Announcements

• Assignment 6 is due Dec 2, 11:59 PM
• Quiz 6 is Dec 4
• Assignment 7 will be released Dec 2
  – Due Dec 9, 11:59 PM
• Reading
  – Chapter 10: Image segmentation I: edge detection, thresholding, and region detection
    • Sections 10.1, 10.2, and 10.3
Image segmentation

• General approach
  1. Spatial filtering
  2. Additional processing
  3. Thresholding

• Global thresholding (simplest)

\[ g(x, y) = \begin{cases} 
1 & \text{if } f(x, y) > T \\ 
0 & \text{otherwise} 
\end{cases} \]

where

\( T \) is threshold value
Image segmentation

Input

Edges

Segmentation

Edge-based

Region-based
Derivatives in 1D

• Forward difference

\[
\frac{\partial f(x)}{\partial x} = \frac{f(x + \Delta x) - f(x)}{\Delta x}
\]

• Backward difference

\[
\frac{\partial f(x)}{\partial x} = \frac{f(x) - f(x - \Delta x)}{\Delta x}
\]

• Central difference

\[
\frac{\partial f(x)}{\partial x} = \frac{f(x + \Delta x) - f(x - \Delta x)}{2\Delta x}
\]
Image derivatives

Intensity values:

Ramp
Isolated point
Line
Flat segment
Step

First derivative:

Second derivative:

CSE 166, Fall 2020
Detection of isolated points

Laplacian (second derivative)

Input
Segmentation
Threshold absolute value
Line detection

Input

Threshold absolute value

Double lines

Laplacian (second derivative)

Threshold value
Line detection, specific directions

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<th>Vertical</th>
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Spatial filters
Line detection, specific directions

+45°

Negative values set to zero

Threshold
Edge models

Step

Ramp

Roof edge
Edge models

Ramp

Step

Roof edge
Ramp edge

Horizontal intensity profile

First derivative

Second derivative

Zero crossing

Two points

First derivative

Second derivative

One point
Noise and image derivatives

First derivative

Second derivative

Input

Noise
Edge detection

1. Image smoothing for noise reduction
2. Detection of image points (edge point candidates)
3. Edge localization (select from candidates, set of edge points)
Gradient and edge direction

Gradient direction is orthogonal to edge direction
Gradient operators

Forward difference

Roberts

Prewitt

Sobel
Gradients

Input

Magnitude of horizontal gradient

Magnitude of vertical gradient

Magnitude of gradient vector
Gradients

Smooth image prior to computing gradients. Results in more selective edges.

Input

Magnitude of horizontal gradient

Magnitude of vertical gradient

Magnitude of gradient vector
Edge detection

1. Smooth the input image
2. Compute the gradient magnitude image
3. Apply nonmaximal suppression to the gradient magnitude image
4. Threshold the resulting image
Edge detection

Threshold magnitude of gradient vector

Without smoothing  With smoothing
Advanced edge detection

Magnitude of gradient vector (with smoothing)

Input

Marr-Hildreth

Canny

Figure 10.25 in textbook looks better
Canny edge detector

1. Smooth the input image with a Gaussian filter
2. Compute the gradient magnitude and angle images
3. Apply nonmaximal suppression to the gradient magnitude image
4. Use double thresholding and connectivity analysis to detect and link edges
Double thresholding

• Use a high threshold to start edge curves and a low threshold to continue them
  – Define two thresholds $T_H$ and $T_L$
  – Starting with output of nonmaximal suppression, find a point $q_0$, which is a local maximum greater than $T_H$
  – Start tracking an edge chain at pixel location $q_0$ in one of the two directions
  – Stop when gradient magnitude is less than $T_L$
Double thresholding

Single threshold

$T = 15$

$T = 5$

Double threshold

$T_H = 15$ and $T_L = 5$
Canny edge detector
Canny edge detector
Next Lecture

• Image segmentation

• Reading
  – Chapter 10: Image segmentation I: edge detection, thresholding, and region detection
    • Sections 10.3, 10.4, 10.5, and 10.6