Digital Image Processing

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Topic

- Image Segmentation
  - Thresholding
  - Region-Based Segmentation
  - Morphological Watersheds
  - K-means

Introduction

The shape of an object can be described in terms of:

- Its boundary – requires image edge detection
- The region it occupies – requires image segmentation in homogeneous regions, Image regions generally have homogeneous characteristics (e.g. intensity, texture)

Introduction

- The goal of Image Segmentation is to find regions that represent objects or meaningful parts of objects. Major problems of image segmentation are result of noise in the image.
- An image domain X must be segmented in N different regions R(1),...,R(N)
- The segmentation rule is a logical predicate of the form P(R)

Introduction

- Image segmentation partitions the set X into the subsets R(i), i=1,…,N having the following properties
  - X = i=1,..N U R(i)
  - R(i) ∩ R(j) = 0 for I ≠ j
  - P(R(i)) = TRUE for i = 1,2,…,N
  - P(R(i) U R(j)) = FALSE for i ≠ j

Introduction

- The segmentation result is a logical predicate of the form P(R,x,t)
- x is a feature vector associated with an image pixel
- t is a set of parameters (usually thresholds) A simple segmentation rule has the form:

$$P(R) : I(r,c) < T$$

Introduction

- In the case of color images the feature vector x can be three RGB image components {IR(r,c),IG(r,c),IB(r,c)
- A simple segmentation rule may have the form:

  P(R,x,t) : (IR(r,c) <T(R)) && (IG(r,c)<T(G))&&
  (IB(r,c) < T(B))

Image Segmentation

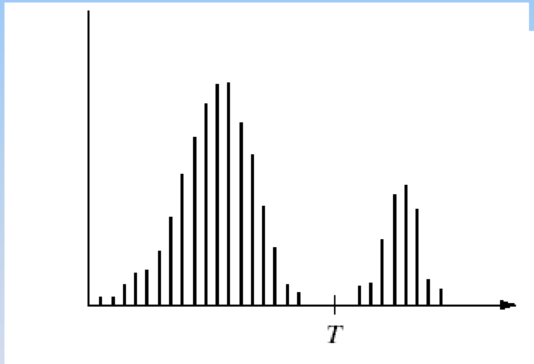
- Group similar components (such as, pixels in an image, image frames in a video) to obtain a compact representation.
- Applications: Finding tumors, veins, etc. in medical images, finding targets in satellite/aerial images, finding people in surveillance images, summarizing video, etc.
- Methods: Thresholding, region growing, watershed, meanshift, etc.

Image Segmentation

- Segmentation algorithms for monochrome images generally are based on one of two basic properties of gray-scale values:
  - Discontinuity
    - The approach is to partition an image based on abrupt changes in gray-scale levels.
    - The principal areas of interest within this category are detection of isolated points, lines, and edges in an image.
  - Similarity
    - The principal approaches in this category are based on thresholding, region growing, and region splitting/merging.

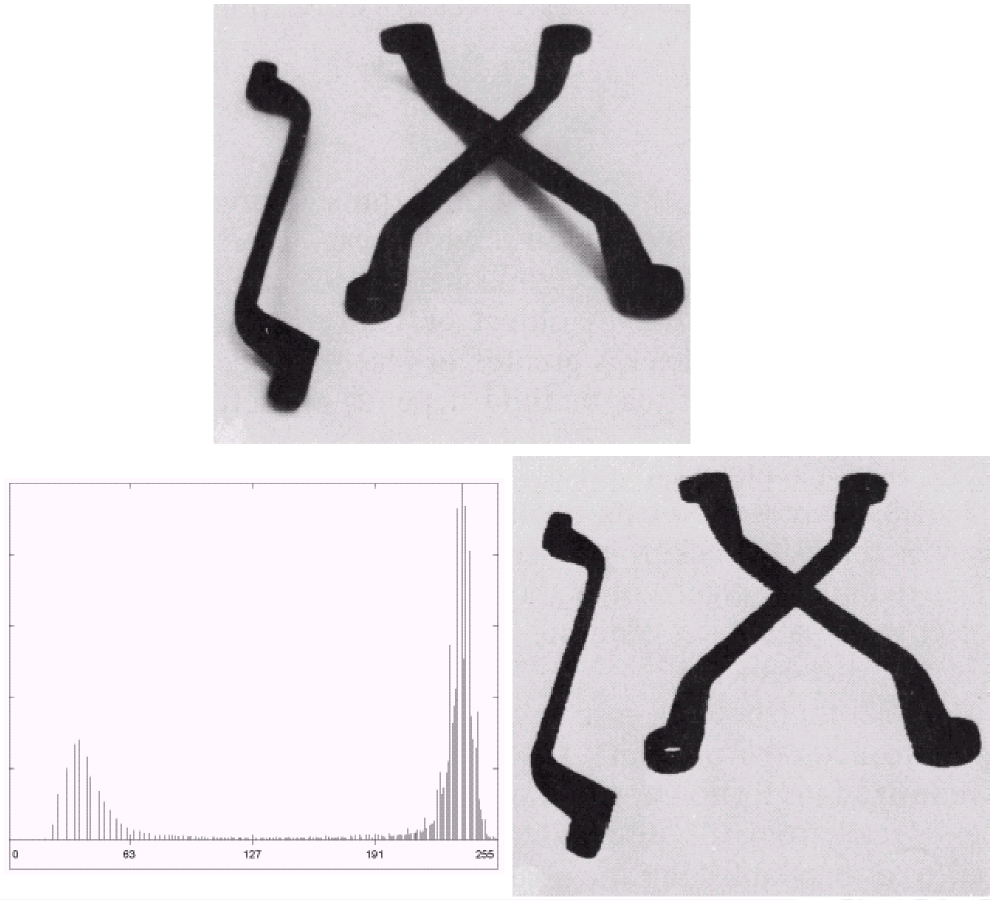
Thresholding

- Suppose that an image, f(x, y), is composed of light objects on a dark background, and the following figure is the histogram of the image.



- Then, the objects can be extracted by comparing pixel values with a threshold T.

Thresholding



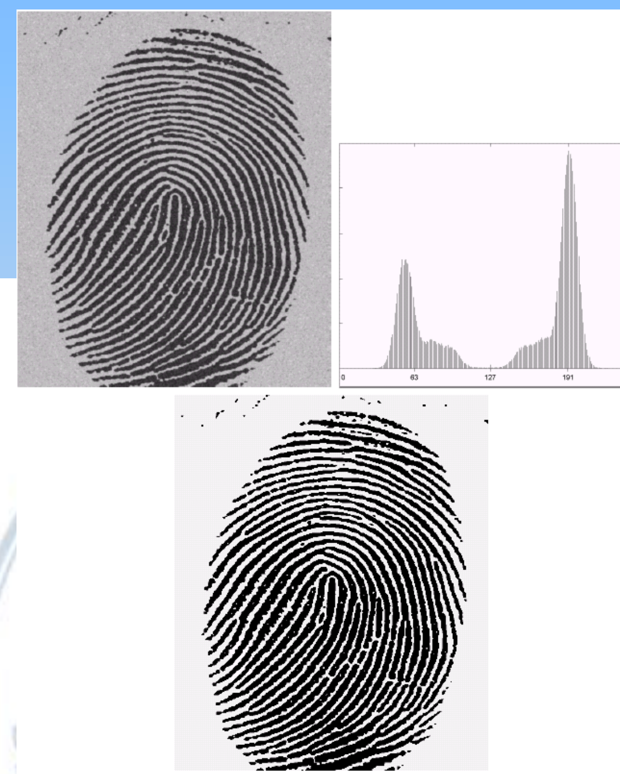
a
b c

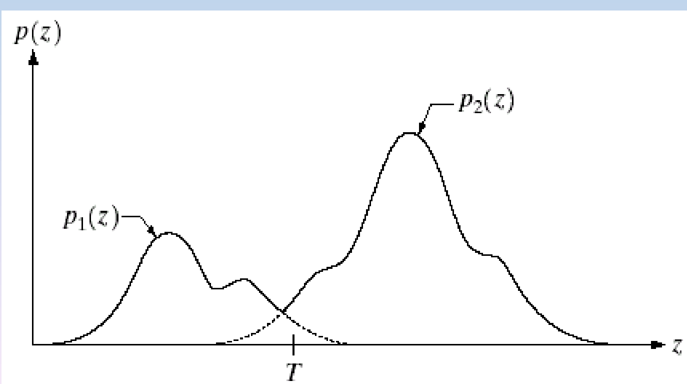
FIGURE 10.28 (a) Original image. (b) Image histogram. (c) Result of global thresholding with *T* midway between the maximum and minimum gray levels.

Finding thresholds

There are many methods to automatically find the optimum (in some sense) threshold from a histrogram,

Note that there will often be misclassified pixels, they have to be handled when forming the regions.





Basic Global Thresholding

1. Based on visual inspection of histogram, select an initial estimate for T.
2. Segment the image using T. This will produce two groups of pixels: G_1 consisting of all pixels with gray level values > T and G_2 consisting of pixels with gray level values ≤ T
3. Compute the average gray level values μ_1 and μ_2 for the pixels in regions G_1 and G_2
4. Compute a new threshold value

$$T = 0.5\,(\mu_1 + \mu_2)$$

5. Repeat steps 2 through 4 until the difference in T in successive iterations is smaller than a predefined parameter T_o.

Otsu’s Method

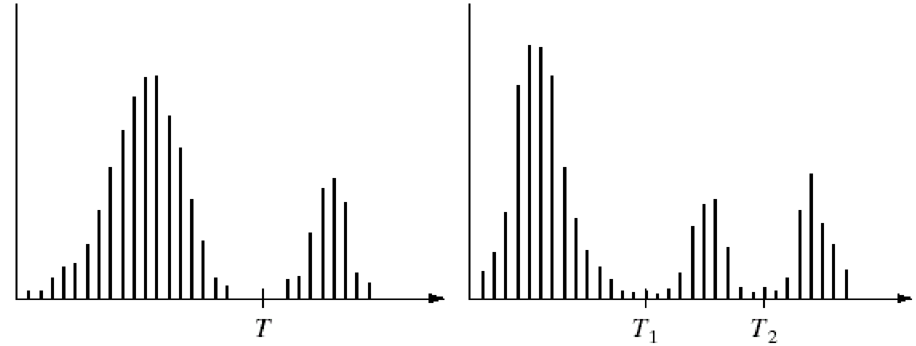
- The optimal global thresholding
- Core idea:

Maximize the distance between two groups.

Please refer to the textbook ch10.3.3 for details.

Thresholding

- It is also possible to extract objects that have a specific intensity range using multiple thresholds.



a b

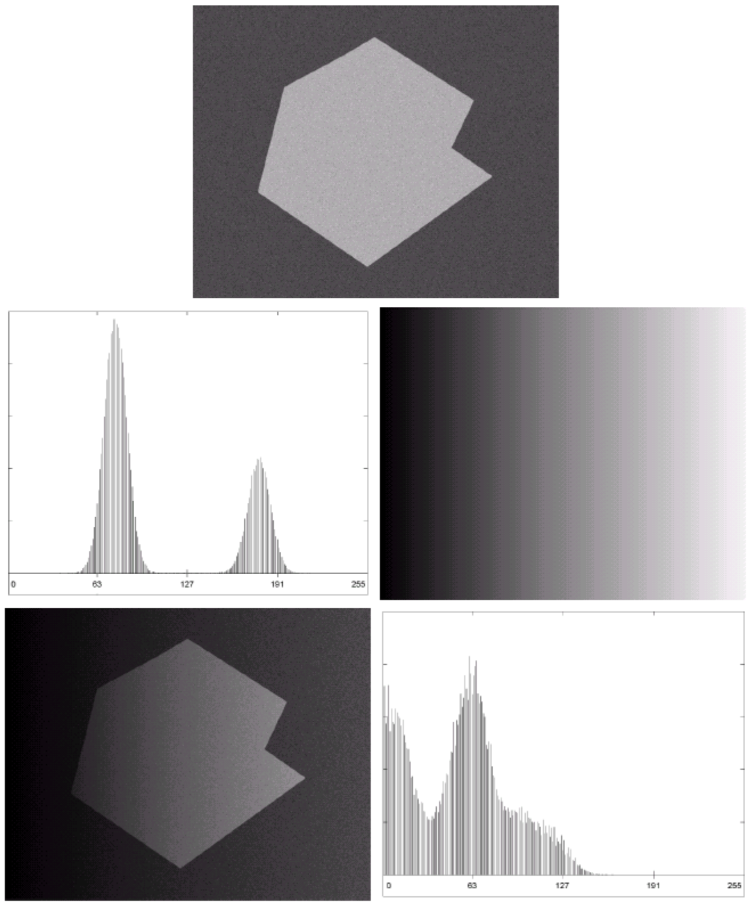
FIGURE 10.26 (a) Gray-level histograms that can be partitioned by (a) a single threshold, and (b) multiple thresholds.

Extension to color images is straightforward: There are three color channels, in each one specify the intensity range of the object... Even if objects are not separated in a single channel, they might be with all the channels... Application example: Detecting/Tracking faces based on skin color...

Thresholding

- Non-uniform illumination may change the histogram in a way that it becomes impossible to segment the image using a single global threshold.
- Choosing local threshold values may help.

Thresholding



a
b c
d e

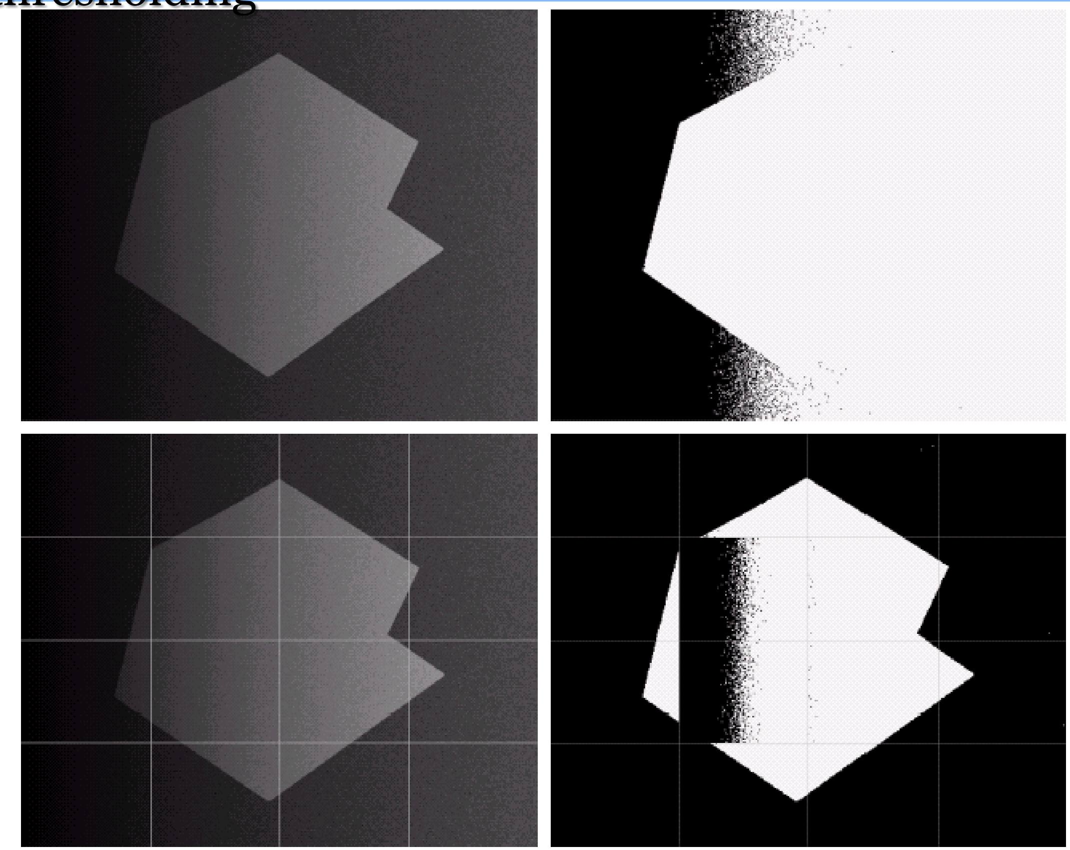
FIGURE 10.27
(a) Computer generated reflectance function.
(b) Histogram of reflectance function.
(c) Computer generated illumination function.
(d) Product of (a) and (c).
(e) Histogram of product image.

Thresholding

- Adaptive thresholding

a b
c d

FIGURE 10.30 (a) Original image. (b) Result of global thresholding. (c) Image subdivided into individual subimages. (d) Result of adaptive thresholding.



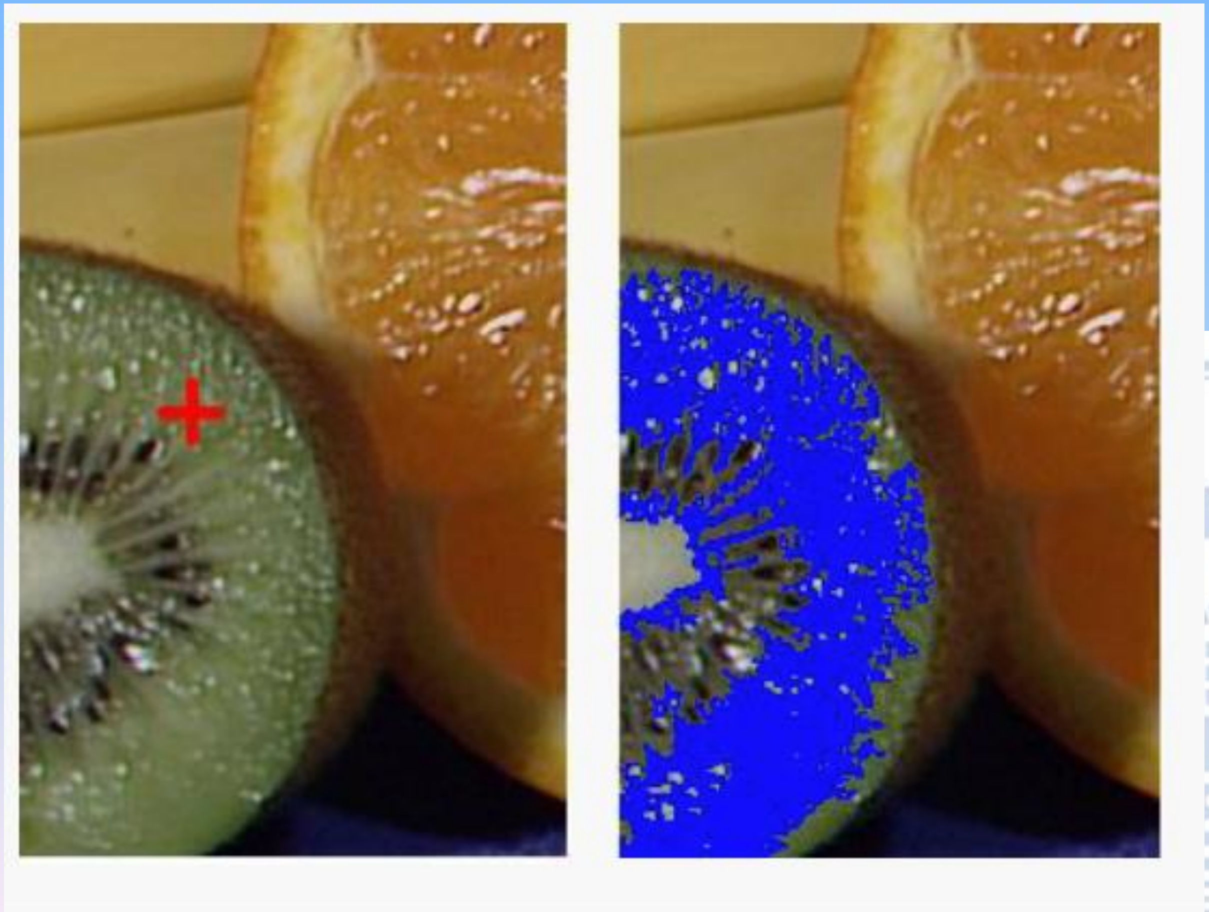
Basic Adaptive Thresholding

- Subdivide original image into small areas.
- Utilize a different threshold to segment each subimages.
- Since the threshold used for each pixel depends on the location of the pixel in terms of the subimages, this type of thresholding is adaptive.

Region-Oriented Segmentation

- Region Growing
  - Region growing is a procedure that groups pixels or subregions into larger regions.
  - The simplest of these approaches is pixel aggregation, which starts with a set of "seed" points and from these grows regions by appending to each seed points those neighboring pixels that have similar properties (such as gray level, texture, color, shape).

Results – Region grow



select all seed points with gray level 255

Region Growing

a b
c d

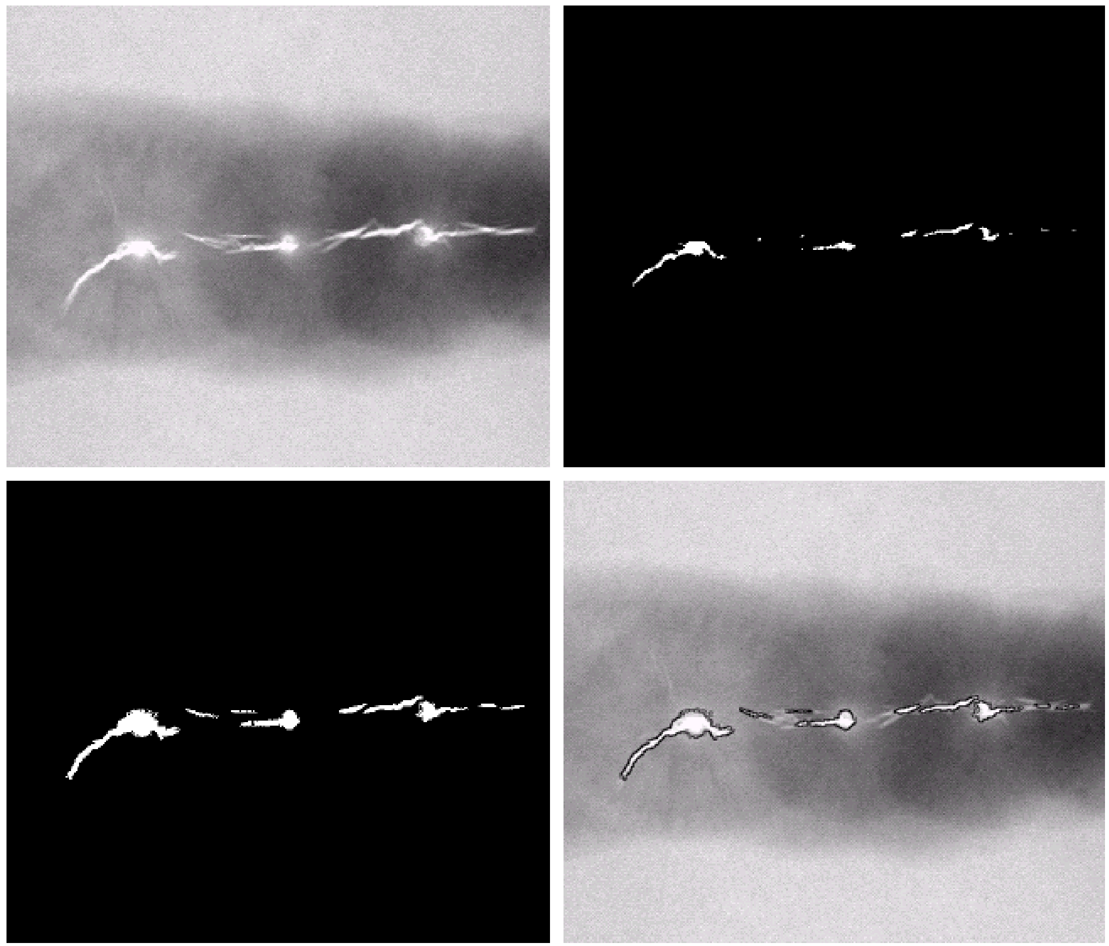


FIGURE 10.40 (a) Image showing defective welds. (b) Seed points. (c) Result of region growing. (d) Boundaries of segmented defective welds (in black). (Original image courtesy of X-TEK Systems, Ltd.).

Region-Oriented Segmentation

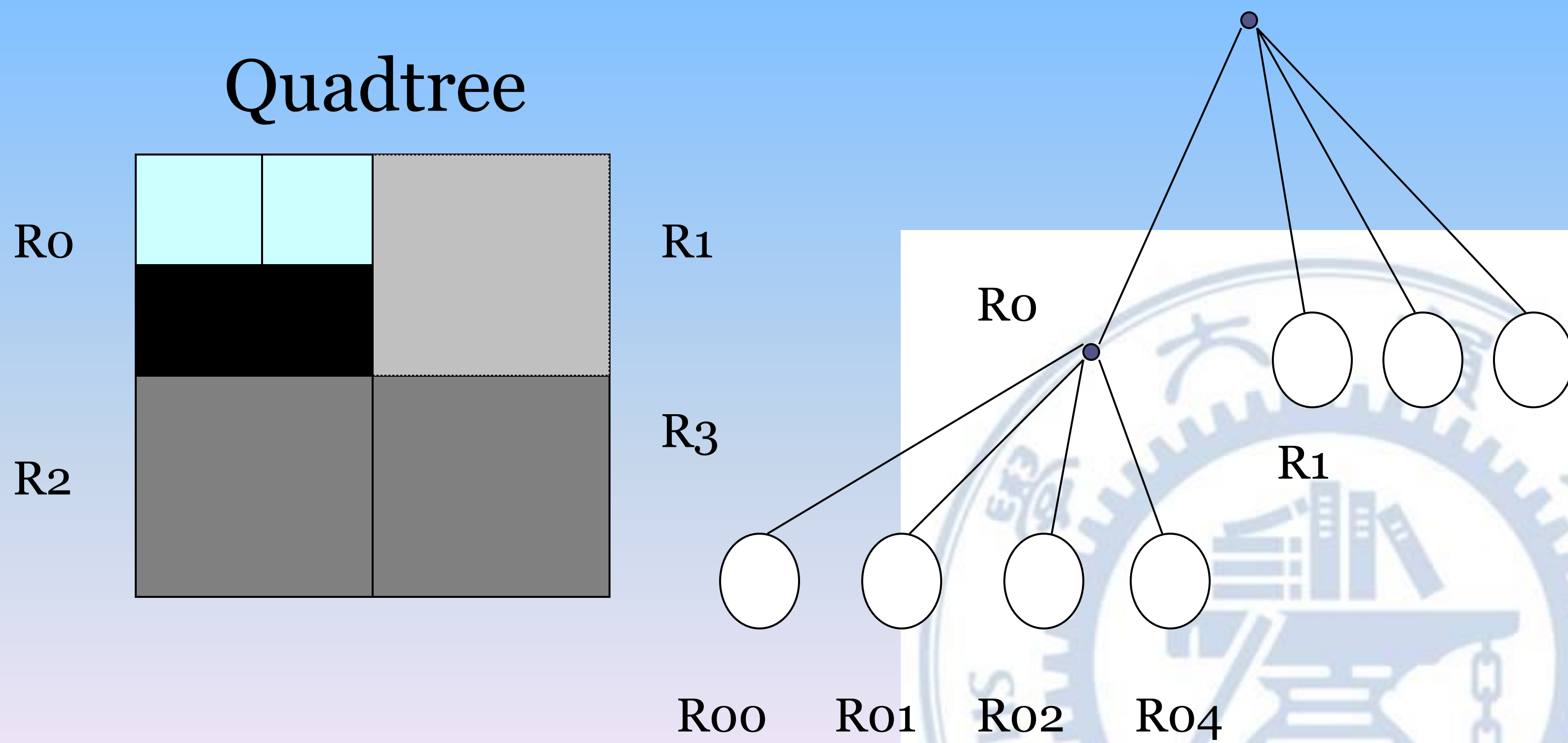
- Split / Merge
  - The opposite approach to region growing is region shrinking (splitting).
  - It is a top-down approach and it starts with the assumption that the entire image is homogeneous
  - If this is not true , the image is split into four sub images
  - This splitting procedure is repeated recursively until we split the image into homogeneous regions

Region-Oriented Segmentation

- Split / Merge
  - If the original image is square N x N, having dimensions that are powers of 2(N = 2n):
  - All regions produced but the splitting algorithm are squares having dimensions M x M , where M is a power of 2 as well (M=2m,M<= n).
  - Since the procedure is recursive, it produces an image representation that can be described by a tree whose nodes have four sons each
  - Such a tree is called a Quadtree.

Region-Oriented Segmentation

Quadtree

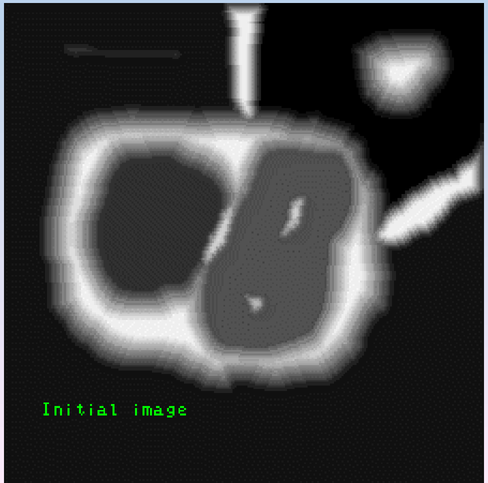


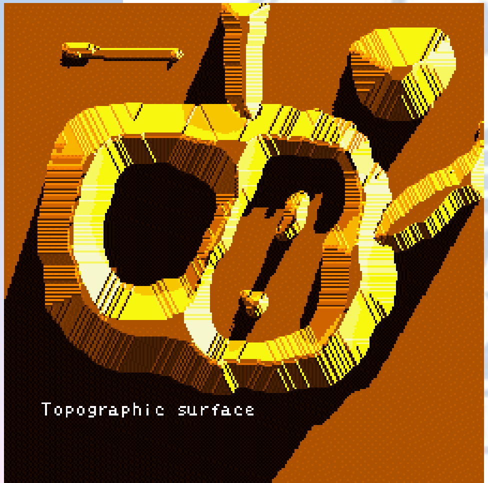
Region-Oriented Segmentation

- Split / Merge
  - Splitting techniques disadvantage, they create regions that may be adjacent and homogeneous, but not merged.
  - Split and Merge method – It is an iterative algorithm that includes both splitting and merging at each iteration
  - If a region R is inhomogeneous (P(R)= False) then is split into four sub regions
  - If two adjacent regions Ri,Rj are homogeneous (P(Ri U Rj) = TRUE), they are merged
  - The algorithm stops when no further splitting or merging is possible
  - The split and merge algorithm produces more compact regions than the pure splitting algorithm

Watershed Segmentation Algorithm

- Visualize an image in 3D: spatial coordinates and gray levels.
- In such a topographic interpretation, there are 3 types of points:
  - Points belonging to a regional minimum
  - Points at which a drop of water would fall to a single minimum. (→The *catchment basin* or *watershed* of that minimum.)
  - Points at which a drop of water would be equally likely to fall to more than one minimum. (→The *divide lines* or *watershed lines*.)





Watershed Segmentation Algorithm

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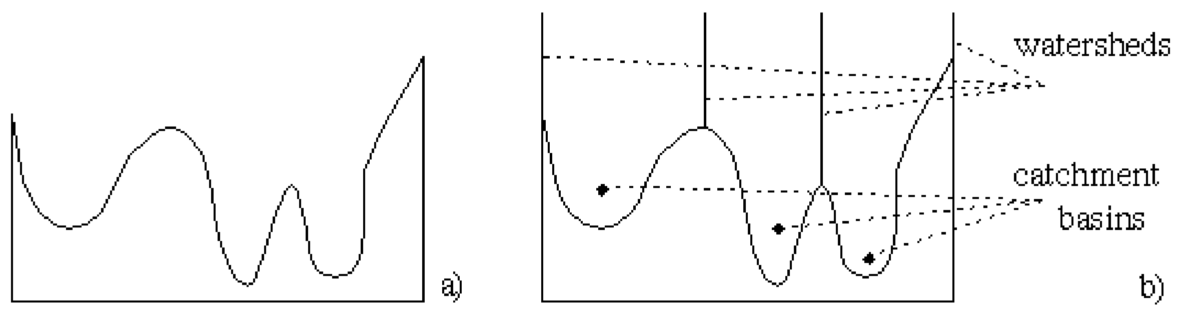
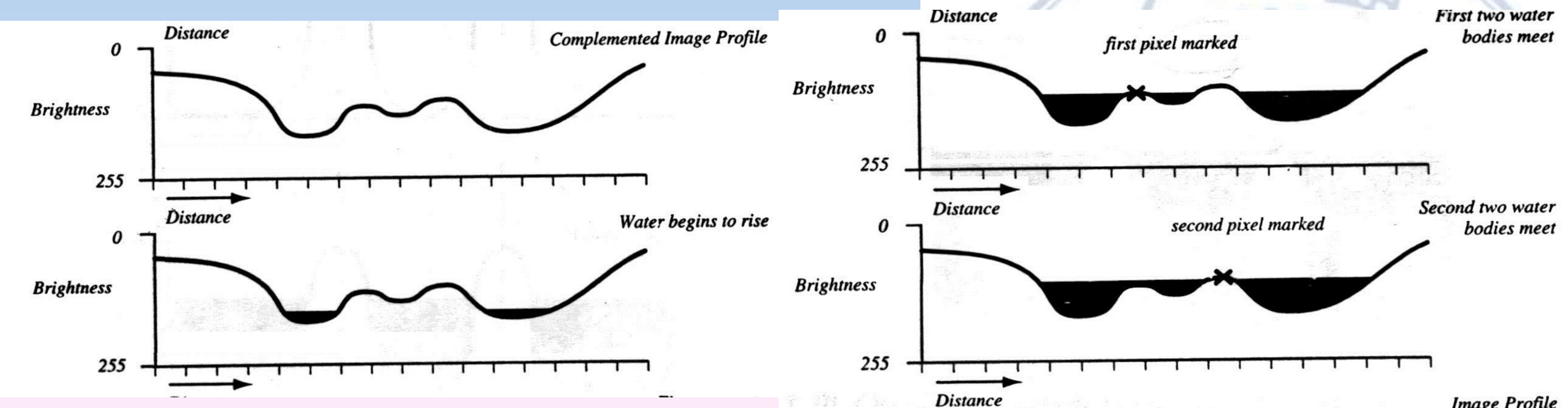
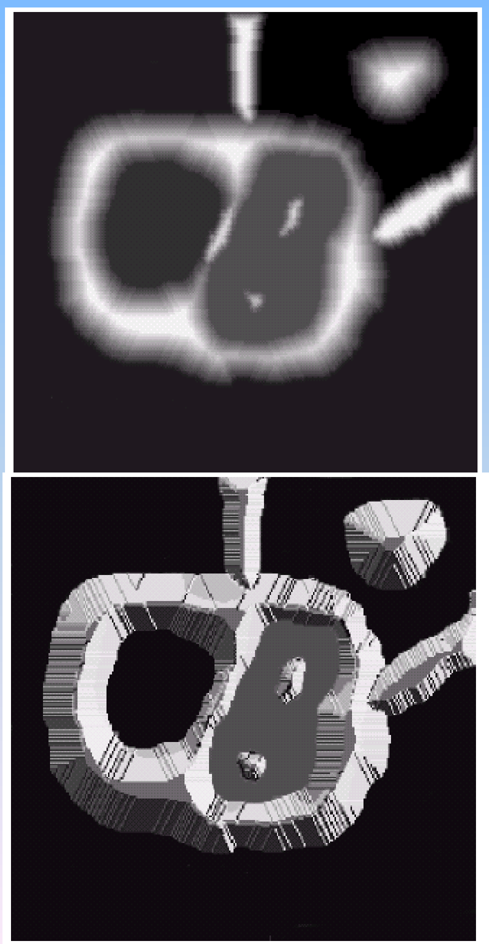


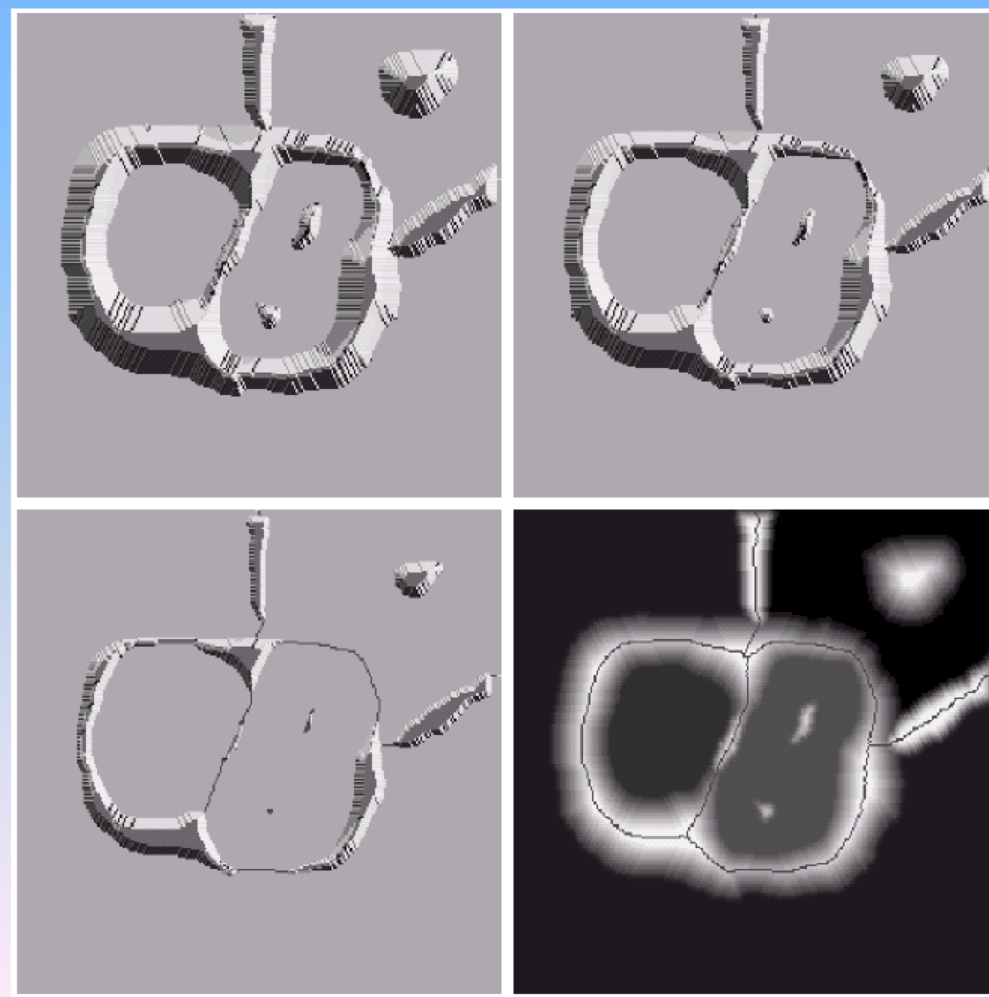
Watershed Segmentation Algorithm

- The objective is to find watershed lines.
- The idea is simple:
  - Suppose that a hole is punched in each regional minimum and that the entire topography is flooded from below by letting water rise through the holes at a uniform rate.
  - When rising water in distinct catchment basins is about the merge, a dam is built to prevent merging. These dam boundaries correspond to the watershed lines.



Watershed Segmentation Algorithm





e	f
g	h

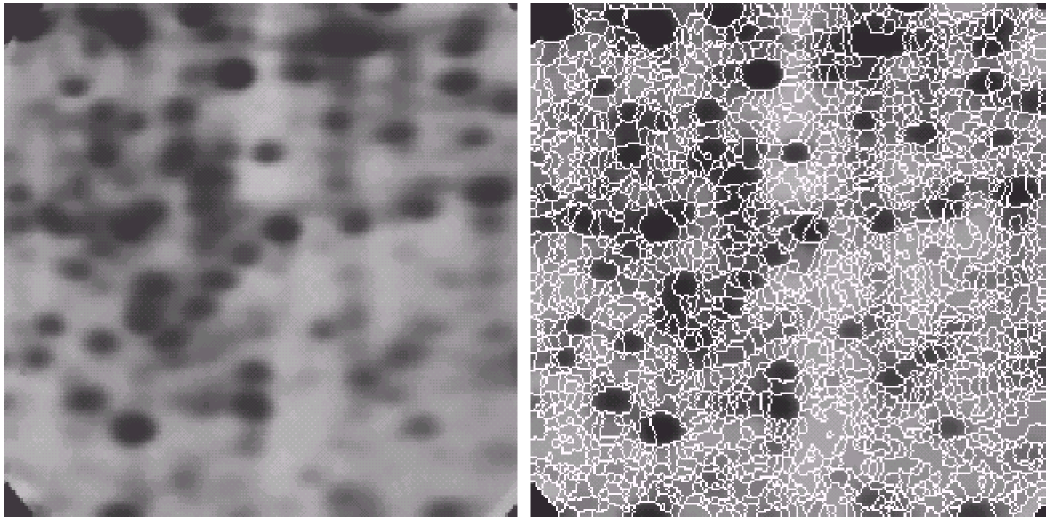
FIGURE 10.44 *(Continued)* (e) Result of further flooding. (f) Beginning of merging of water from two catchment basins (a short dam was built between them). (g) Longer dams. (h) Final watershed (segmentation) lines. (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)

Watershed Segmentation Algorithm

- Start with all pixels with the lowest possible value.
  - These form the basis for initial watersheds
- For each intensity level k:
  - For each group of pixels of intensity k
    - If adjacent to exactly one existing region, add these pixels to that region
    - Else if adjacent to more than one existing regions, mark as boundary
    - Else start a new region

Watershed Segmentation Algorithm

Due to noise and other local irregularities of the gradient, oversegmentation might occur.

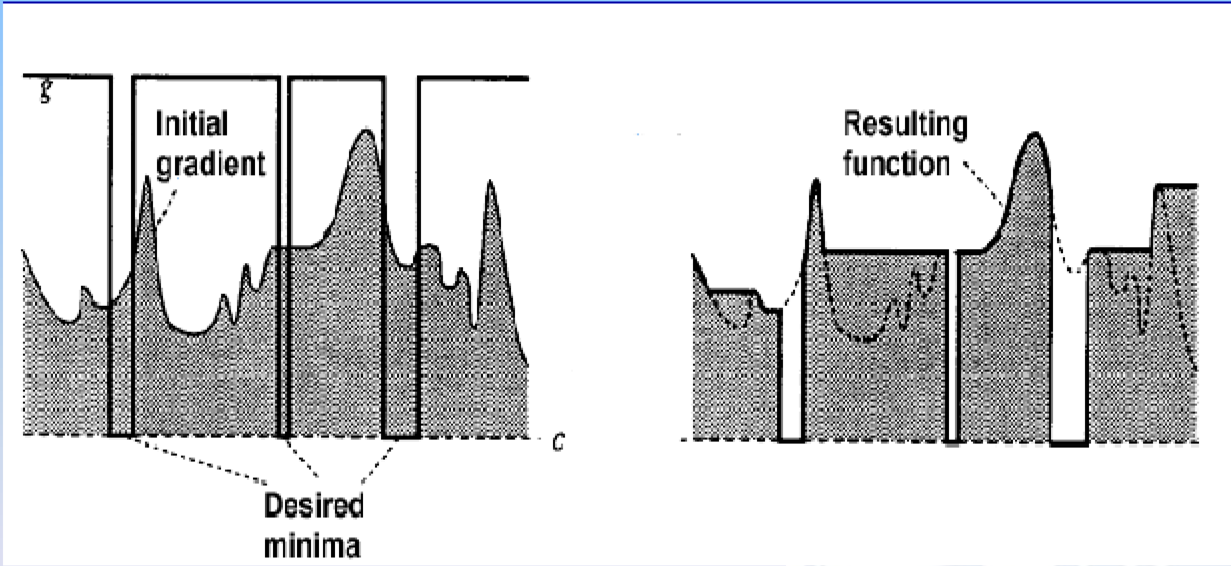


a b

FIGURE 10.47 (a) Electrophoresis image. (b) Result of applying the watershed segmentation algorithm to the gradient image. Oversegmentation is evident. (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)

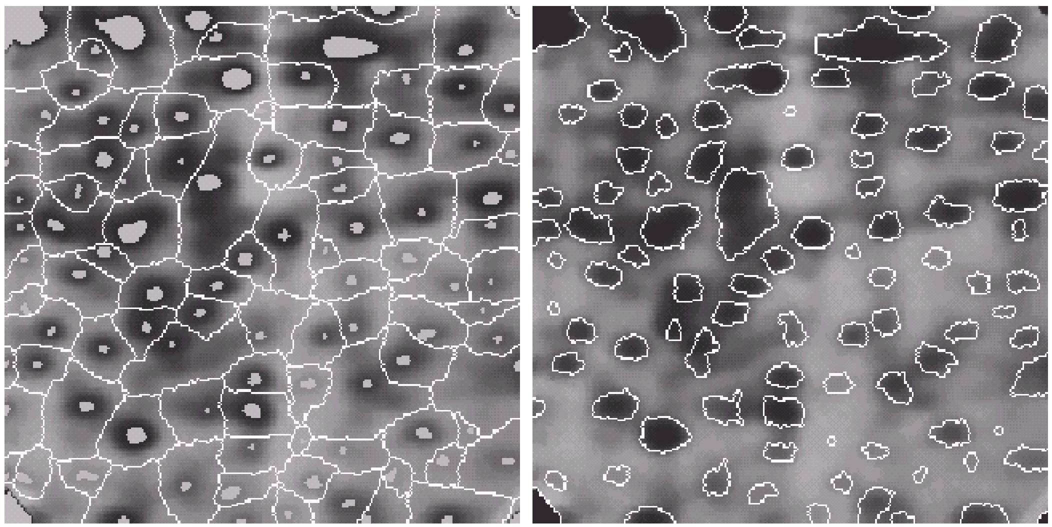
Watershed Segmentation Algorithm

A solution is to limit the number of regional minima. Use markers to specify the only allowed regional minima.



Watershed Segmentation Algorithm

A solution is to limit the number of regional minima. Use markers to specify the only allowed regional minima. (For example, gray-level values might be used as a marker.)



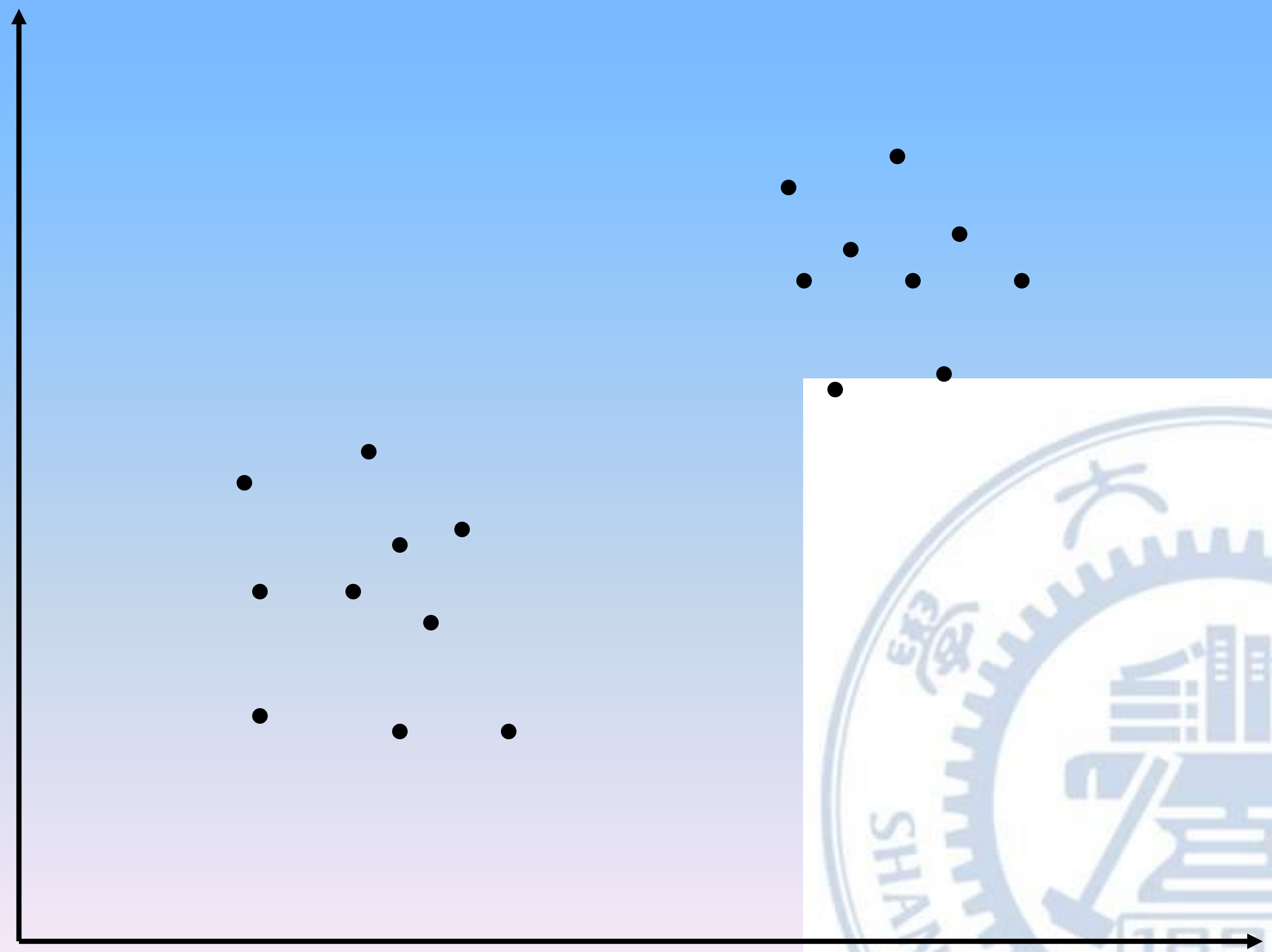
a b

FIGURE 10.48 (a) Image showing internal markers (light gray regions) and external markers (watershed lines). (b) Result of segmentation. Note the improvement over Fig. 10.47(b). (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)

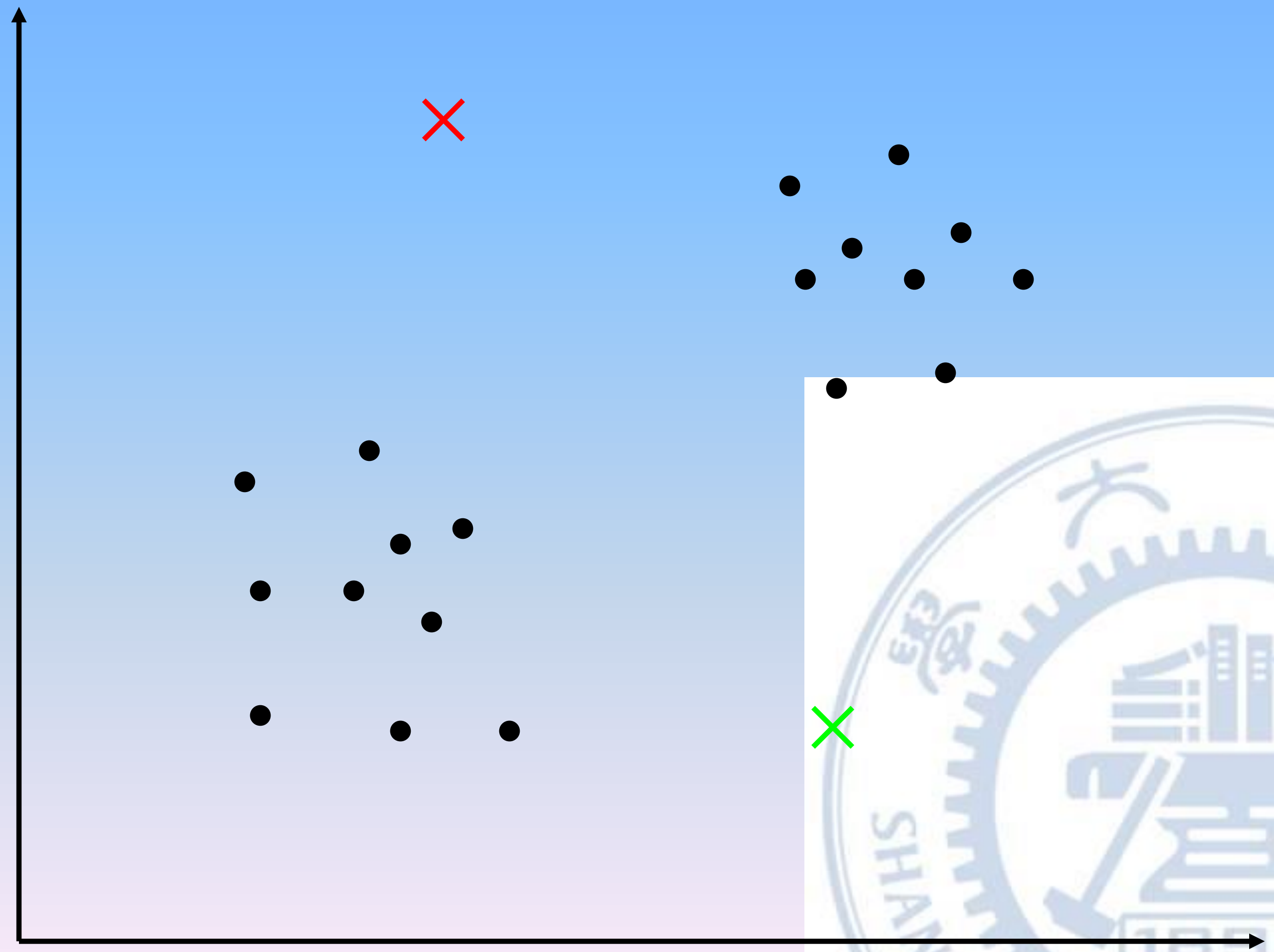
K-Means Clustering

1. Partition the data points into K clusters randomly. Find the centroids of each cluster.
2. For each data point:
   - Calculate the distance from the data point to each cluster.
   - Assign the data point to the closest cluster.
3. Recompute the centroid of each cluster.
4. Repeat steps 2 and 3 until there is no further change in the assignment of data points (or in the centroids).

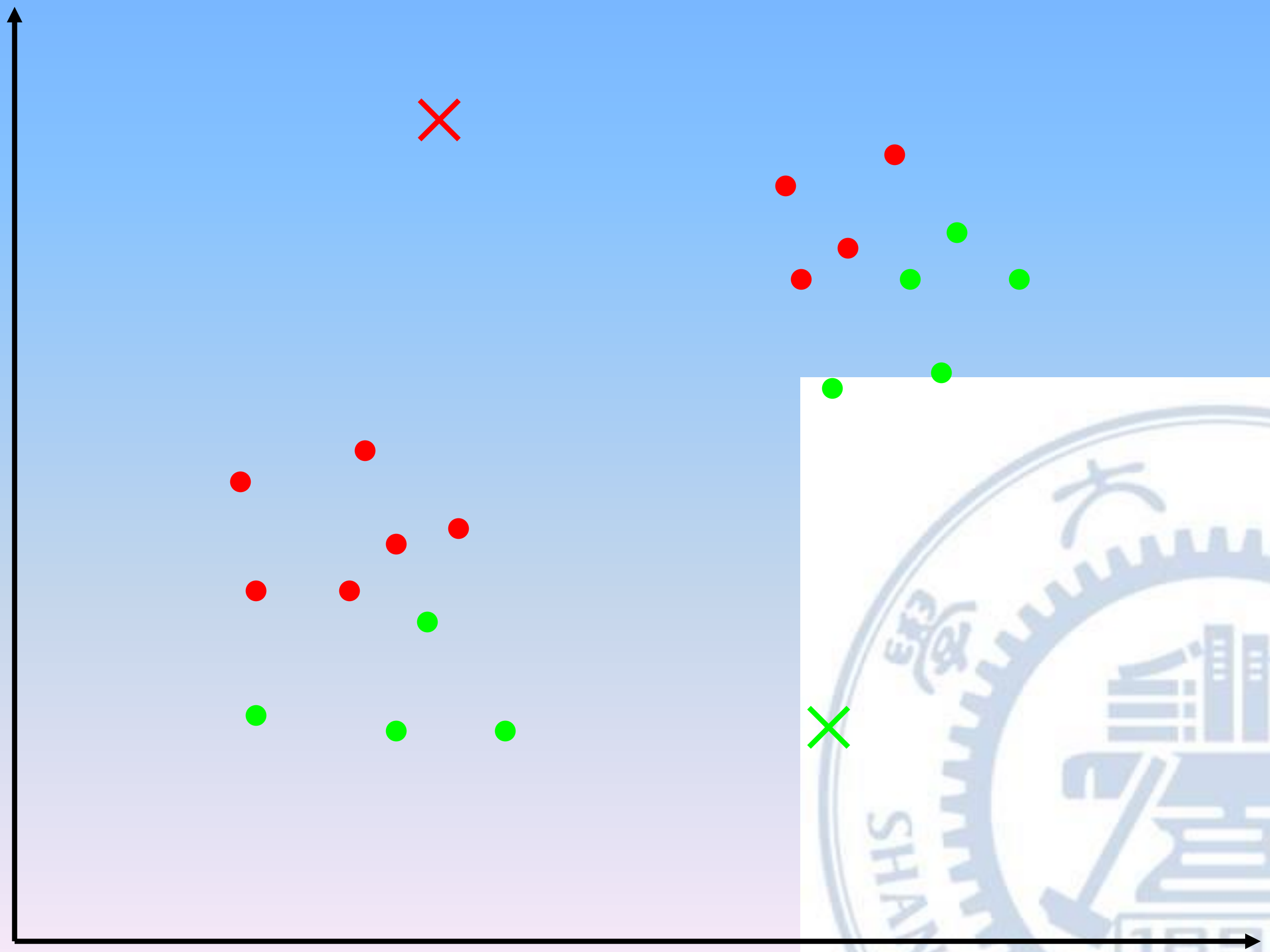
K-Means Clustering



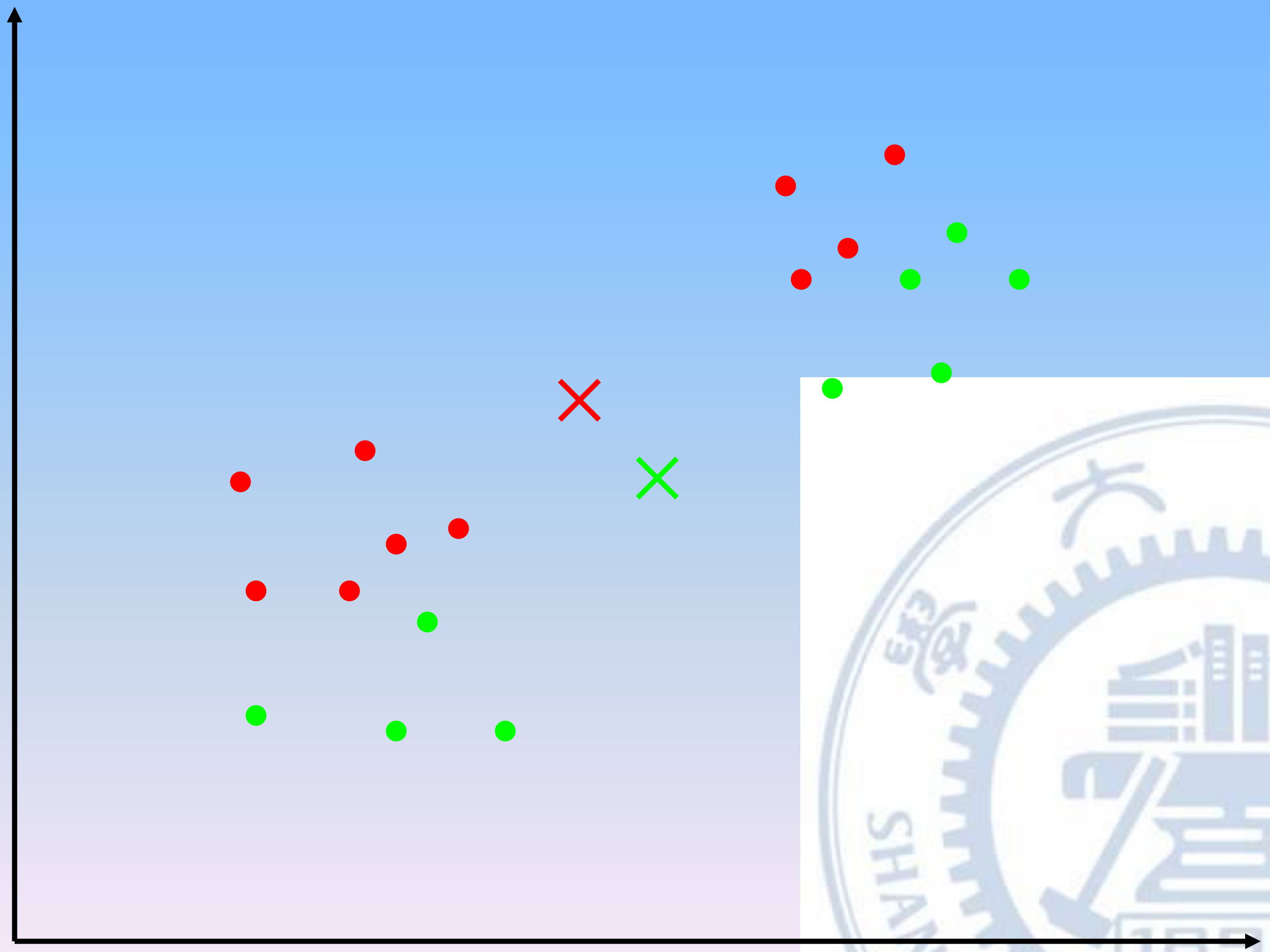
K-Means Clustering



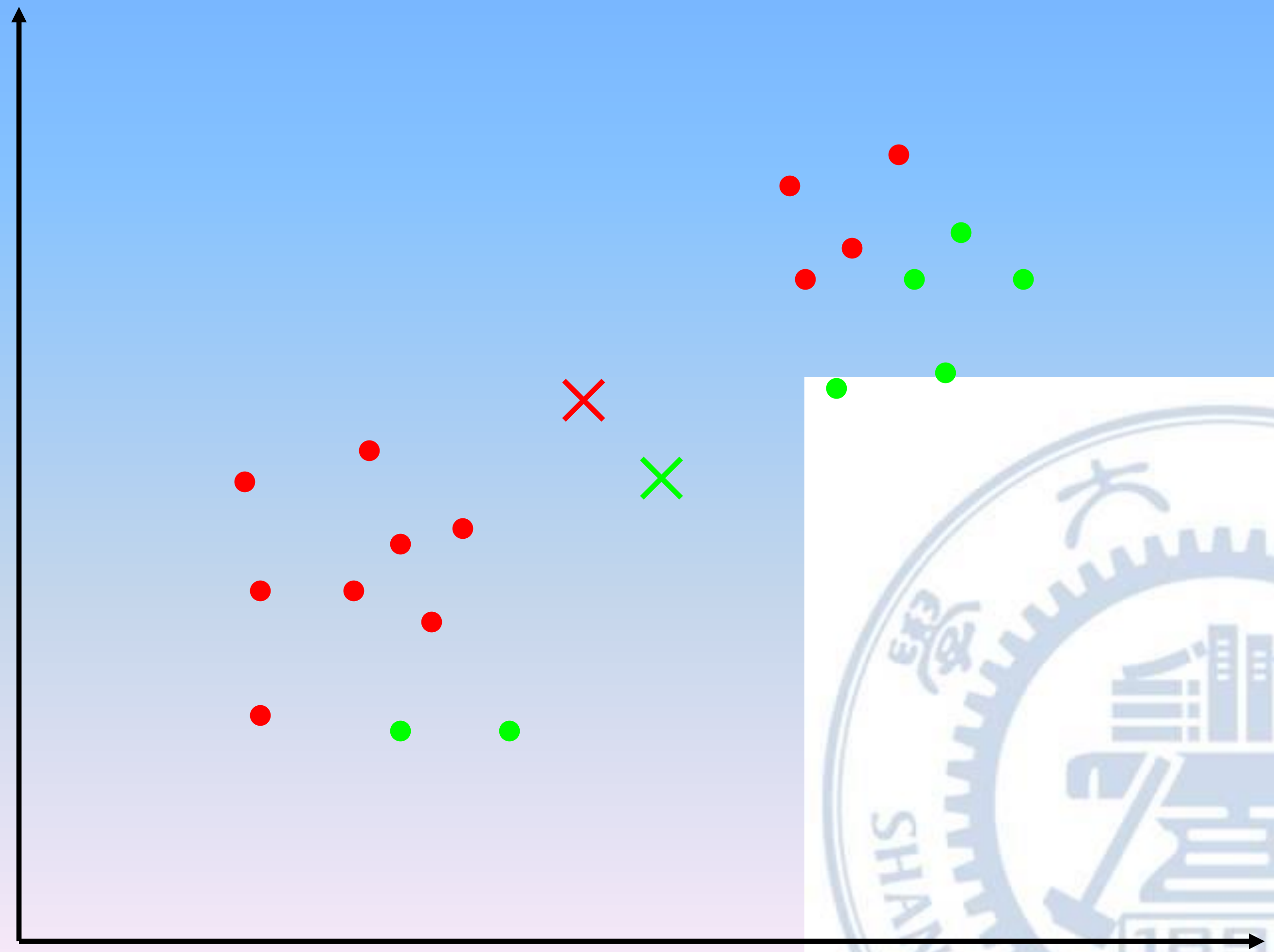
K-Means Clustering



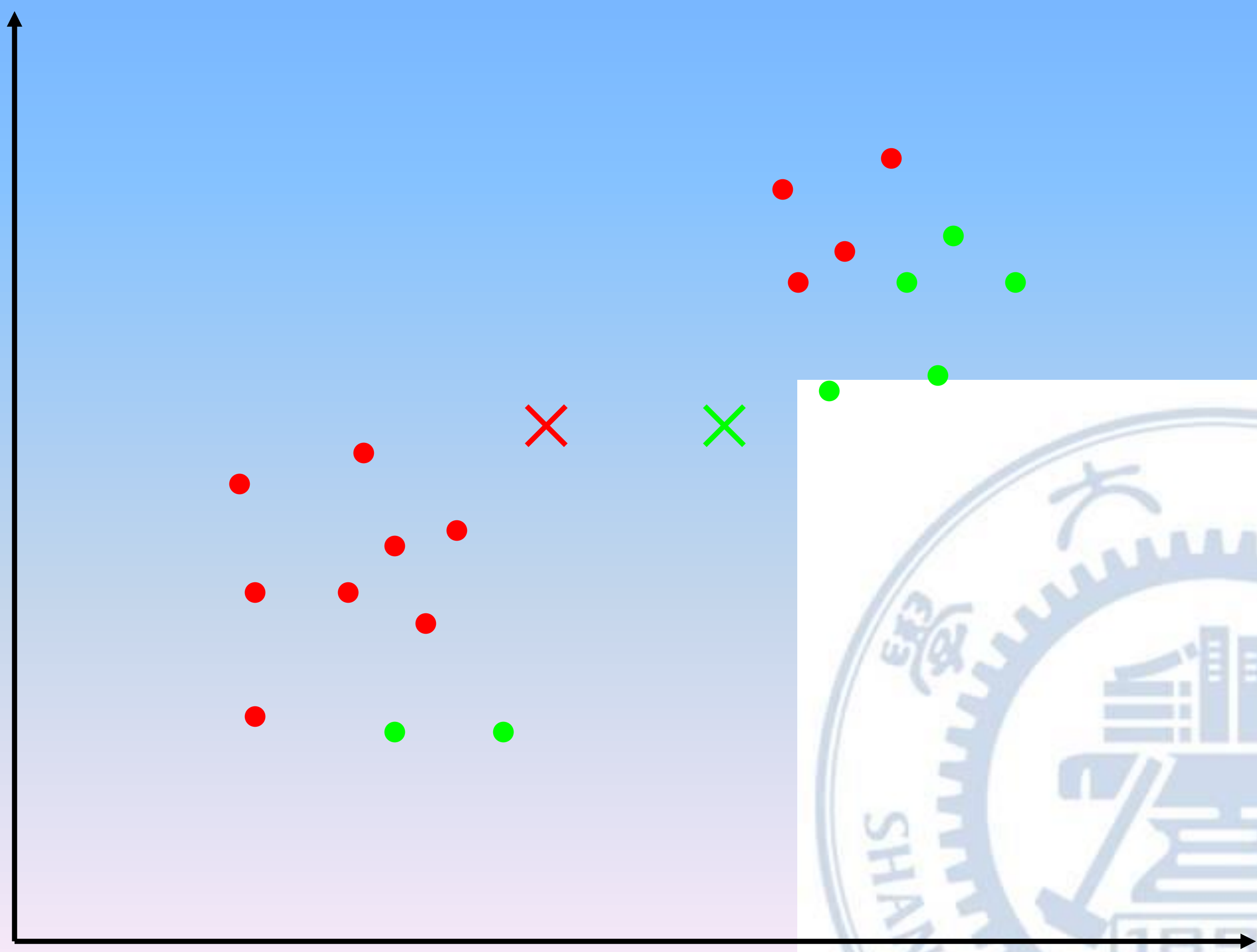
K-Means Clustering



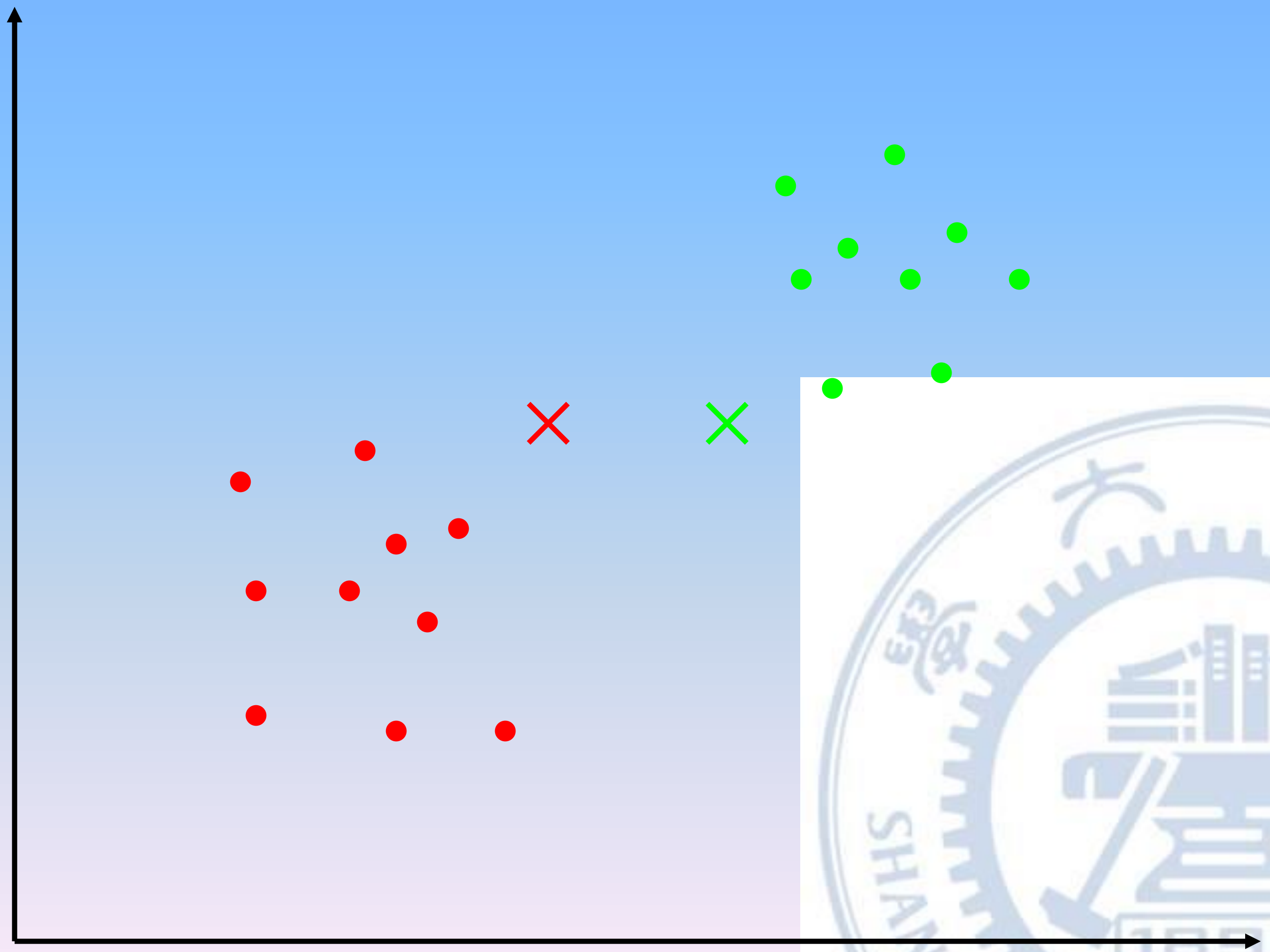
K-Means Clustering



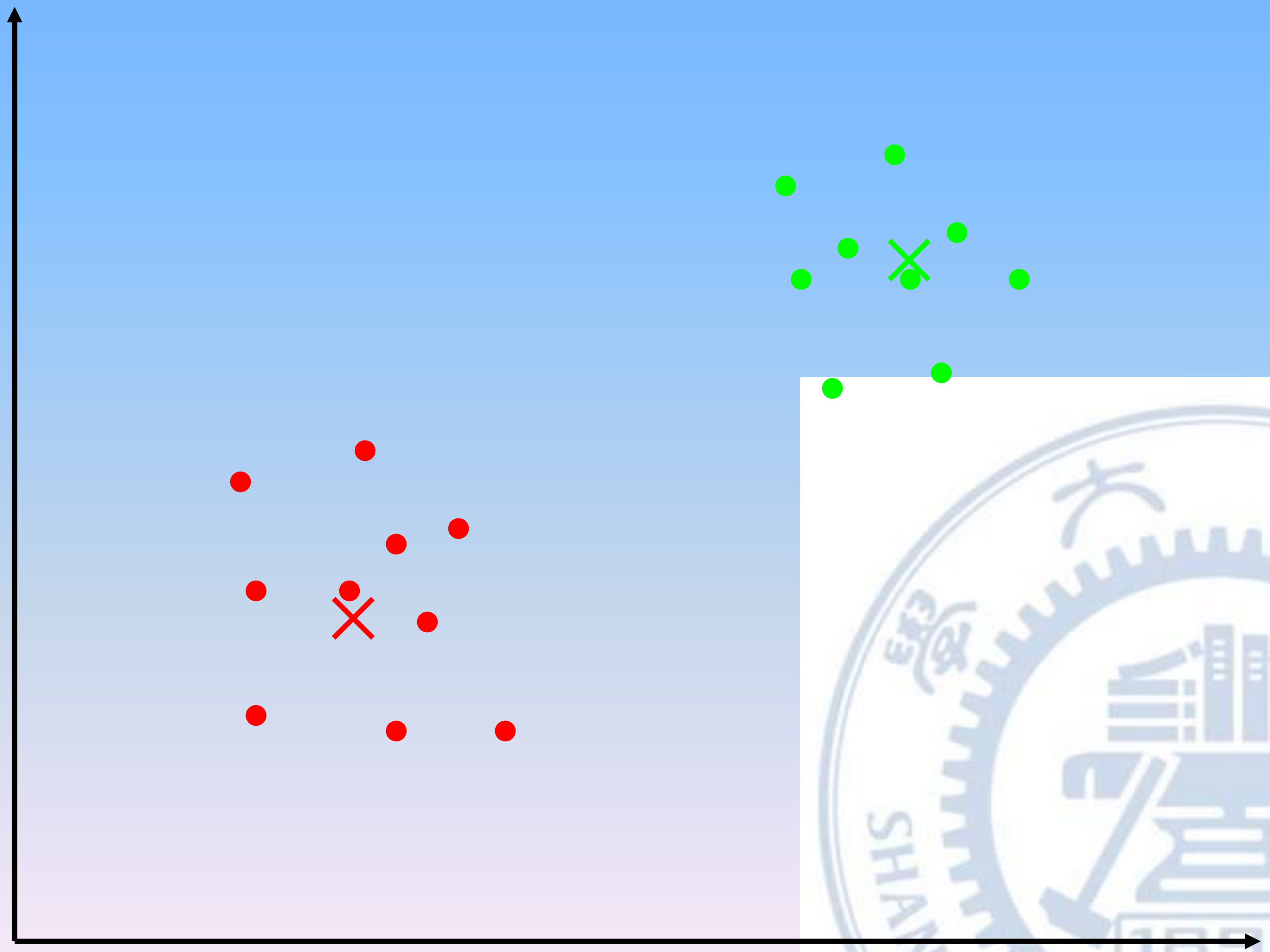
K-Means Clustering



K-Means Clustering



K-Means Clustering



K-Means Summary

- A clustering algorithm
- An approximation to an NP-hard combinatorial optimization problem
- It is unsupervised
- "*K*" stands for number of clusters, it is a user input to the algorithm
- From a set of data points or observations (all numerical), *K*-means attempts to classify them into *K* clusters
- The algorithm is iterative in nature

Thank You!