Edge Detection

From [Sandlot Science](#)

Today's reading
- [Cipolla & Gee on edge detection](#) (available online)

Announcements

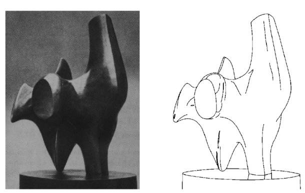
Your ID card should open Sieg 327 lab
- check to make sure ASAP

Mailing list: [cse455@cs.washington.edu](#)
- you should have received a message--if not, [signup](#)

Office hours [online](#)

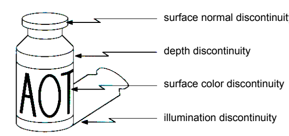
Project 1 out today (due in two weeks)
  - posted on [course web page](#)
  - help session today
- Sign up for demo (grading) session
  - online signup (see top of project1 page)
  - 10 minutes to demo/explain your project to us

Edge detection



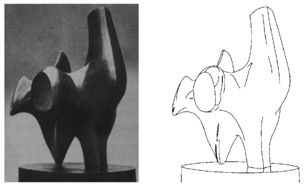
Convert a 2D image into a set of curves
- Extracts salient features of the scene
- More compact than pixels

Origin of Edges



Edges are caused by a variety of factors

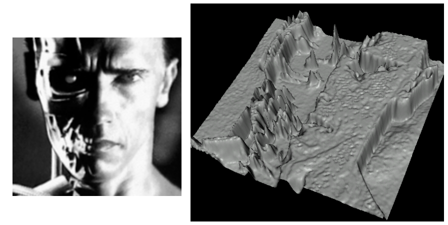
Edge detection



How can you tell that a pixel is on an edge?

snoop demo

Images as functions…

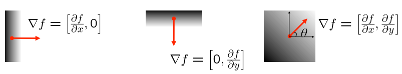


Edges look like steep cliffs

Image gradient

The gradient of an image:

$$\nabla f = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right]$$



The gradient points in the direction of most rapid increase in intensity

The gradient direction is given by:

$$\theta = \tan^{-1}\left(\frac{\partial f}{\partial y} / \frac{\partial f}{\partial x}\right)$$

- how does this relate to the direction of the edge?

The *edge strength* is given by the gradient magnitude

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

give definition of partial derivative: lim h->0 [f(x+h,y) – f(x,y)]/h

The discrete gradient

How can we differentiate a *digital* image F[x,y]?

Work out on board

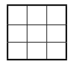
The discrete gradient

How can we differentiate a *digital* image F[x,y]?

- Option 1: reconstruct a continuous image, then take gradient
- Option 2: take discrete derivative ("finite difference")

$$\frac{\partial f}{\partial x}[x,y] \approx F[x+1,y] - F[x,y]$$

How would you implement this as a cross-correlation?



H

filter demo

The Sobel operator

Better approximations of the derivatives exist

- The *Sobel* operators below are very commonly used

$\frac{1}{8}$

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

s_x

$\frac{1}{8}$

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

s_y

- The standard defn. of the Sobel operator omits the 1/8 term
  - doesn't make a difference for edge detection
  - the 1/8 term **is** needed to get the right gradient value, however

Q: Why might these work better?

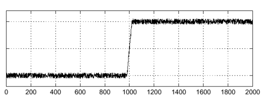
A: more stable when there is noise

Effects of noise

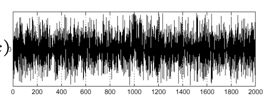
Consider a single row or column of the image

- Plotting intensity as a function of position gives a signal

$f(x)$



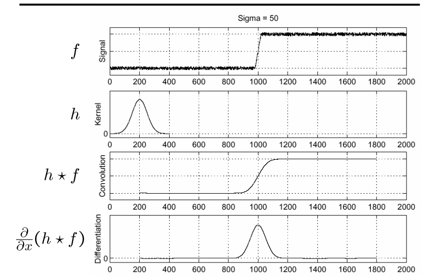
$\frac{d}{dx}f(x)$



Where is the edge?

How to fix?

Solution: smooth first

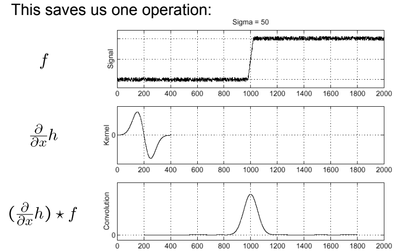


Where is the edge? Look for peaks in $\frac{\partial}{\partial x}(h \star f)$

Derivative theorem of convolution

$$\frac{\partial}{\partial x}(h \star f) = (\frac{\partial}{\partial x}h) \star f$$

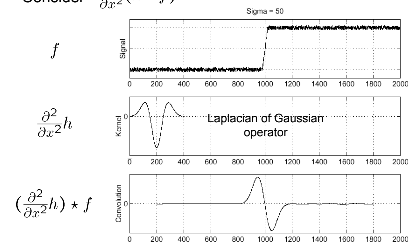
This saves us one operation:



How can we find (local) maxima of a function?

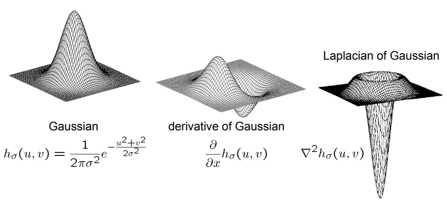
Laplacian of Gaussian

Consider $\frac{\partial^2}{\partial x^2}(h \star f)$



Where is the edge? Zero-crossings of bottom graph

2D edge detection filters



$h_\sigma(u,v) = \frac{1}{2\pi\sigma^2}e^{-\frac{u^2+v^2}{2\sigma^2}}$ $\quad \frac{\partial}{\partial x}h_\sigma(u,v)$ $\quad \nabla^2 h_\sigma(u,v)$

∇^2 is the **Laplacian** operator:

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

filter demo

How many 2nd derivative filters are there? There are four 2nd partial derivative filters.

In practice, it's handy to define a single 2nd derivative filter—the Laplacian

Edge detection by subtraction

original

Edge detection by subtraction

smoothed (5x5 Gaussian)

Edge detection by subtraction

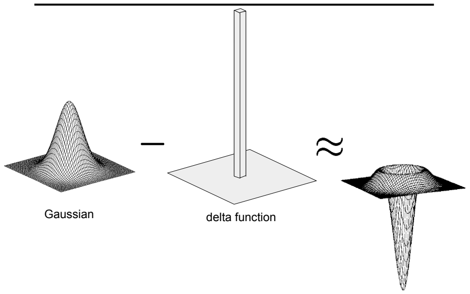
smoothed – original

(scaled by 4, offset +128)

Why does this work?

filter demo

Gaussian - image filter



Gaussian

delta function

Laplacian of Gaussian

The Canny edge detector

original image (Lena)

The Canny edge detector

norm of the gradient

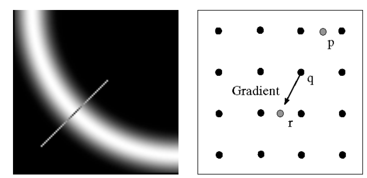
The Canny edge detector

thresholding

The Canny edge detector

thinning
(non-maximum suppression)

Non-maximum suppression



Check if pixel is local maximum along gradient direction

- requires checking interpolated pixels p and r

Effect of σ (Gaussian kernel spread/size)

original — Canny with $\sigma = 1$ — Canny with $\sigma = 2$

The choice of σ depends on desired behavior

- large σ detects large scale edges
- small σ detects fine features