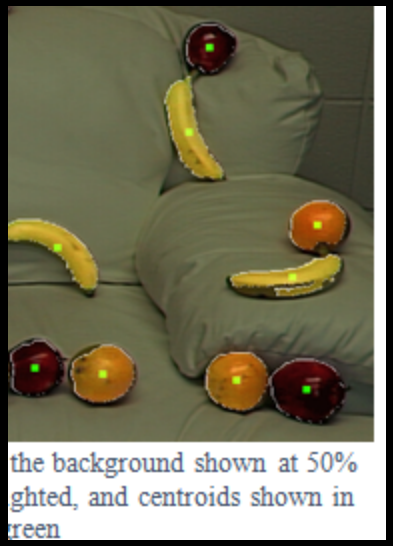
CSSE463: Image Recognition Day 6

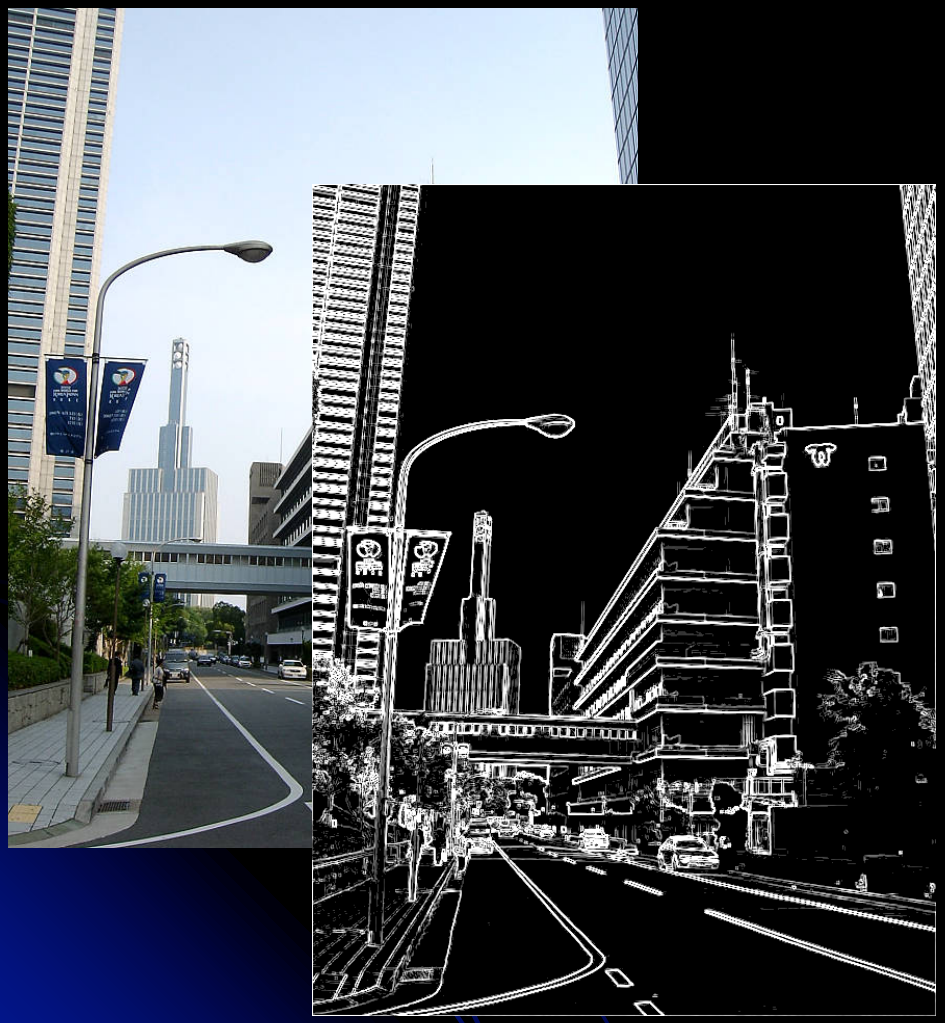
- Yesterday: Local, global, and point operators use different context, but **all**
  - operate on entire image,
  - changing one pixel at a time!!
- Lab due tomorrow
- Fruit-finder deadline **Friday**, 11:00pm
  - Please leave time for a solid write-up
  - Nice example of how to show results:
  - See rubric online for other standards
  - Questions?
- Today: edge features (another local operator)
  - Sonka 5.3



- There are 2 types of programmers in the world:
    1. Those who prefer 1-based indexing
    1. Those who prefer 0-based indexing

Thanks to 463 student John Krasich for clarifying this for us.

Edge Features – Why?

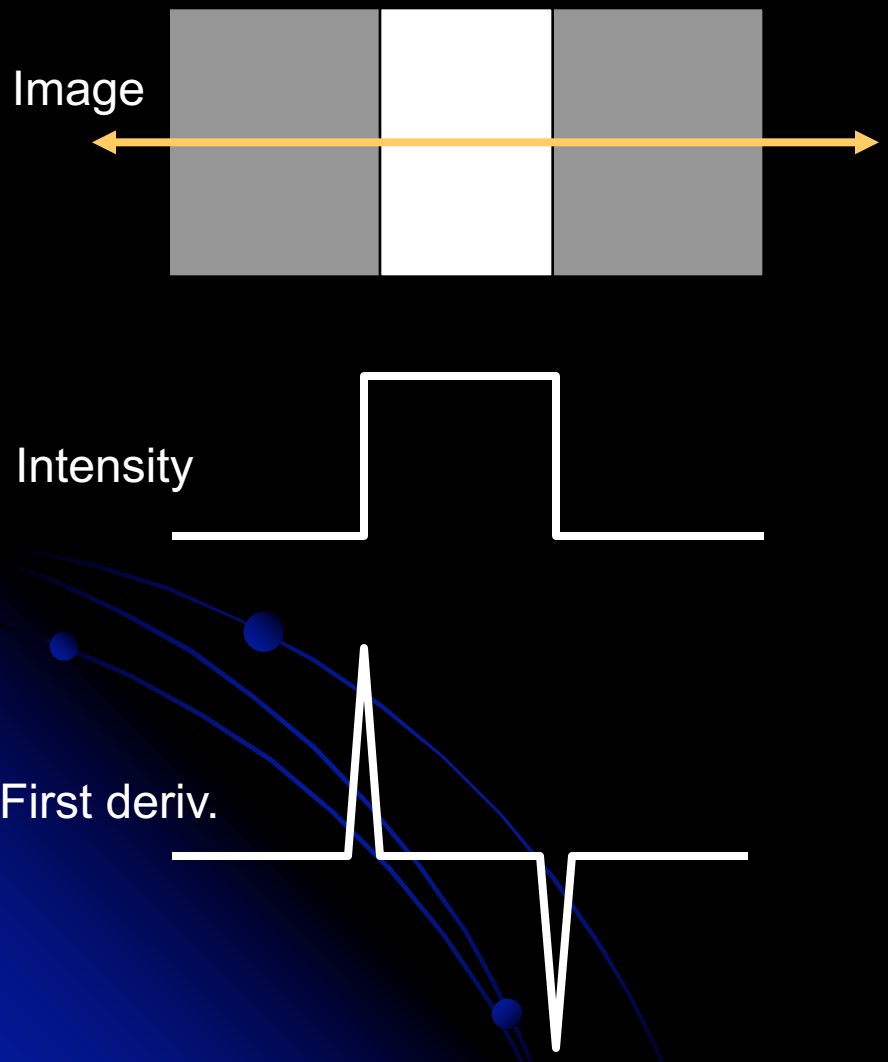


- "Edginess" (# edges) and their directions can give you info about the scene content
  - Orientation of the image
  - Natural vs. manmade images
- Edges can be used to segment the image.
  - Color information is usually used as well.
  - Specifically, boundaries occur where the chroma and/or luminance change (drastically).
- We could use to enhance the fruit-finder in a later assignment (*not* now).

Outline for next 2 sessions

- Concept: How to find “edges” in 1D signal
- Edges in 2D images
- Limitations
- Edges vs edgels, Canny edge detector

Intuition: Finding edges



- What's an edge?
- How to find changes in intensity?
- How to find first derivative?

Finding derivatives (1D)

- Let y be intensity of point at location x
- Def:

$$\frac{\partial y}{\partial x} \approx \frac{\Delta y}{\Delta x}$$

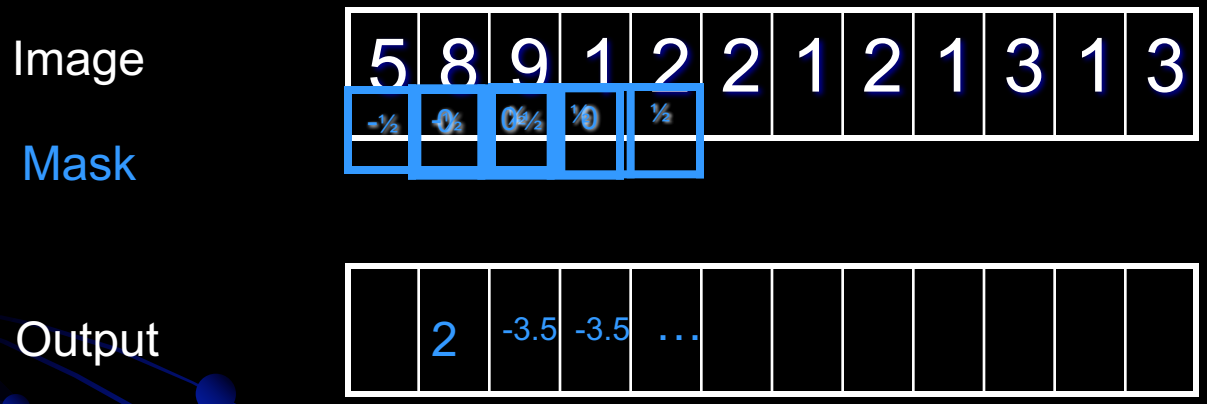
- Fix $\Delta x = 1$ pixel
- $dy/dx = y_2 - y_1$

```
f:  [0  0  0  0  0  50  50  50  50  0  0  0  0  0];
f':[  0  0  0  0  50  0   0   0  -50  0  0  0  0  ];
```

- Correlate image with filter [-1,1] to find positions of change.
  - Edges “between” pixels.
  - What is significance of magnitude of first deriv. ?

Applying Filters

- *Example for differential with* $\Delta x = 2$ pixels:
  (Better; no output "between" pixels)



- Could you do
  - *Ramps? Impulse? Step edges? (on quiz)*
- *Properties*
  - *If no contrast?*

Q1,3

Why should the values in an edge filter sum to 0?

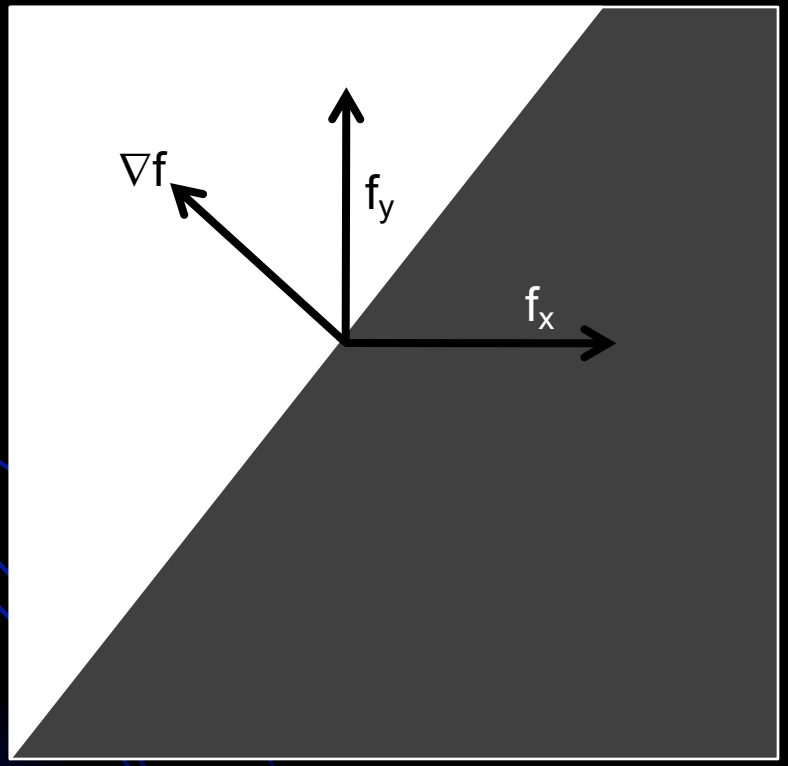
- What if they didn't?
- Consider running it on a homogeneous region: 40, 40, 40, 40, 40, 40

2D Edges

- Local operators
  - Prewitt operators
  - Sobel masks
  - Roberts 2x2 cross-operators
- Gradient: magnitude
- Gradient direction

Edge gradient

Vector pointing in direction of greatest positive change.
We want its magnitude and direction



1. Find partials using filters

$$\text{To find } \frac{\delta f}{\delta x}\text{, use Prewitt : } \frac{1}{6}\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \text{ or Sobel : } \frac{1}{8}\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \text{ filter}$$

$$\text{To find } \frac{\delta f}{\delta y}\text{, use Prewitt : } \frac{1}{6}\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \text{ or Sobel : } \frac{1}{8}\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \text{ filter}$$

Note that this is 1D filter, but averaged over 3 rows (for df/dx) or 3 cols (for df/dy) and with 1/6 factored out to allow integer multiplication

Roberts 2x2 cross operators $\begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$ are more sensitive to noise

Q4,Q5

Demo

- My homemade edgefinder
  - Finds vertical and horizontal edges using filters
  - Combines to find edge magnitude
  - Combines to find edge direction
  - Re-scale for display
- Similar to part of Lab 3.
  - So I can’t post code

2. Find edge gradient magnitude

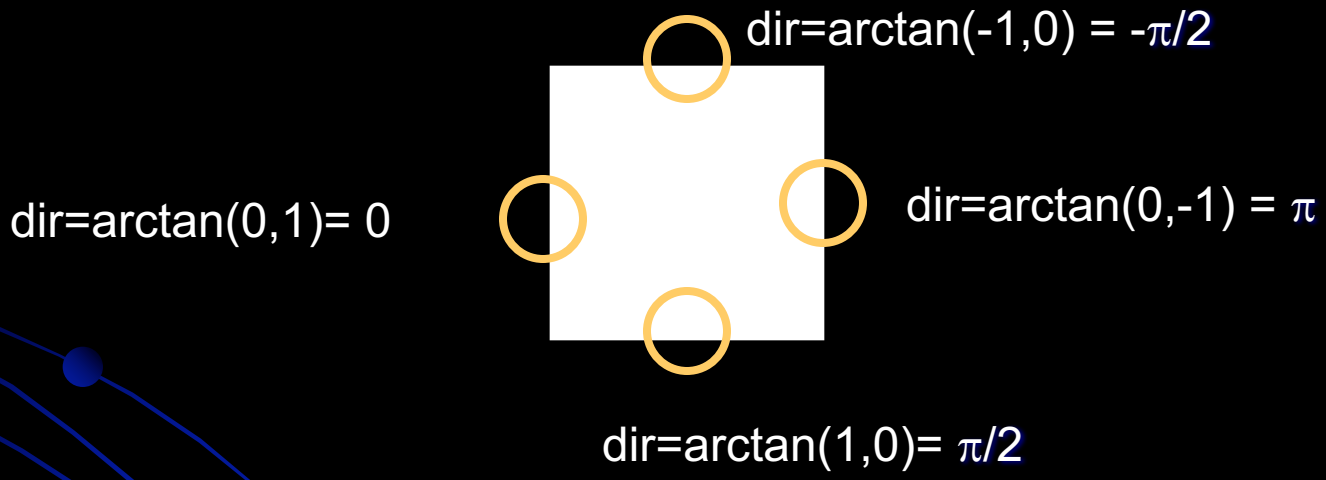
- Definition: the gradient, ∇f, is the vector pointing in the direction of greatest change.

- To find its magnitude:

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

3. Find edge gradient direction

- $\tan^{-1}(y,x)$
- Matlab's atan2(y,x) gives full range, $[-\pi, \pi]$



- Direction is thus the angle formed by the x-axis and the line "pointing towards" light region.

Review: filters to reduce noise

$$\begin{bmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{bmatrix}$$

- From last slide from Day 5 class
- To get the output at a single point, take cross-correlation (basically a dot-product) of filter and image at that point
- To filter the whole image, shift the filter over each pixel in the original image

- This is a 3x3 version of which filter?

Color edges

- Rarely used historically
- Intuition: edges occur between regions of different hue but same intensity.
- One technique patented by David Cok, Eastman Kodak Co.

Limitations of edgel-finders

- Natural variation
  - Shadows and highlights can obscure edges
- Internal vs. external edges
  - We might want the outline of an article of clothing, but the stripes in our shirt are edges too.
- Noise!
  - Signal-to-noise ratio important in determining how hard it is to find edges.

Dealing with noise by smoothing

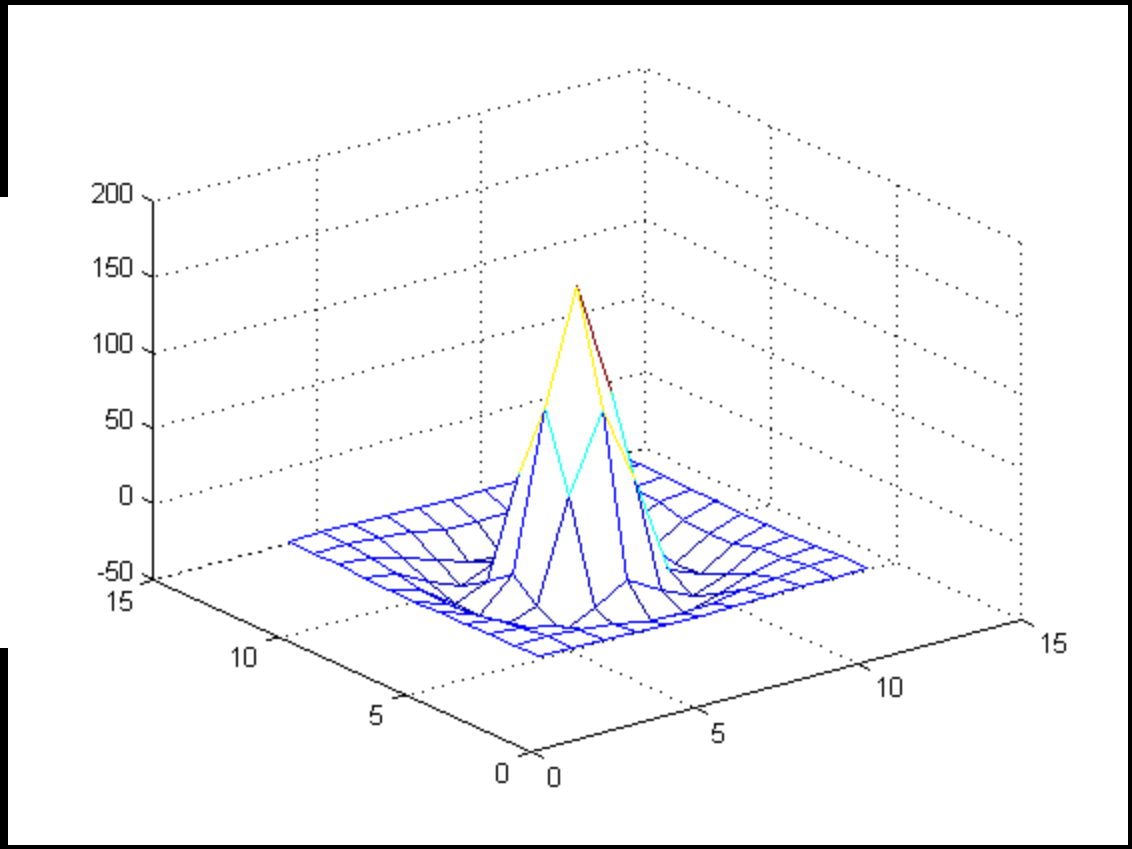
0	-1	0
-1	4	-1
0	-1	0

3x3

- Our goal is to combine smoothing and edgel detection.

0	0	0	-1	-1	-2	-1	-1
0	0	-2	-4	-8	-9	-8	-4
0	-2	-7	-15	-22	-23	-22	-15
-1	-4	-15	-24	-14	-1	-14	-24
-1	-8	-22	-14	52	103	52	-14
-2	-9	-23	-1	103	178	103	-1
-1	-8	-22	-14	52	103	52	-14
-1	-4	-15	-24	-14	-1	-14	-24
0	-2	-7	-15	-22	-23	-22	-15
0	0	-2	-4	-8	-9	-8	-4
0	0	0	-1	-1	-2	-1	-1

11x11



Edgels vs. Edges

- *Edgels* are unconnected groups of pixels detected by a mask
- *Edges* are longer segments found by grouping edgels
  - Intuitively, we think of edges
- Different data structure
- How might you process a “raw” edge image?

From mask output to edgels: ideas

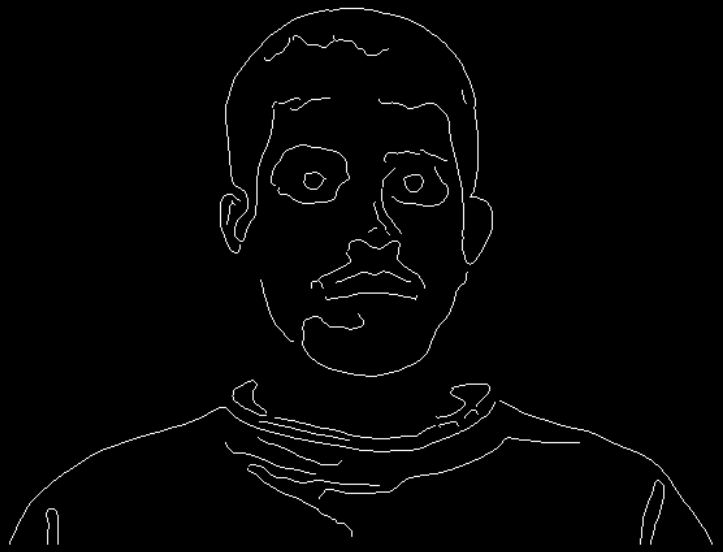
- Threshold away “weak” output
  - What threshold to use?
  - Always fixed or should it vary?
- “Thin” edges by nonmaximum suppression.
  - Idea: If an edge is 5 pixels wide, we can replace it with only the innermost segment.
  - Remove the edge response of an pixel not greater than its 2 neighbors in the direction of the gradient.

Canny edge detection

- First smoothes the intensity image
  - Parameter σ controls how many edges found
- Non-maximal suppression
- Uses **two thresholds**:
  - High: to initiate contour following
  - Low: to follow along a contour
  - Result: segments from noise are less likely to be found (unless the noise is too strong)
- Aggregates neighboring edgels into curves ("edges")

Canny edge detection

- You'll get to play with various edgefinders in Lab 3 using Matlab's built-in *edgedemo*



- Some neat image rec/computer vision demos using the kinect:
  - http://www.youtube.com/watch?v=7QrnwoO1-8A&feature=mfu_in_order&list=UL
  - http://www.engadget.com/2010/12/09/kinect-finally-fulfills-its-minority-report-destiny-video/