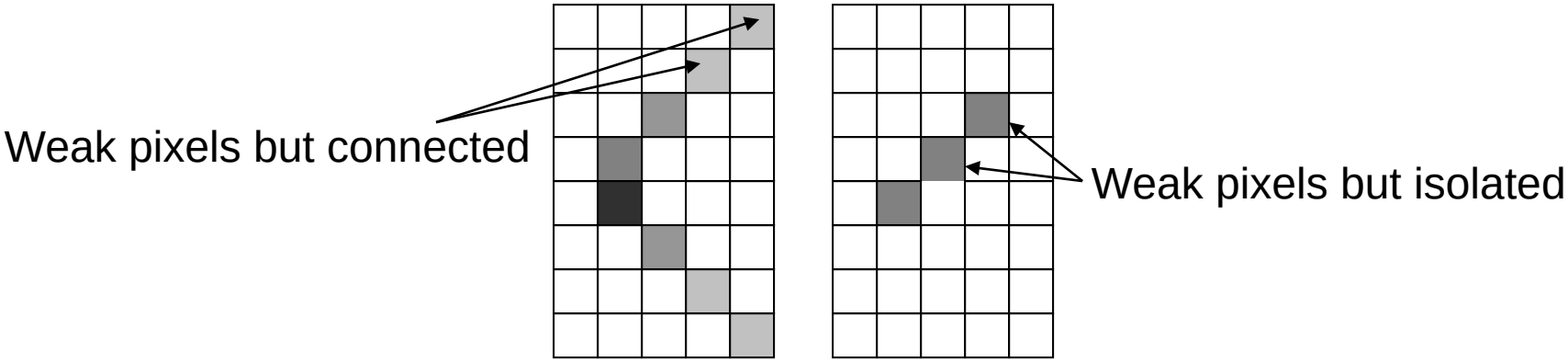
Source: Steve Seitz

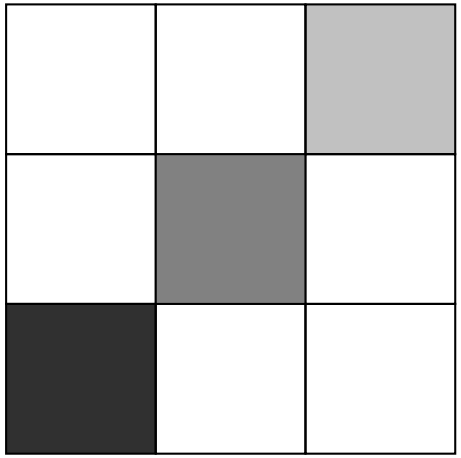


T = 15 T = 5

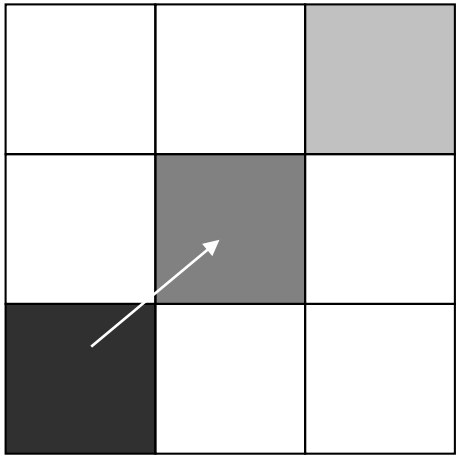
Two thresholds applied to gradient magnitude

Hysteresis Thresholding

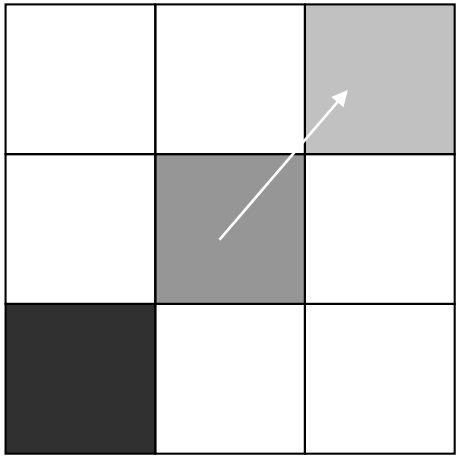




Very strong edge response.
Let's start here



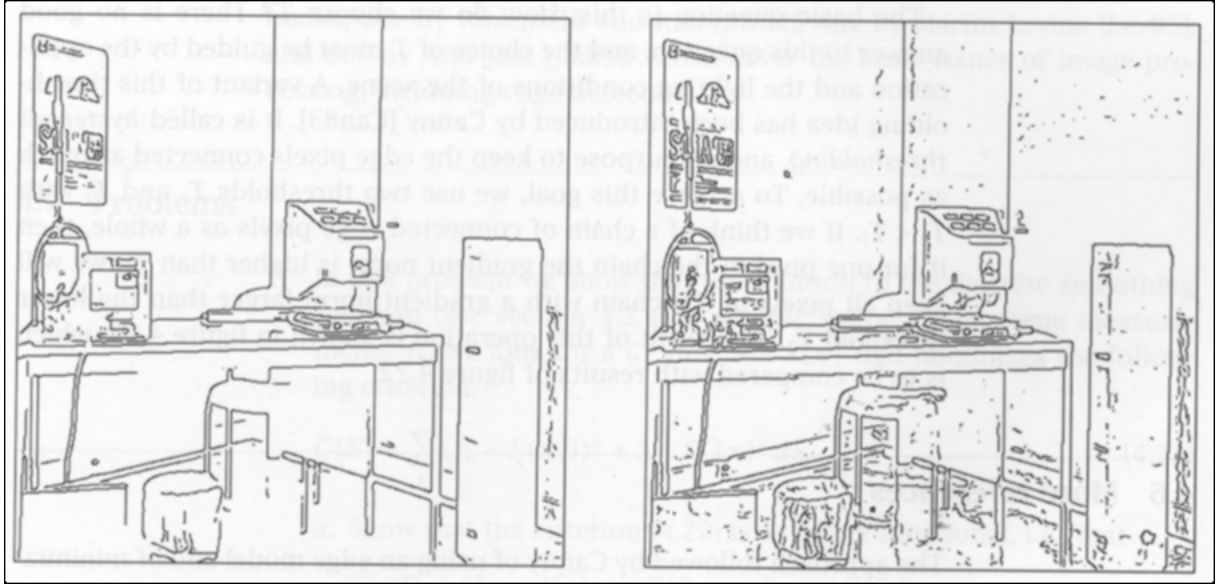
Weaker response but it is connected to a confirmed edge point. Let's keep it.



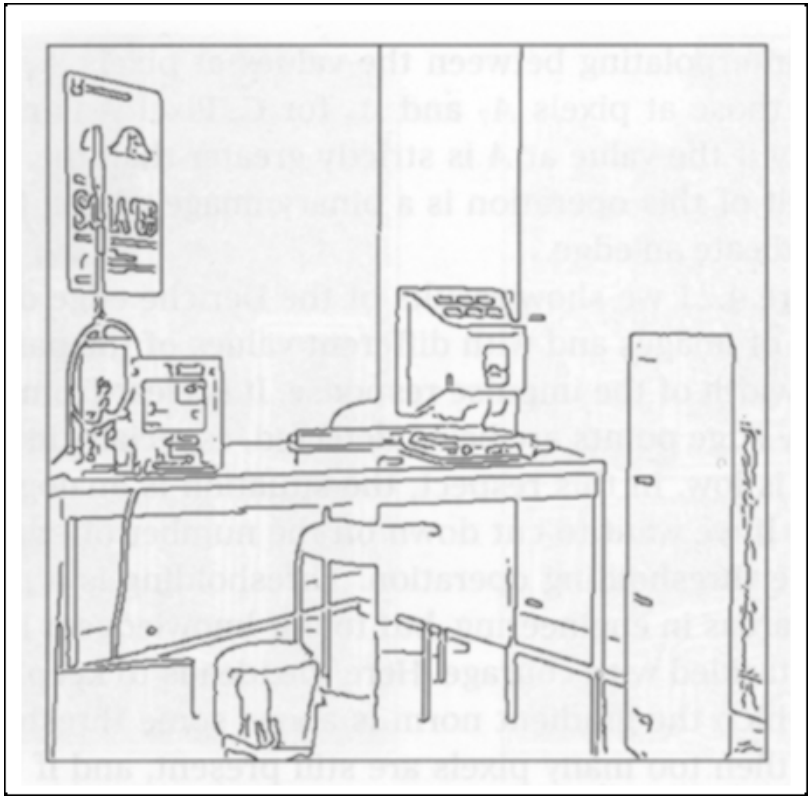
Continue….

Note: Darker squares illustrate stronger edge response (larger *M*)

T=15



T=5



Hysteresis
T_h=15 T_l = 5

Hysteresis
thresholding

Recap: Canny edge detector

1. Filter image with derivative of Gaussian
2. Find magnitude and orientation of gradient
3. **Non-maximum suppression**:
   - Thin wide “ridges” down to single pixel width
4. **Linking and thresholding** (**hysteresis**):
   - Define two thresholds: low and high
   - Use the high threshold to start edge curves and the low threshold to continue them

MATLAB: `edge(image, ‘canny’);`

J. Canny, ***A Computational Approach To Edge Detection***, IEEE Trans. Pattern Analysis and Machine Intelligence, 8:679-714, 1986.

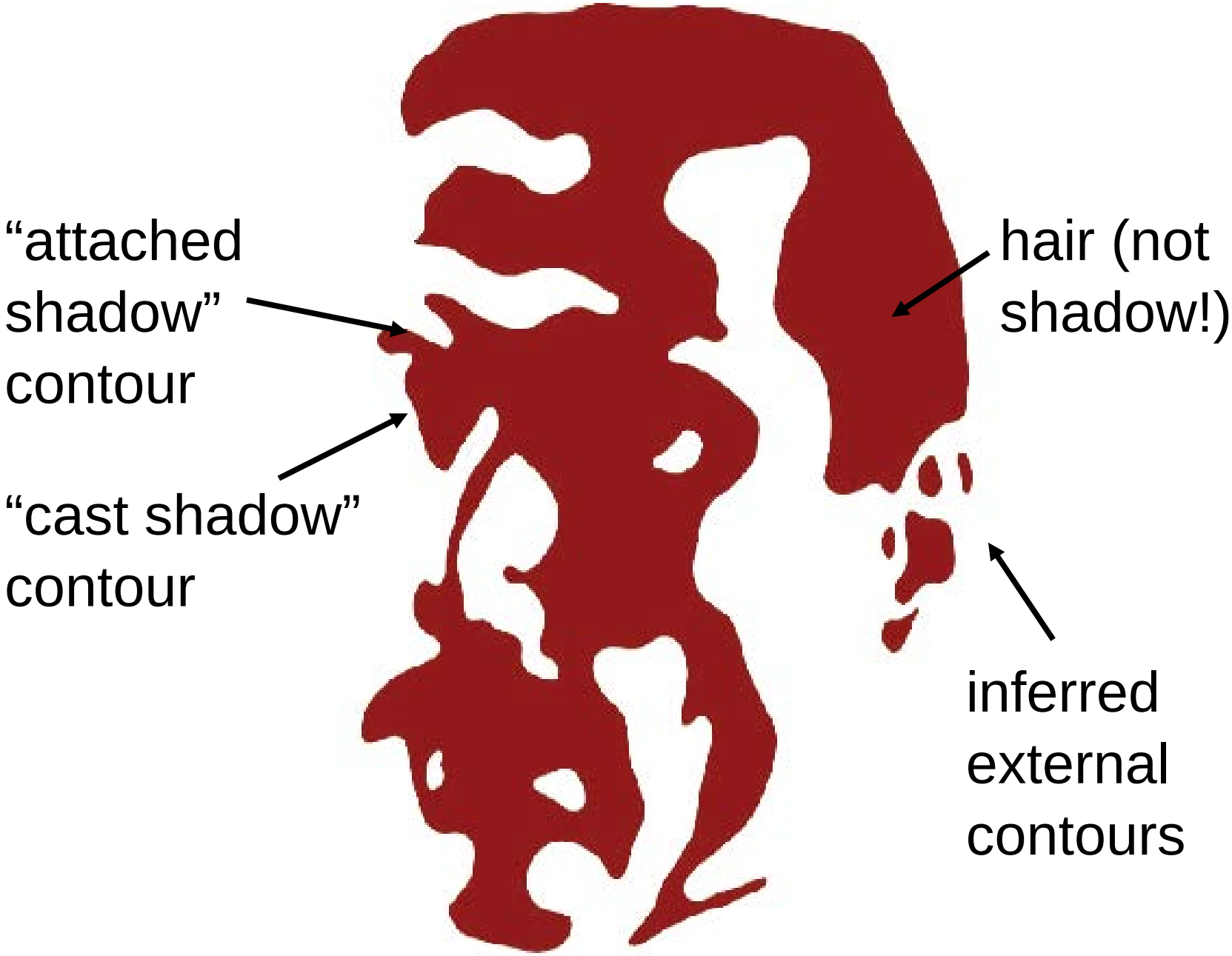
Edge detection is just the beginning…

image | human segmentation | gradient magnitude

Berkeley segmentation database:

http://www.eecs.berkeley.edu/Research/Projects/CS/vision/grouping/segbench/

two-tone images


“attached shadow” contour
“cast shadow” contour
hair (not shadow!)
inferred external contours