Region-based Segmentation

Outline
- What is region-based segmentation
- Region growing
  - Flood fill
- Watershed
  - Gradient watershed
  - Distance transform watershed
- K-mean clustering

Segmentation Problem
- Partition image $R$ into $n$ regions $R_i$, such that:
  - $\bigcup_{i=1}^{n} R_i = R$: all pixels belong to a region
  - $R_i \cap R_j = \emptyset$: regions must be disjoint
  - $P(R_i) = \text{true}$: pixels within each region must satisfy a predicate function defined
  - $P(R_i \cup R_j) = \text{false}$: regions are different in the sense of predicate

Region-based Segmentation
- Aims to determine the regions directly
- Thresholding & edge detection also segment images
  - Thresholding analyzes histogram and suggests segmenting criteria
  - Edge detection extracts object boundaries, which need to be connected to form closed regions

Region Growing
- A family of methods that groups pixels or sub-regions into larger regions based on predefined criteria for growth
  - Starts with a set of "seed" points
  - Append to each seed point its neighboring pixels based on gray level, texture, color, shape...

Flood Fill
- Simplest region growing algorithm
  - Start with a single seed pixel
  - Label all similar neighboring pixels with a uniform color
  - Output a single contiguous region
  - Similar to flood fill for polygon filling
**Seeded Region Growing**

- Find all connected components in input seed map $S(x,y)$;
- Erode each connected component to 1 pixel;
- Label remaining pixels as 1 and other pixels in $S$ as 0;
- Form an image $f_g$ such that, at a pair of coordinates $(x,y)$, let $f_g(x,y) = 1$ if the is satisfied otherwise $f_g(x,y) = 0$.
- Label each connected component in $g$ with a different region label. This is the segmented image obtained by region growing.

**Watershed**

- Geological watershed separates adjacent drainage basins
- Watershed segmentation is defined on a grayscale image
  - It treats it as a topographic map
  - Brightness of each pixel represents its height
  - Finds the lines that run along the tops of ridges

**Types of Points**

- 3 types of points in a topographic interpretation:
  - Points belonging to a regional minimum
  - Catchment basin or watershed of regional minimum:
    - Points at which a drop of water would fall to a single minimum
  - Divide lines or watershed lines:
    - Points at which a drop of water is equally likely to fall to more than one minimum
  - Identifying all watershed lines gives us segmentation boundaries

**Watershed by Flooding**

- For each $k$ from min to max intensity:
  - For each group of pixels with intensity $k$:
    - If doesn't adjacent to any existing region, start a new region;
    - Else is adjacent to one existing region:
      - Add the group of pixels to the region;
    - Else:
      - Mark as boundary;
- The algorithm requires traverse all pixels under each intensity level
- More efficient algorithm is proposed later
- Uses priority queue to organize the pixels

**Priority-Flood**

- A set of markers are chosen, which specifies where the flooding shall start:
  - Each marker is given a different label:
  - Neighboring pixels of each marked area are inserted into a priority queue with a priority level corresponding to the gradient magnitude of the pixel
- Repeat:
  - Extract the pixel with the lowest priority from the queue:
    - If the neighbors of the extracted pixel that have already been labeled all have the same label:
      - Label the pixel with their label:
      - All non-marked neighbors that are not yet in the priority queue are put into the priority queue;
    - Else:
      - Mark as boundary;
- Until the priority queue is empty
Gradient Watershed

- Watershed is often applied to gradient magnitude images
- Homogeneous regions with low gradiences correspond to catchment basins
- Watershed lines run along region boundaries
- Due to noise in gradient, over-segmentation might occur

Distance Transform Watershed

- Watershed can also be applied to distance transform of binary images
- Often used for object counting
- First apply thresholding to generate binary image
- Then perform distance transform
- Finally segment objects based on shape contour

K-means Clustering

- Perform segmentation in feature space
  - Based on pixel color, local texture descriptor, etc.
  - Non-adjacent pixels may be assigned to the same cluster
- Capable of segmenting color images

Demo on a 2D Case