CAP 5415 Computer Vision
Fall 2005

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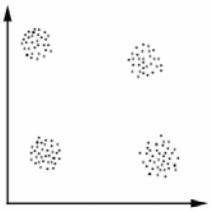
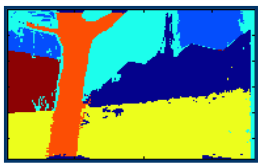
Recap
Clustering

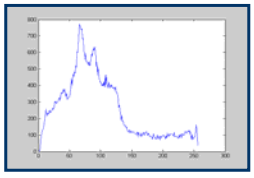


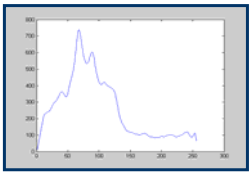


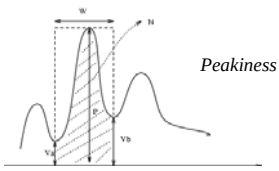
Recap
Similarity Constraints

- Same gray levels.
- Distance less than threshold
- Distance to mean less than threshold
- Small standard deviation within region

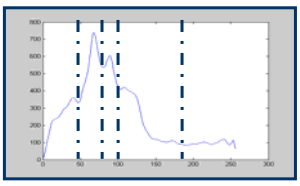
Recap
Histogram and segmentation







$$Peakiness = \left(1 - \frac{(V_a + V_b)}{2P}\right) + \left(1 - \frac{N}{(W.P)}\right)$$



Recap
Connected Components

- Recursive algorithm
  - One pass
- Sequential algorithm
  - Two pass
    - Labeling
    - Merging

$$\begin{bmatrix} 0 & 0 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 \end{bmatrix}$$

Steps in Seed Segmentation

1. Compute the histogram.
2. Smooth the histogram
3. Detect good peaks
4. Segment image into binary images using thresholds at the valleys.
5. Apply connected component algorithm.

Improving Seed Segmentation

- Merge small neighboring regions
  - Region growing step
- Split large regions
  - Region splitting
- Remove weak boundaries between adjacent regions

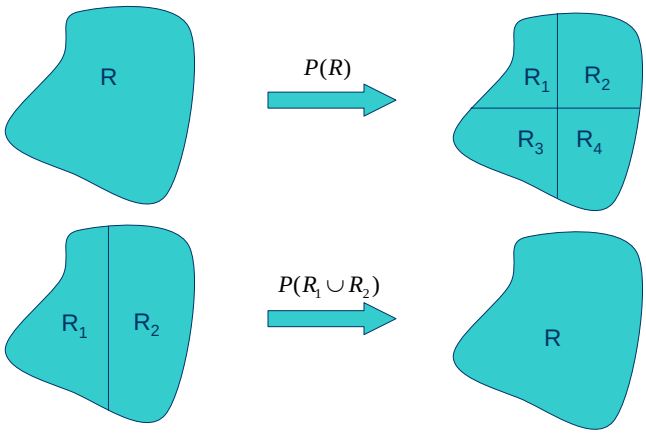
Region Growing

- Seed segmentation (histogram based seg.)
- Region splitting and merging
- Phagocyte algorithm
- Likelihood ratio test

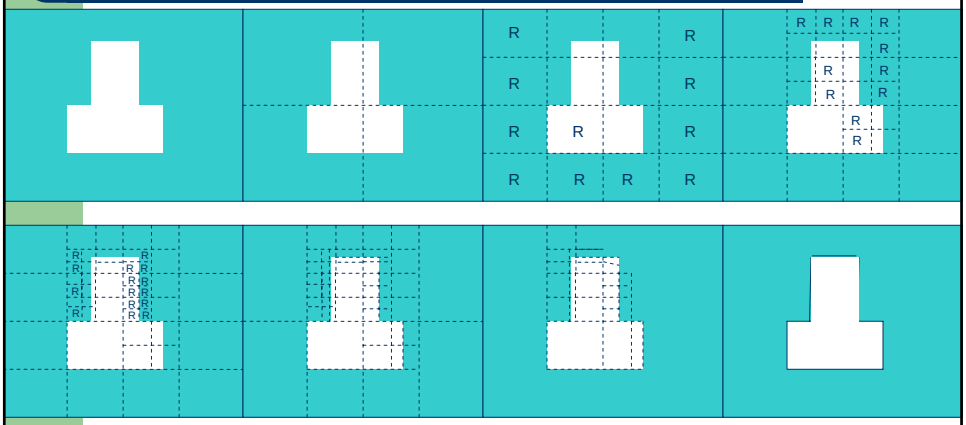
Region Split and Merge

- Splitting: split non uniform region into 4 adjacent regions
- Merging: merge similar regions
- Stop when no splitting merging are possible
- Uniformity/similarity function: P

Example



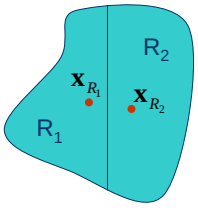
Example



Phagocyte Algorithm

- Boundary melting
  - Remove weak boundaries
  - Similar to region merging
- Boundary weakness is based on color similarity

$$S(\mathbf{x}_{R_1}, \mathbf{x}_{R_2}) = \left| I(\mathbf{x}_{R_1}) - I(\mathbf{x}_{R_2}) \right|$$

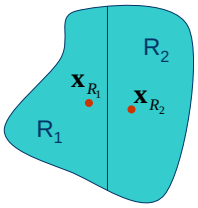


Phagocyte Algorithm

$$S(\mathbf{x}_{R_1}, \mathbf{x}_{R_2}) = \left| I(\mathbf{x}_{R_1}) - I(\mathbf{x}_{R_2}) \right|$$

$$W(\mathbf{x}_{R_1}, \mathbf{x}_{R_2}) = \begin{cases} 1 & S(\mathbf{x}_{R_1}, \mathbf{x}_{R_2}) > T \\ 0 & \text{otherwise} \end{cases}$$

$$W(R_1, R_2) = \sum_{\mathbf{x}_{R_1} \in R_1 \wedge \mathbf{x}_{R_2} \in R_2} W(\mathbf{x}_{R_1}, \mathbf{x}_{R_2})$$



Phagocyte Merging Heuristics

- Merge two regions if

$$\frac{W(Boundary)}{\min(P_1, P_2)} > T_2, \quad 0 \le \mathrm{T}_2 \le 1$$ Phagocyte

where P_1 and P_2 are the perimeters of regions R_1 and R_2.

- Merge regions if

$$\frac{W(Boundary)}{\text{Total number of points on the border}} > T_3, \quad 0 < \mathrm{T}_3 \le 1$$ Weakness

Likelihood Ratio Test

- Two region hypothesis
  - There is only one region
  - There are indeed two regions
- Intensity at every pixel is independent
  - Joint probability
  - Gaussian distribution

Likelihood Ratio Test

$$p(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$ observing intensity under Gaussian model

Likelihood of region *A*

$$p(x_1, x_2, \ldots, x_{m_1}) = \left(\frac{1}{\sqrt{2\pi}\sigma}\right)^{m_1} e^{-\frac{m_1}{2}} \qquad x_1, x_2, \ldots, x_{m1} \in A$$

Likelihood of region *B*

$$p(x_{m_1+1}, x_{m_1+2}, \ldots, x_{m_1+m_2}) = \left(\frac{1}{\sqrt{2\pi}\sigma}\right)^{m_2} e^{-\frac{m_2}{2}} \qquad x_{m1+1}, x_{m1+2}, \ldots, x_{m1+m2} \in B$$

Likelihood Ratio Test

- There is 1 region hypothesis

$$P(H_1) = p(x_1, x_{2,\ldots}, x_{m_1}, x_{m_1+1}, x_{m_1+2}, \ldots, x_{m_1+m_2}) = \left(\frac{1}{\sqrt{2\pi}\sigma_{\text{one region}}} \right)^{m_1+m_2} e^{-\frac{m_1+m_2}{2}}$$

- There are 2 regions hypothesis

$$P(H_2) = p(x_1, x_{2,\ldots}, x_{m_1}) p(x_{m_1+1}, x_{m_1+2}, \ldots, x_{m_1+m_2}) = \left(\frac{1}{\sqrt{2\pi}\sigma_A} \right)^{m_1} e^{-\frac{m_1}{2}} \left(\frac{1}{\sqrt{2\pi}\sigma_B} \right)^{m_2} e^{-\frac{m_2}{2}}$$

Likelihood Ratio Test

$$P(H_1) = \left(\frac{1}{\sqrt{2\pi}\sigma_{\text{one region}}} \right)^{m_1+m_2} e^{-\frac{m_1+m_2}{2}}$$

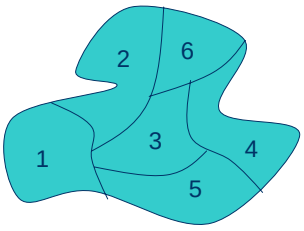
$$P(H_2) = \left(\frac{1}{\sqrt{2\pi}\sigma_A} \right)^{m_1} e^{-\frac{m_1}{2}} \left(\frac{1}{\sqrt{2\pi}\sigma_B} \right)^{m_2} e^{-\frac{m_2}{2}}$$

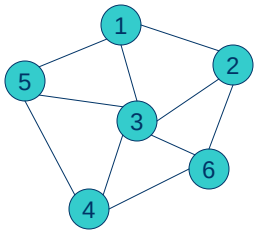
$$LH = \frac{P(H_2)}{P(H_1)} = \frac{(\sigma_0)^{m_1+m_2}}{(\sigma_A)^{m_1}(\sigma_B)^{m_2}}$$

Merge regions if $LH < T$.

Region Adjacency Graph

- Common data structure to represent regions
- Regions are nodes of the graph
- Edges between nodes represents adjacency





Region Growing Methods

- Different algorithms have different number of thresholds
- How much merging is required
  - Stopping criterion
- Though simple, seed segmentation succeed by region growing is usually successful

Difference Between Segmentation and Edge Detection

- Closed boundary
  - Edges are usually open
  - Segmentation provides closed boundaries
- Local or global
  - Edges are computed in the locality
  - Segmentation is global
- Increasing feature vector dimensionality
  - Does not drastically improve edge detection
  - Improves segmentation (motion, texture information etc.)
- Boundary position
  - Localized in edge detection
  - Usually not localized (recent advancements use locality as well)
    - Especially contour based segmentation

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