Image Segmentation-IV

Region-Based Segmentation

May 21, 2020

Region-Based Segmentation

- R - the entire spatial region occupied by an image.
- Segmentation - a process that partitions R into n subregions, $R_1, R_2, \ldots, R_n$ such that:

(a) $\bigcup_{i=1}^{n} R_i = R$.

(b) R_i is a connected set, for $i = 0, 1, 2, \ldots, n$.

(c) $R_i \cap R_j = \varnothing$ for all i and j, $i \neq j$.

(d) $Q(R_i) = \text{TRUE}$ for $i = 0, 1, 2, \ldots, n$.

(e) $Q(R_i \cup R_j) = \text{FALSE}$ for any adjacent regions R_i and R_j.

$Q(R_k)$ is a logical predicate property defined over the points in set R_k

ex. $Q(R_i)$ = TRUE if all pixel in R_i have the same gray level i

Region-Based Segmentation

$$(a) \quad \bigcup_{i=1}^{n} R_i = R$$

Segmentation must be complete (every pixel belongs to a region)

Points in a region be connected in some predefined sense

$$(b) \quad R_i \text{ is a connected region}, i = 1, 2, \ldots, n$$

$$(c) \quad R_i \cap R_j = \phi \text{ for all i and j}, i \neq j$$

Regions must be disjoint

$$(d) \quad Q(R_i) = TRUE \text{ for } i = 1, 2, \ldots, n$$

$$(e) \quad Q(R_i \cup R_j) = FALSE \quad \textit{for any adjacent regions } R_i \textit{ and } R_j$$

Properties must be satisfied by the pixels in a segmented region

Two adjacent regions must be different in the sense of predicate Q

$Q(R_i)$ is a logical predicate property defined over the points in set R

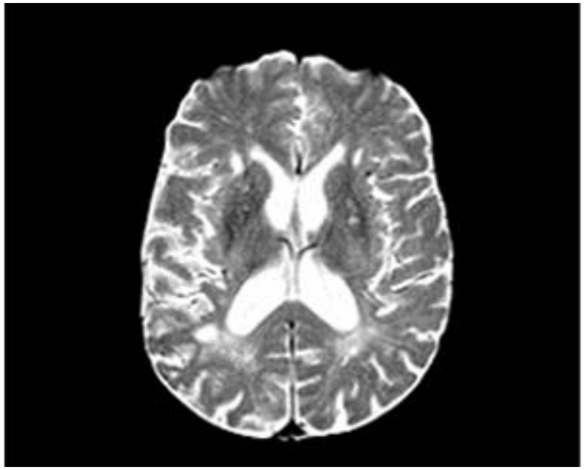
ex. $Q(R_i)$ = TRUE if all pixel in R_i have the same gray level i

Region-Based Segmentation Approaches

- Various approaches
  - Region Growing
  - Region Splitting and Merging
  - Clustering
  - Superpixels
  - Graph cuts
- Morphological Watersheds
  - A method that finds the regions and their boundaries simultaneously

Region Growing

- A procedure that groups pixels or sub-regions into larger regions based on predefined criteria for growth
- Pixel aggregation: start with a set of **"seed"** points
- Growing by appending to each seed those neighbors that have predefined properties similar to the seed (e.g., gray-level, texture, color)



An MR brain image and the segmented ventricles using the region-growing method

Region Growing - Concerns

1. Selection of initial seeds that properly represent regions of interest
   - Based on the nature of the problem
   - if a priori information is not available, then compute at every pixel the same set of properties that are supposed to be used to assign pixels to regions
     - If the result of these computations shows clusters of values, the pixels whose properties place them near the centroid of these clusters can be used as seeds

Region Growing - Concerns

2. Selection of suitable properties (similarity criteria)
   - Depends on the problem under consideration; and
   - Type of image data available (descriptors)
3. Connectivity or adjacency information
   - Grouping pixels with the same intensity value to form a "region," without paying attention to connectivity, would yield a meaningless segmentation result
4. Formulation of a stopping rule
   - Region growth should stop when no more pixels satisfy the criteria for inclusion in that region

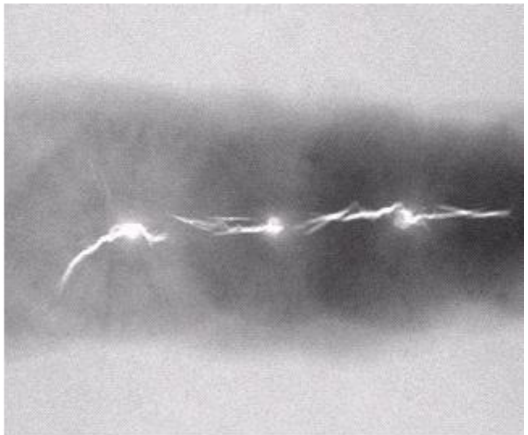
Region Growing

- Let $f(x, y)$: input image;
  $S(x, y)$: seed array containing 1s at the location of seed points and 0s elsewhere;
  Q: predicate to be applied at each location (x, y)
- A basic region growing algorithm based on 8-connectivity

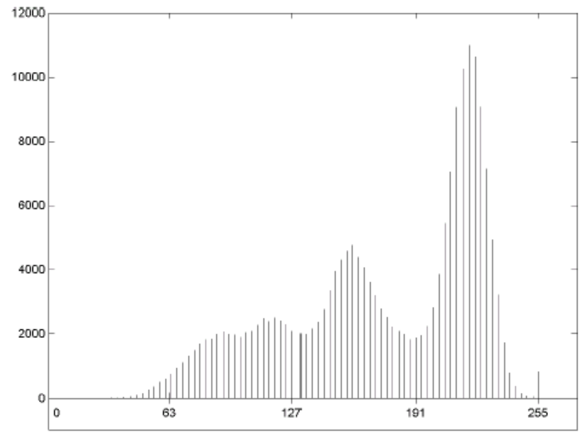
1. Find all connected components in $S(x, y)$ and erode each connected component to one pixel; label all such pixels found as 1. All other pixels in S are labeled 0
2. Form an image f_Q s.t., at each point (x, y), $f_Q(x, y) = 1$ if $f(x, y)$ satisfies the given predicate at these coordinates; otherwise $f_Q(x, y) = 0$
3. Let g be an image formed by appending to each seed point in S all the 1-valued points in f_Q that are 8-connected to that seed point
4. Label each connected component in g with a different region label (e.g., 1, 2, 3…). This is the segmented image obtained by region growing

Region Growing – Example (1/2)

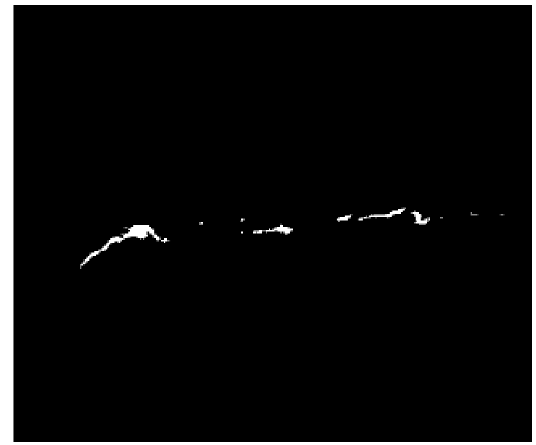
(a) Image showing defective welds

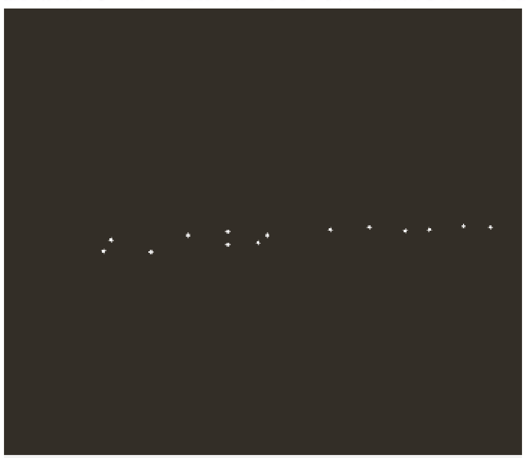


(b) Histogram



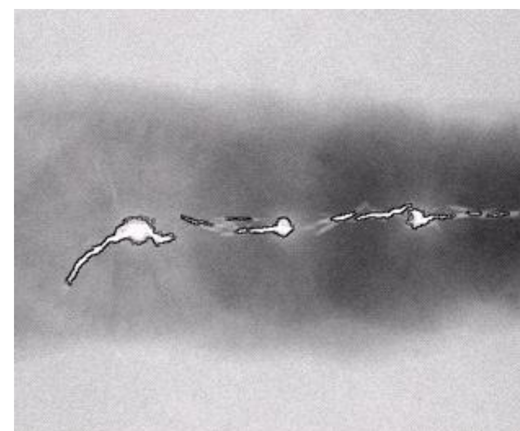
(c) Initial Seed Image





(d) Final Seed Image

(e) Region growing (8-connected to seed & similar to it)



(e) Boundaries of segmented defective welds in black

Region Growing – Example (2/2)

- Histogram of image is used to find the criteria of the difference gray-level between each pixels and the seeds
  - select all seed points with gray level 255 in this case
- Criteria for a pixel to be annexed to a region:

1. The absolute gray-level difference between any pixel and the seed has to be less than 65
2. The pixel has to be 8-connected to at least one pixel in that region (if more, the regions are merged)

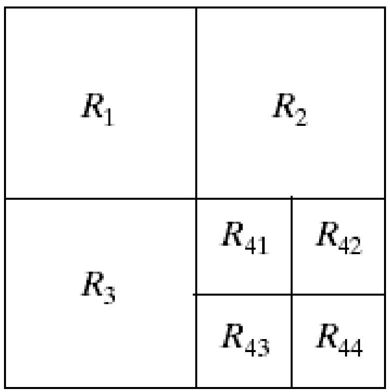
Region Splitting and Merging

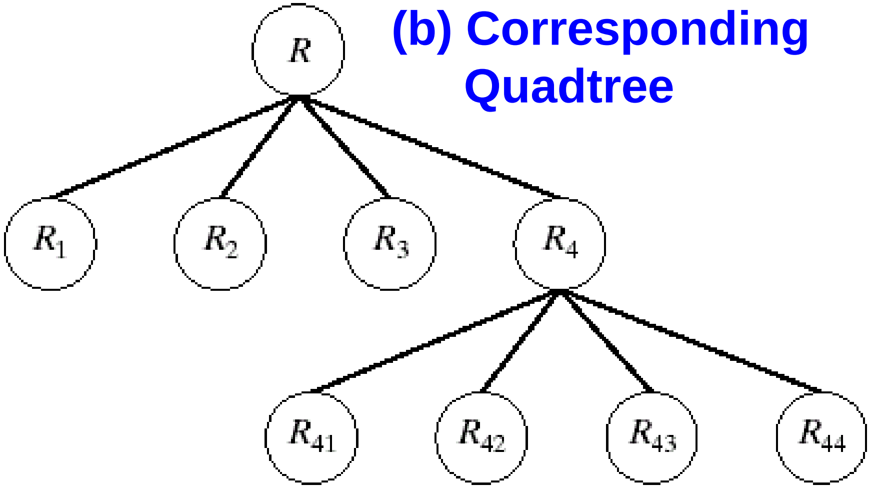
- Alternative approach
- Sub-divide an image initially into a set of arbitrary disjoint regions and then merge and/or split the regions in an attempt to satisfy the conditions of segemntation
- Need to develop a split and merge algorithm that iteratively works toward satisfying constraints

Region Splitting and Merging

- Procedure: (Convenient representation: "**quadtree**")
  - Let R represent the entire region, select a predicate Q
  - **Splitting**
    - Subdivide R successively into smaller and smaller quadrant region, so that for any region R_i, $Q(R_i)$= TRUE
    - Start with the entire region, R
    - If $Q(R)$=FALSE, divide the image into quadrants
    - If Q is FALSE for any quadrant, we subdivide that quadrant into subquadrants, and so on
  - **Merging**
    - Only splitting results in adjacent regions with identical properties
    - Merge adjacent regions whose combined pixels satisfy the predicate Q (merge adjacent regions R_j & R_k, if $Q(R_j \text{ U } R_k)$ = TRUE)

Quadtree





Summarized Procedure:

1. Split into 4 disjoint quadrants any region R_i for which $Q(R_i)$ = FALSE
2. Merge any adjacent region R_j and R_k for which $Q(R_j \cup R_k)$ = TRUE
3. Stop when no further merging or splitting is possible

Region Splitting and Merging - Example

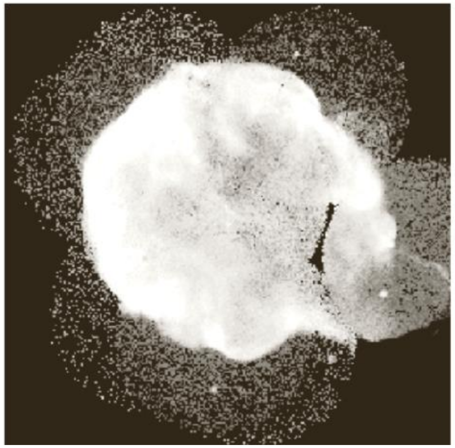
- $Q(R_i)$ = TRUE if at least 80% of the pixels in R_i have the property $|z_j - m_i| \le 2\sigma_i$, where
  - z_j is the gray level of the jth pixel in R_i
  - m_i is the mean gray level of that region
  - σ_i is the standard deviation of the gray levels in R_i
- If $Q(R_i)$ = TRUE under this condition, the values of all the pixels in R_i were set equal to m_i
- Splitting and merging by the defined algo

(a) Original image

(b) Result of split and merge

Quantify the texture of a region: Texture segmentation

Region Splitting and Merging - Example



566 566 × X-ray image of the Cygnus Loop supernova, taken by NASA's Hubble Telescope

Objective: segment out the "ring" of less dense matter surrounding the dense inner region

RoI characteristics to help in its segmentation:

Data in this region has a random nature

Standard deviation and mean can be used effectively

Predicate to segment the RoI:

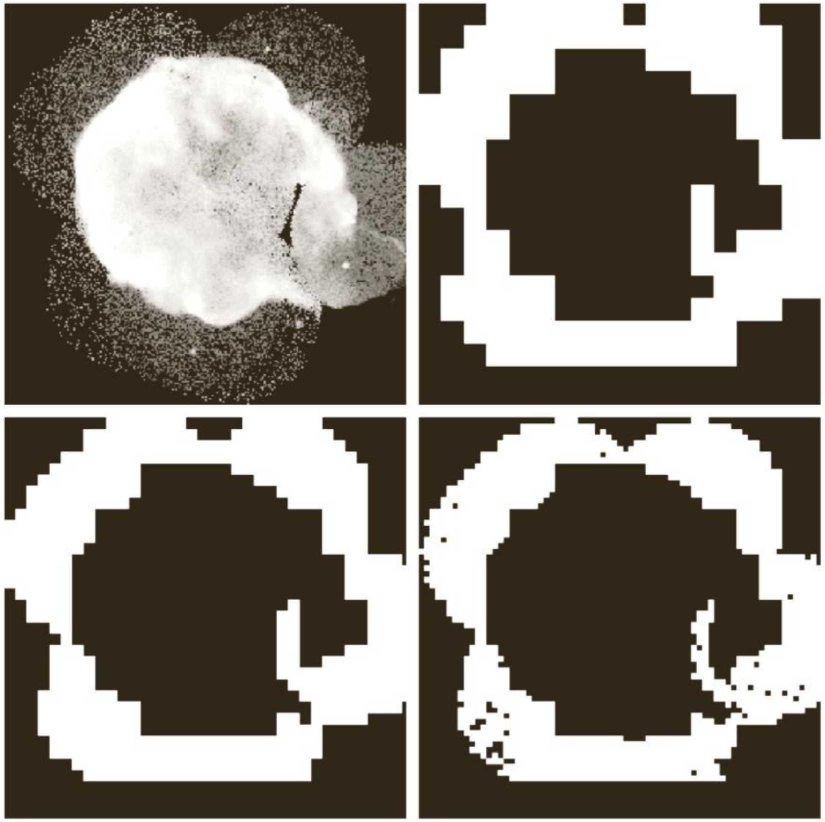
$$Q = \begin{cases} TRUE\ if\ \sigma_R > a\ AND\ 0 < m_R < b \\ FALSE\ otherwise \end{cases}$$

σ_R and m_R - standard deviation and mean of the region being processed,

a and b - nonnegative constants

Region Splitting and Merging - Example

(a) (b) (c) (d)



(b - (d) Results of limiting the smallest allowed quadregion to be of 32 × 32, 16 × 16, and 8 × 8 pixels

The best result in terms of capturing the shape of the outer region was obtained using 16 ×16 pixels quadregions

Constants ‘a’ and ‘b’ are obtained through image analysis. Here, analysis of several regions reveals that the mean intensity of pixels in those regions did not exceeds 125 and the standard deviation is always greater than 10