Segmentation

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Image Segmentation

- Image segmentation is the partition of the image into non-overlapping regions, where their union is an entire image
- Purpose of segmentation: decompose an image into meaningful parts with respect to unique application
- Segmentation is based on the information taken from the image such as greylevel, texture, color and depth or motion

Image Segmentation

Applications ...

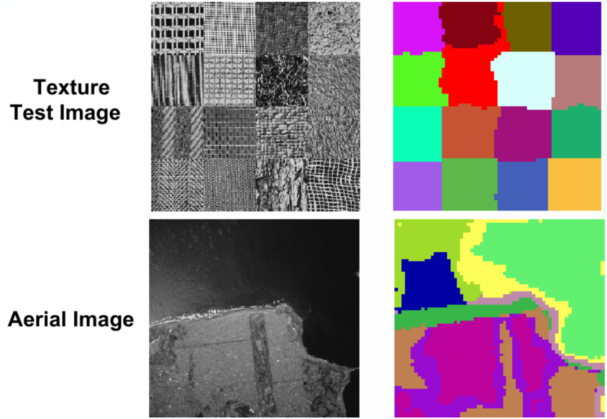
- Identifying objects in a scene for object-based measurements/recognition
- Identifying objects in a moving scene for object based video compression
- Identifying objects at different depths
- Its a necessary and fundamental step in a general frameworks of detection, tracking or classification

Image Segmentation

Techniques

- Region-based
  - Region growing
  - Split and merge
- Edge-based
  - Contours/ boundary surface
  - Deformable wrapping
  - Deformable registration to atlases
- Clustering-based
  - Threshold
  - K-means
  - Hierarchical clustering, Graph cuts
- Texture-based

Image Segmentation



Region Based Segmentation

Region Growing

- Starting with some pixels (seeds) representing distinct image regions
- Grow the region of each seed, using connected pixels until they cover the entire image
- Two rules: growth mechanism and region homogeneity after each growth step
- Growth mechanism: for each stage k and each region $R_i(k), i = 1, ..., N$, check if there are unclassified pixels in 8 neighborhood of each pixel in the region
- Region homogeneity: Pixel $P_{x,y}$ can join $R_i(k)$ if $|f(x,y) - \mu_{R_i(k)}| \leq \Delta$

Region Based Segmentation

Region Growing

- Merging two region:
- Mean (μ) and standard deviation (σ) of each region (R_i) can be used to decide if two region can merge:

$$\mu_{R_i} = \frac{1}{n} \sum_{(r,c) \in R_i} I(r,c)$$

$$\sigma_{R_i} = \sqrt{\frac{1}{n} \sum_{(r,c) \in R_i} [I(r,c) - M_{R_i}]^2}$$

if $|M_{R_1 - M_{R_2}}| < k\sigma_{R_i}$ for $i = 1,2$ two region are merged

Image Segmentation
Region Based Methods

Region Growing - Kind of unseeded RG

Using one seed only, the first pixel:

for All the pixels n the image **do**
  if $P_{x,y} \notin R_{1,2,\ldots,n}$ **then**
    $P_{x,y} \in R_{n+1}$
    for S: The 4 or 8 neighbors of x, y **do**
      if $P_{x',y'} \notin R_{1,2,\ldots,n}$ **then**
        if $|f(x',y') - \mu_{R_i}| \leq \Delta$ **then**
          $P_{x',y'} \in R_{n+1}$
          Search the neighbors of x', y'
        else
          $P_{x',y'} \in R_{n+2}$
          Search the 4 or 8 neighbors of x', y'
        end if
      end if
    end for
  end if
end for

Region Based Segmentation

Region Growing

seed growing final region

Fabrice example

Region Based Segmentation

Split Method

- Opposite of previous method
- Top to down approach
- Starts with the assumption that the whole image is a homogeneous region
- If this is not true, subdivides the image to smaller homogeneous regions
- If original Image $I_{N \times N} = I_{2^n \times 2^n} \rightarrow$ square produced regions $R^i_{M \times M} = R^i_{2^m \times 2^m}$
- Recursive procedure $\Rightarrow$ Image representation can be modeled by a tree whose nodes have four sons each
- **Quadtree**
- Created regions might be adjacent and homogeneous but are not merged

Region Based Segmentation

Split Method

Criterion of Homogeneity: Variance

0	1	0	0	7	7	7	7
1	0	2	2	7	7	7	7
0	2	2	2	7	7	7	7
4	4	2	2	7	7	7	7
0	0	1	1	3	3	7	7
1	1	2	2	3	7	7	7
2	4	3	0	5	7	7	7
2	3	3	5	5	0	7	7

original image

0	1	0	0	7	7	7	7
1	0	2	2	7	7	7	7
0	2	2	2	7	7	7	7
4	4	2	2	7	7	7	7
0	0	1	1	3	3	7	7
1	1	2	2	3	7	7	7
2	4	3	0	5	7	7	7
2	3	3	5	5	0	7	7

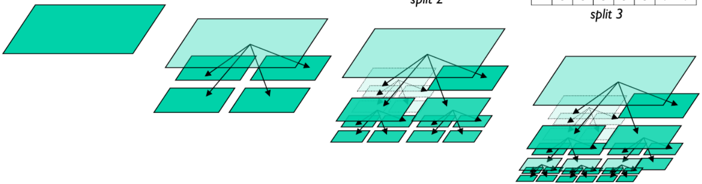
split 1

0	1	0	0	7	7	7	7
1	0	2	2	7	7	7	7
0	2	2	2	7	7	7	7
4	4	2	2	7	7	7	7
0	0	1	1	3	3	7	7
1	1	2	2	3	7	7	7
2	4	3	0	5	7	7	7
2	3	3	5	5	0	7	7

split 2

0	1	0	0	7	7	7	7
1	0	2	2	7	7	7	7
0	2	2	2	7	7	7	7
4	4	2	2	7	7	7	7
0	0	1	1	3	3	7	7
1	1	2	2	3	7	7	7
2	4	3	0	5	7	7	7
2	3	3	5	5	0	7	7

split 3



Region Based Segmentation

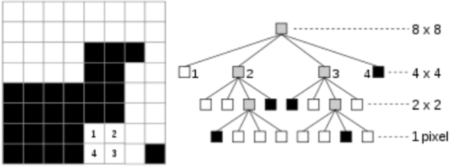
Split and Merge Method

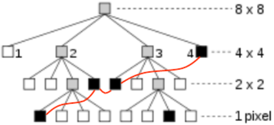
- Iterative technique that included both splitting and merging at each iteration
- If R_i is inhomogeneous, split R_i into four sub-regions
- If two adjacent region R_i and R_j are homogeneous, merge them
- The algorithm stops when no more merge or split is possible
- Produce more compact regions than just splitting

Region Based Segmentation

Split and Merge Method - Data Structure

- Quadtree for splitting
  Top-down approach,
  regions are split but not
  merged
- RAG(region adjacency
  graph)
  Split and merge iteratively
  at each iteration of
  quadtree partitioning
  RAG has quadtree
  embedded that represent 4
  relations
  4 adjacent relations(one
  per square side)

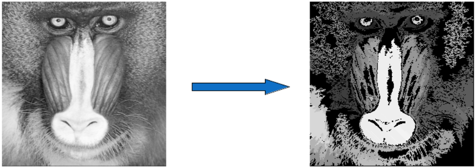




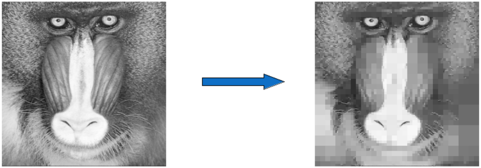
RAG with adjacency relations (in red) for big black region.

Region Based Segmentation

Region Growing

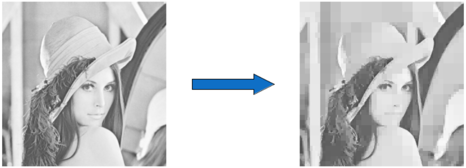


Split and Merge

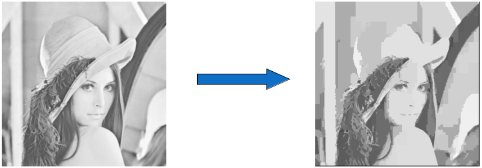


Region Based Segmentation

Splitting



Split and Merge



Clustering

Image Clustering vs. Image Segmentation

- In clustering the grouping is done in measurement space
- In segmentation the grouping is done in spatial domain

Approaches

- Threshold
- K-means
- Hierarchical clustering, Graph cut, ...

Clustering

- Grouping of pixels considering 1 or more features
- Grouping similar features, feature selection
- Spatial distribution of the pixels is not considered
- Feature space is considered
- Clusters has compact shape, spherical, ellipsoidal, elongated, ..
- A pixel belongs to a cluster based on a proximity measure (distance)
- Result may be subjective
- **Question**, how to choose the number of clusters in the image ?
- How many times N points can be assigned to N clusters ?

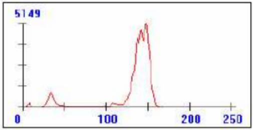
$$S(N,m) = \frac{1}{m!}\sum_{i=0}^{m}(-1)^{m-1}\binom{m}{i}i^N$$

$S(15,3) = 2,375,101,\ S(100,5) = 10^{68}$!!

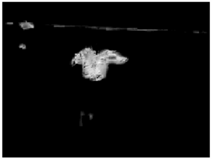
Clustering Techniques

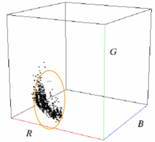
Thresholding

- Clustering in 1D $\rightarrow$ histogram analysis $\rightarrow$ thresholding



- Clustering in 2D, color image $\rightarrow$ color thresholding





Clustering Techniques

Thresholding

- Fixed or Global threshold: Threshold value is fixed through the image

- Local or Adaptive threshold: Two or more threshold is used through the image
  - Local or Adaptive threshold: Local threshold for small patches, Patch size (7×7), $P_{T_1} = \mu$, $P_{T_2} = \mu - 7$, $P_{T_3} = \mu - 10$

Clustering Techniques

Optimal Thresholding

- Isodata, Peak and valley, Otsu, p-tile,...
- **ISODATA** (Iterative Self-Organising Data Analysis Technique Algorithm):
  - $T_i = T_0$, median, maximum gray level, ...
  - Segmenting the histogram into two parts
  - Computing the mean value associated to each part (μ_1, μ_2)
  - New threshold, $T_{i+1} = (\mu_1 + \mu_2)/2$
  - Repeat until convergence, $T_i = T_{i-1}$