LECTURE 8: Medical Image Segmentation (II) (Region Growing/Merging)

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Outline

- Region Growing algorithm
- Homogeneity Criteria
- Split/Merge algorithm
- Examples from CT, MRI, PET
- Limitations
Region Based Segmentation Algorithms

**Region:** A group of connected pixels with similar properties

Closed boundaries

Computation of regions is based on similarity

Regions may correspond to Objects in a scene or parts of objects

Spatial proximity + similarity
Region Growing/Merging

- Perhaps, one of the simplest approaches among region based methods.

1. Select a seed point/points
2. Define a growth criteria
3. Joint all voxels connected to the seed that follow the growth criteria
4. Stop when no adjacent voxel agree with the growth criteria

- 4-connectivity
- 8-connectivity
Example: Fat Segmentation in MRI

T1 weighted MRI
Red: visceral fat
Purple: liver
Blue: Subcutaneous fat

Credit: Dougherty, G., Medica Image Processing.
Region-based Segmentation

3D segmented two nodules are shown. 

Red: interactive RG, white: manual segm. of lung regions pertaining to rabbits with infections
*Credit: Bagci et al. EJNMMI Research 2013*
Simplest RG Pseudo-Code

1. We select a seed point $p_{seed}$ in a grey-level or colour image having brightness $B(p_{seed})$. At the beginning, the current segment only contains $p_{seed}$.
2. In an iteration process, we merge any pixel $q$ to the current segment that is 8-adjacent to a pixel in the current segment, not yet labelled, and has an intensity $B(q)$ satisfying $|B(q) - B(p_{seed})| \leq \tau$.
3. We stop if there is no further not yet labelled pixel $q$, 8-adjacent to the current segment, which still can be merged.

$\tau > 0$
Pictorial Illustration

1. Choose the seed pixel
Pictorial Illustration

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2. Check the neighboring pixels and add them to the region if they are similar to the seed
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2. Check the neighboring pixels and add them to the region if they are similar to the seed
3. Repeat step 2 for each of the newly added pixels; stop if no more pixels can be added

\[ |\text{neighboring pixels} - \text{seed}| < Threshold \]
**Algorithm Illustration**

**growRegion:** red nodes are the “active_front” (queue or stack)

**Algorithm:**
Remove pixel $p$ from active_front and mark it as $\text{region}[p] = 1$.
Add all neighbors $q$ such that $\text{region}[q] = 0$, $|I_p - I_q| < T$ and set $\text{region}[q] = -1$. 

Object with small intensity variation within the image.
Split and Merge Algorithm

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- Solution?
  - REGION MERGING
Split and Merge Algorithm

- When a homogeneous region is created, its neighboring regions are checked and the newly created region is merged with an existing one if they have identical properties.
- If the similarity criteria are met by more than one adjacent region, the new region is merged with the most similar one.
Muscle/Bone Separation in CT
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Virtual Endoscopy/Colonoscopy - CT

(a) Original CT image through the colon.
(b) A 3D RG initiated from a seed point.
(c) 3D rendering of the segmented colon.

Credit: P. Seutens
Adaptive Parameterization of RG

- Literature is vast!
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\[ I(x, y, z) \geq T.\text{mean}(R_0) \]

T: threshold,
mean of R₀ \(\rightarrow\) mean intensity of current grown region
Adaptive Parameterization of RG

- Original image
- Threshold/Volume curve
- ROI
- Thresholding
- Adaptive RG

Credit: Hua Li et al
MedPhys 2008
Left Ventricular Function in Cardiac CT

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Left Ventricular Function in Cardiac CT

• The gold standard for the functional evaluation of the left ventricle (LV) is magnetic resonance imaging (MRI)
• Contrast-enhanced retrospectively electrocardiogram (ECG)-gated multi-slice spiral computed tomography (MSCT) has been accepted as an efficient noninvasive tool for the detection of coronary artery stenosis, providing good sensitivity and specificity
• Assessment of the LV volume at end diastole and end systole is used for quantification of function!
Left Ventricular Function in Cardiac CT

Endocardial contours in systole

Endocardial contours in diastole

Homogenous region and high contrast helps region growing to be suitable for this case!

CT Lung/Soft Tissue Separation

- Seed > -200 HU
Airway Segmentation (Basic RG)
Slicer Implementation of RG and Airway Segmentation
Airway Segmentation (Basic RG)

Bone Vanishing Disease - CT
Bone Vanishing Disease - CT

(credit: Papadakis, G.Z., NIH)
Bone Vanishing Disease - CT

Controlling the homogeneity parameter (similarity criteria) in RG is extremely difficult due to large variation in bone density shifting towards lower densities.

(credit: Papadakis, G.Z., NIH)
Limitations of Region Growing

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1) Objects in medical images are often non-homogeneous
2) Poor contrast causes leakages
3) Noise
Summary

• Region Growing based segmentation algorithms
  – Still in use for many applications in radiology
    • Lung, bone, homogenous (isolated) tumors, …
  – Either terminal use or in-between step
  – Similarity criteria: homogenous regions
Slide Credits and References

- Jayaram K. Udupa, MIPG of University of Pennsylvania, PA.
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- Nardelli et al BiomedOnline 2015
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