7. REGION BASED SEGMENTATION

Introduction

Whereas in edge-based segmentation we try to delineate object boundaries based on brightness discontinuities, i.e. edges; in region-based segmentation we try to group together pixels based on their *similarity*. The goal remains the same: "To partition an image into disjoined regions which correspond to objects or their parts."

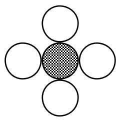
One of the key issues is the definition of "similarity" (also referred to as *homogeneity* or *uniformity*).

Definitions

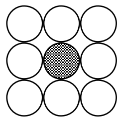
Region-based segmentation:- the partitioning of an image into set of mutually non-overlapping regions, each of which is maximum connected uniform region.

Connected region:- each element of the region is adjacent to at least one other element of this region (4 and 8 connectedness).

4-connected pixels



8-connected pixels



Uniformity (homogeneity):- a measure of being of the same kind; consisting of parts of the same kind; being uniform. For example, the simplest criterion of region uniformity is that all the pixels within it have the same grey level:

$$\forall\ p_i,p_j \in R\ \{\ p_i = p_j\ \}$$

Another example: pixels within the region differ by no more than a certain value t:

$$\forall\ p_i,p_j \in R\ \{\ |\ p_i - p_j\ | < t\ \}$$

Uniformity criteria can be based not only on pixel values, but on other, derived properties, such as for example: edge strength, shape simplicity, particular texture, ...

Uniform region:- a region whose every subset is uniform according to the same criterion.

Maximum connected uniform region:- no other pixel, adjacent to the region, can be added to it without the region becoming non-uniform.

Overview of region based segmentation methods

The most common classification of the region based segmentation techniques is into global and local:

- global - pixels are grouped into regions on the basis of properties (normally statistical properties) of a large population of pixels.
- local - pixels are assigned to regions on the basis of properties of their close neighbours.

Pixel classification - global methods

Region segmentation can be considered to be a process of pixel classification - the picture is segmented into subsets by assigning the individual pixels to classes. In global methods the choice of the class depends on the global properties (statistics) of the image.

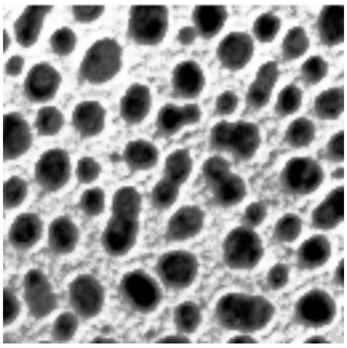
Thresholding

We have already come across thresholding in Unit 1. Thresholding is the simplest case of classification: it uses single property and assigns pixels into one of the two classes.
- the classes being normally object(s) and a background
- the property being normally grey level (but not necessarily)

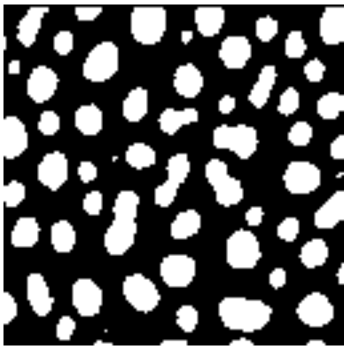
The main problem is to find a threshold value which would separate the two classes.
The simplest solution is to build a histogram and find the valley between two peaks (why?)
There exist methods for automatic threshold selection (see, e.g. Sonka, section 5.1.1).

Multi-level thresholding

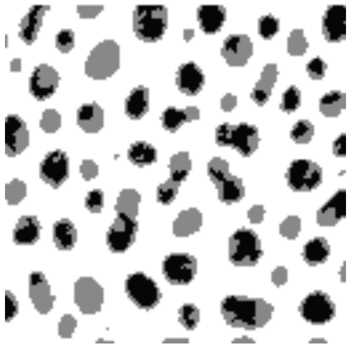
Multi-thresholding is segmentation into more than two classes; it is an example of classification according to single property, into many classes.



Original image



Thresholded image showing cell bodies in white



Multi-thresholded image showing cell bodies (grey) and nuclei (black)

General classification methods

Thresholding is just one, very simple, example of pixel classification. In general, the task is to assign each pixel to a class. Classes and their properties may or may be not known in advance. Classes can be determined in spatial domain or in a feature domain (statistical classification). Classification methods are not unique to pixel classification and are just briefly reviewed here. The methods are normally classified :-) as follows:

Statistical classification

supervised classification (classes are known in advance)
- user selects a group of representative pixels from each known class
- a classification algorithm determines characteristics of each class
- each pixel is then assigned to the most likely class
- stages: training and classification

unsupervised classification (classes are not known in advance)
- the classes are determined by the algorithm, for example by locating clusters in a feature space
- each cluster is assumed to correspond to a class
- each pixel is then assigned to a most likely class

Feature spaces used in pixel classification

- histogram is a 1-dimensional feature space; a “feature” under consideration is grey level

- scatter plot - 2 (or more) - dimensional histogram
- examples of 2D scatter plots
  - grey level v/s average grey level in the neighbourhood
  - intensity of red v/s intensity of blue
  - grey level v/s grey level difference.

Pixel aggregation or partitioning - local methods

Sequential segmentation

Whereas most global methods classify pixels on the basis of the statistics of the whole population of pixels, the so-called sequential methods classify pixels or their groups one at a time, normally taking into account the result of classification of the pixels already classified. Sequential segmentation can proceed either “bottom-up” or “top-down”.

Bottom-up

These methods rely on region aggregation, i.e. “growing” object in all directions. The following steps are executed:

- find starting pixels (these are normally pixels in the centre of statistically-uniform regions)
- examine all the pixels adjacent to those already selected
- incorporate those adjacent pixels for which a uniformity criterion is met
- terminate if no more candidates found

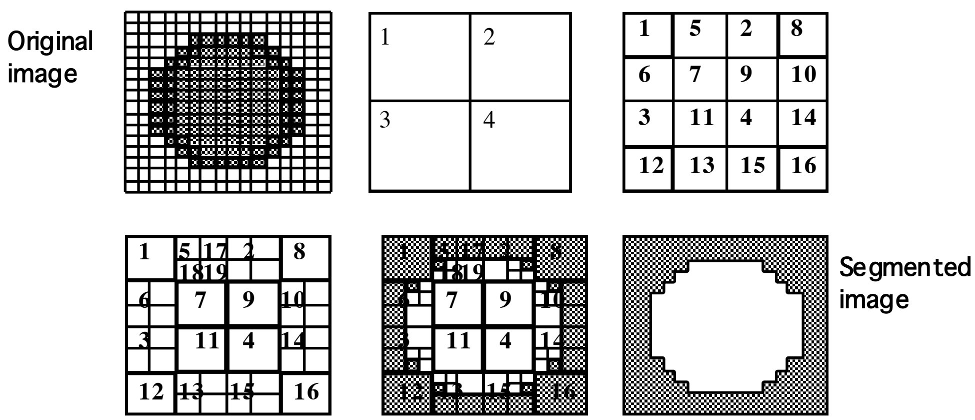
Results of segmentation depend on the choice of starting points and on the order in which pixels or regions are added. The output of the segmentation process is normally pictorial, i.e. it is a label image. A simple “blob colouring” technique is described during the lecture.

Top-down

In bottom-up methods we start with a pixel (or a primitive region) and merge (link, grow) to obtain a larger region. In top-down methods we start from an entire image and *partition* (split) it into uniform regions. Partitioning usually uses a regular tessellation (e.g. at each sub-division a region is split into four further sub-regions, as in the example below (top of the next page).

Combined methods

- start on an intermediate level
- first merge then split the regions
- Example: split and merge method



Notes:

Iterative segmentation (*relaxation*)

Relaxation methods of segmentation are statistically based; in the process of segmentation the assumptions as to whether a pixel belongs to a given class are made progressively less strict - or more and more relaxed - hence the name. The outline of a relaxation algorithm is usually as follows:

- Input is a set of probabilities that each pixel belongs to each possible class;
- During each iteration, these probabilities are updated; criteria for changing probabilities are:
  - possible class assignments of neighbours
  - probabilities of these assignments
  - measure of compatibility of the pixel's and the neighbour's assignment.

Pre- and post-processing

Pixel classification methods often produce objects with irregular boundaries and spurious "holes", and "noise" in the background. There are two strategies for dealing with this problem.

If noise is a problem, smoothing applied prior to segmentation can often solve it completely. Although smoothing blurs the edges, if the Gaussian-based methods are used, the boundary location is usually not affected (see Unit 4, properties of Zero Crossing).

Alternatively, segmentation can be followed by noise removal and boundary smoothing applied to the segmented image, for example through:

- median filtering of the thresholded image
- min/max filtering of the thresholded image
- morphological methods: erosion and dilation (see Unit on Mathematical Morphology)

See the effect of image smoothing before thresholding:


Original image


Original after thresholding


Smoothed original after thresholding

Further reading and exploration

Sonka et al, Sections 7.3 and 7.4.
Gonzalez & Woods, Chapter 5.
Umbaugh, Sections 2.4.1 - 2.4.4.

HIPR

Point Operations:
- Thresholding
- Adaptive Thresholding

Image Analysis:
- Classification
- Connected Components Labelling

CVIP

Analysis -> Segmentation
- Explore all the methods, refer to Umbaugh's book

EXERCISES

1. In image bham.tif, segment out the sky.
2. In image cells.tif, segment out the cells
3. In image mcells.tif, segment out all bright cells. Make sure that each cell is separated from the others.
4. In image board.tif
   - segment out the entire board from the background
   - segment out only the chips on the board
   - segment out both the board and the chips.