Image Processing - Lesson 12

Segmentation

- Threshold Segmentation
  - Local thresholding
  - Edge thresholding
  - Threshold using averaging
  - Gradient Detectors
- Region Growing
- Split & Merge

- Shape Matching
- Shape Representation
Image Segmentation = divide image into (continuous) regions or sets of pixels.

1) Region Based
2) Boundary Based
3) Edge Based
Global Thresholding = Choose threshold $T$ that separates object from background.

Image Histogram
Segmentation using Thresholding

Original

Histogram

Threshold = 50

Threshold = 75
Original

Histogram

Threshold = 21
Thresholding a Grayscale Image

Original Image

Threshold too low

Threshold too high

Thresholded Image
FMRI - Example

Original Image

Threshold = 80

Threshold = 71

Threshold = 88
Simple thresholding is not always possible:

1) Many objects at different gray levels.
2) Variations in background gray level.
3) Noise in image.
Thresholding Example

Original

[Image of an original grayscale image]

Histogram

[Graph showing a histogram with a vertical line at T = 128]

Single Global Threshold

[Image of the thresholded image with T = 128]

T = 128
Local Thresholding - 4 Thresholds

Divide image into regions. Perform thresholding independently in each region.
Adaptive Thresholding

Every pixel in image is thresholded according to the histogram of the pixel neighborhood.

\[ T = \]
Adaptive Thresholding - Example

Original

Sonnet for Lena

O dear Lena, your beauty is so vast
It is hard sometimes to describe it fast.
I thought the entire world I would impress
If only your portrait I could compress.
Also! First when I tried to use VQ
I found that your cheeks belong to only you.
Your silky hair contains a thousand lines
Hard to match with sums of discrete cosines.
And your lips, sensual and tactical
Thirteen Crays found not the proper fractal.
And while these setbacks are all quite severe
I might have fixed them with hacks here or there
But when filters took sparkle from your eyes
I said, 'Damn all this, I'll just digitize.'

Thomas Callibrant

Global Threshold

Adaptive Threshold
Threshold Segmentation of Noisy Images

Noise inhibits localization of threshold.

Smooth image and obtain a histogram for which threshold is easily determined.
Note: Smooth the image, not the histogram...
Threshold using Average

Gray level Histograms

no pixels

Gray level
Threshold using Average

Gray level Histograms
Edge Based Segmentation

Original

Edge Image

Background

Object
Edge Based Thresholding

Original

Edge Pixels

Edge Neighbors

Edge Neighbors Histogram
Thresholding Based on Boundary Characteristics

Original

Threshold (T=182)
Thresholding Based on Boundary Characteristics

Original

Threshold (T=143)

Edge Neighborhood Histogram
Define:

\[ S = \text{the set of pixels inside the region.} \]
\[ Q = \text{queue of pixels to be checked.} \]
\[ (x_0, y_0) = \text{a pixel inside the region.} \]

Algorithm:

Initialize: \[ S = \emptyset \]
\[ Q = \{ (x_0, y_0) \} \]
1) Extract pixel \( P \) from queue \( Q \)
2) Add \( P \) to \( S \).
3) For each neighbor \( P' \) of \( P \):
   
   if \( P' \) is "similar" to \( P \) and \( P' \notin S \) then
   
   add \( P' \) to \( Q \).
4) If \( Q = \emptyset \) then end, else return to 1.

\[ S = \text{the extracted pixels of the region.} \]
Define what "similar" means.
Problematic in small gradient regions.
Region Growing - Example

Seed
Region Growing - Examples

Color Segmentation

Texture Segmentation

Color + Texture Segmentation
Watershed Threshold Algorithm

An Image can be viewed as a topographic map
Initialize threshold at $T_0$ that separates objects well. Determine connected components. Raise threshold, and detect pixels that pass threshold and belong to more than one connected component. Do not let objects merge. Set these pixels as object boundaries.
Watershed Threshold Algorithm
Watershed Threshold Algorithm

Watershed Markers may be chosen manually or local global maxima (as above)
Split & Merge Segmentation

2 Stage Algorithm:

Stage 1: Split
Split image into regions using a Quad Tree representation.

Stage 2: Merge
Merge "leaves" of the Quad Tree which are neighboring and "similar".
Quad Tree - Representation

Image

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Quad Tree

1 2 3 4

Demo
Quad Tree Representation

Original

Thresh = 0.20

Thresh = 0.40

Thresh = 0.55
**Stage 1: Split**

![Split Example](image)

**Stage 2: Merge**

![Merge Example](image)
Split & Merge Example
Graph-Cut Segmentation

\[ G = \{ V, E \} \]

- \( V \) = vertices
- \( E \) = Edges
- \( V \) = image pixels
- \( E \) = pixel similarity

Segmentation = Graph Partitioning
Min-Cut Segmentation

Segmentation by min-cut:

Find A,B such that cut(A,B) is *minimal*.

(Wu and Leahy 1993)
Normalized-Cut Segmentation

Min-cut segmentation favors small segments.

Segmentation by normalized-cut:

Find $A, B$ such that $\text{Ncut}(A, B)$ is \textit{minimal}.

$$\text{Ncut}(A, B) = \sum_{i \in A, j \in B} W_{ij} \left( \frac{1}{\text{vol}(A)} + \frac{1}{\text{vol}(B)} \right)$$

where $\text{vol}(A) = \sum_{i \in A, j \in A} W_{ij}$

(Shi and Malik 2000)
Normalized-Cut Segmentation - Examples

(from Cohen-Or 2005)
Which Model matches the Measurement?

• Which Model
• What is the transformation from Model to Measurement (translation, rotation, scale,...)
HOW CAN THIS BE TRUE?

Below the four parts are moved around

The partitions are exactly the same, as those used above

From where comes this "hole"?