

Digital Image Processing

Lecture 12. Image Segmentation

Autumn 2010



Thresholding

$$g(x, y) = \begin{cases} 1 & \text{if } f(x, y) > T \quad (\text{object point}) \\ 0 & \text{if } f(x, y) \leq T \quad (\text{background point}) \end{cases}$$

T : global thresholding

Thresholding

image with dark background and a light object

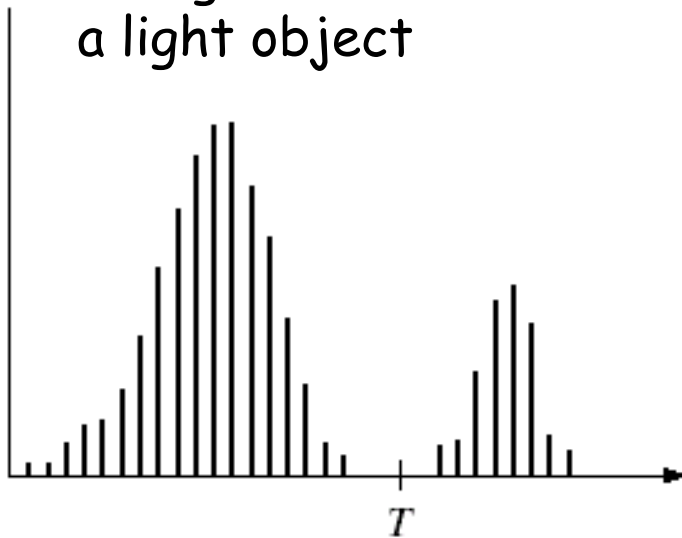
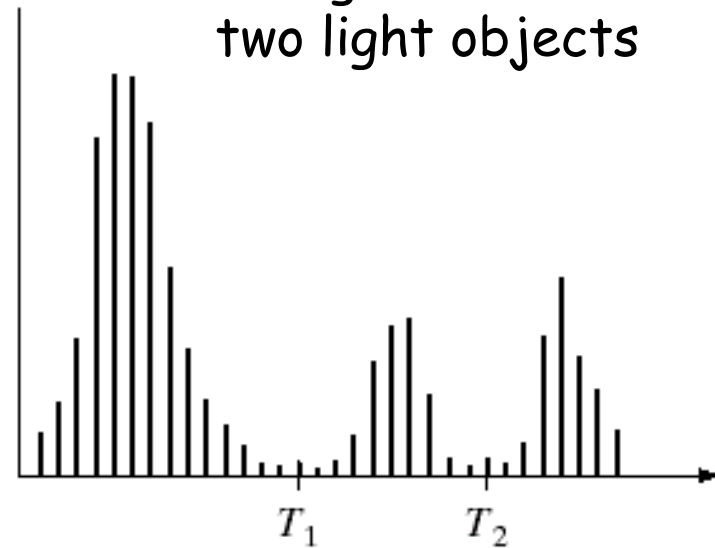


image with dark background and two light objects



a b

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

Multilevel thresholding

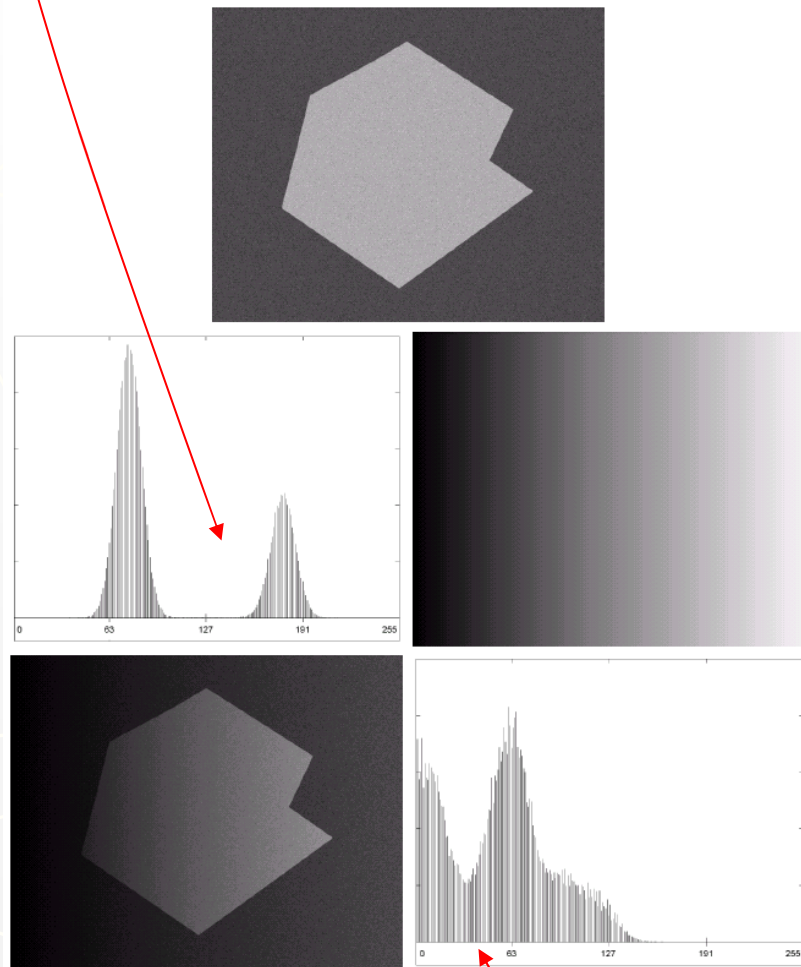
- ▶ a point (x,y) belongs to
 - to an object class if $T_1 < f(x,y) \leq T_2$
 - to another object class if $f(x,y) > T_2$
 - to background if $f(x,y) \leq T_1$
- ▶ T depends on
 - only $f(x,y)$: only on gray-level values \Rightarrow Global threshold
 - both $f(x,y)$ and $p(x,y)$: on gray-level values and its neighbors \Rightarrow Local threshold

easily use global thresholding
object and background are separated

The Role of Illumination

$$f(x,y) = i(x,y) r(x,y)$$

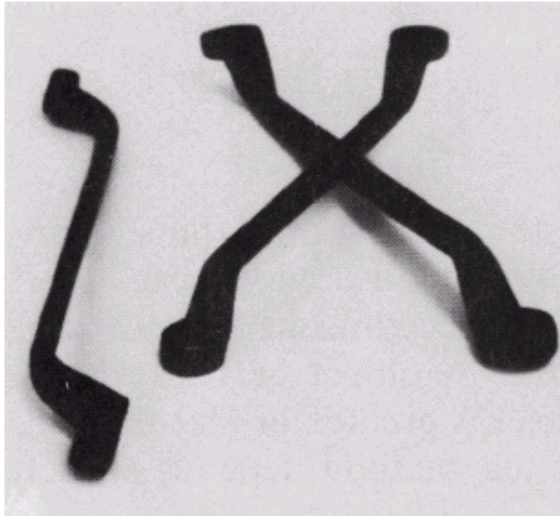
- a). computer generated reflectance function
- b). histogram of reflectance function
- c). computer generated illumination function (poor)
- d). product of a). and c).
- e). histogram of product image



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.

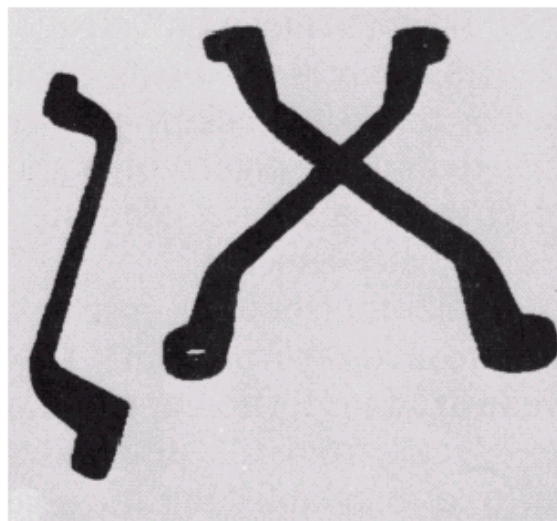
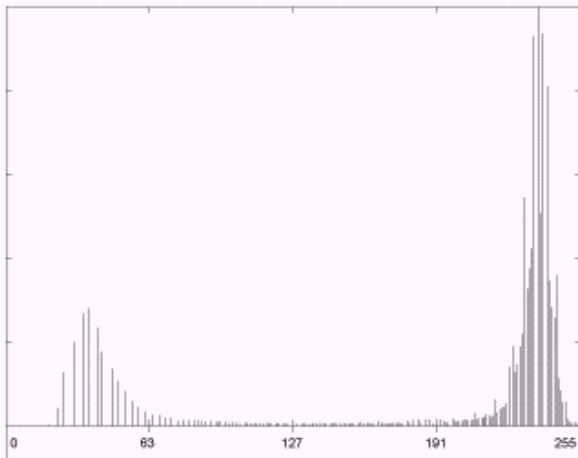
Basic Global Thresholding



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.



use T midway between
the max and min gray
levels

generate binary image

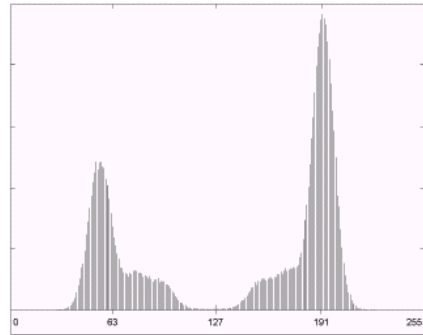
Basic Global Thresholding

1. Select an initial estimate for the global threshold, T .
2. Segment the image using T . It will produce two groups of pixels: $G1$ consisting of all pixels with intensity values $> T$ and $G2$ consisting of pixels with values $\leq T$.
3. Compute the average intensity values $m1$ and $m2$ for the pixels in $G1$ and $G2$, respectively.
4. Compute a new threshold value.

$$T = \frac{1}{2}(m1 + m2)$$

5. Repeat Steps 2 through 4 until the difference between values of T in successive iterations is smaller than a predefined parameter ΔT .

Example: Heuristic method



a b
c
FIGURE 10.29
(a) Original image. (b) Image histogram. (c) Result of segmentation with the threshold estimated by iteration. (Original courtesy of the National Institute of Standards and Technology.)

note: the clear valley of the histogram and the effective of the segmentation between object and background



$T_0 = 0$
3 iterations
with result $T = 125$

Basic Adaptive Thresholding

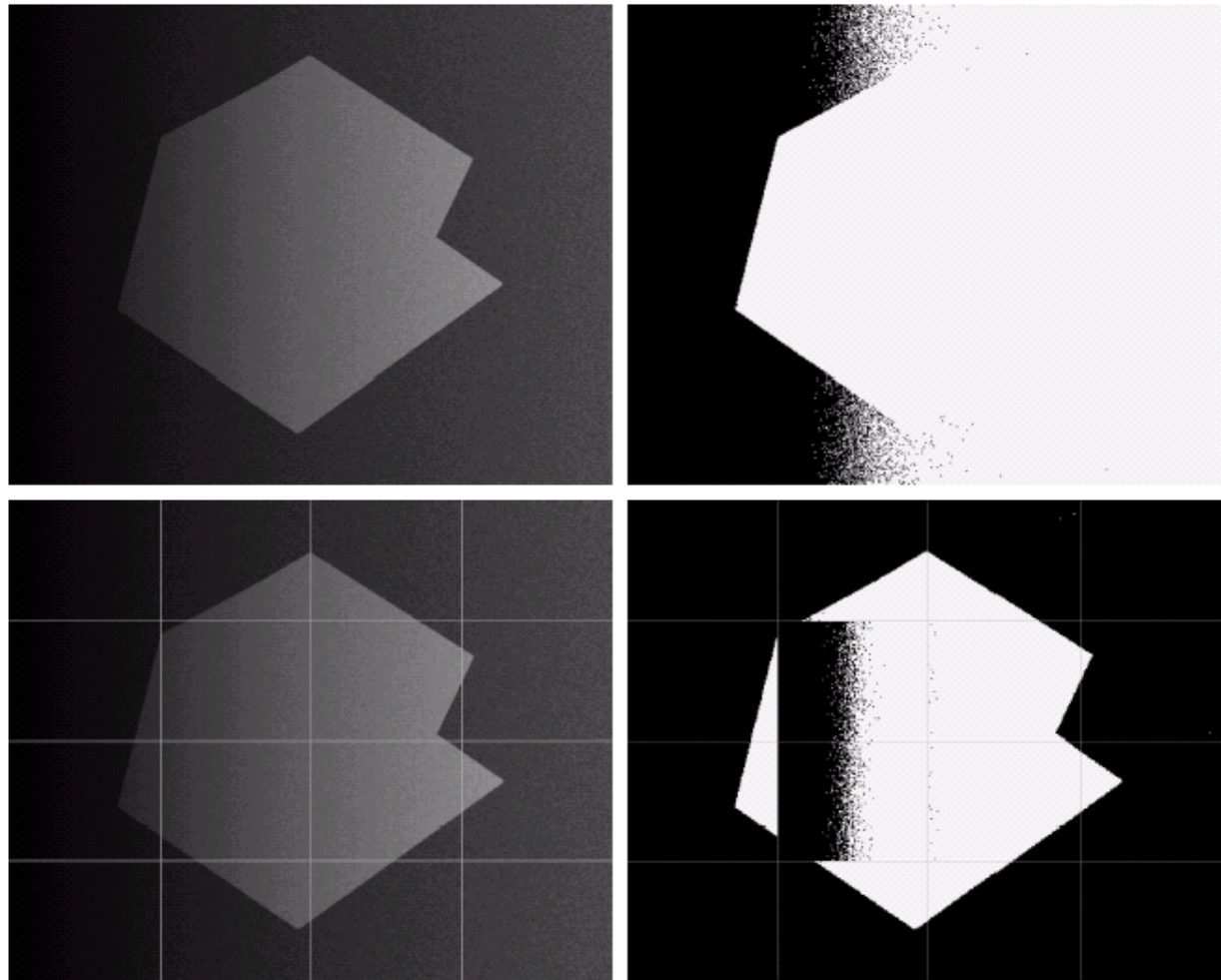
- ▶ subdivide original image into small areas.
- ▶ utilize a different threshold to segment each subimages.
- ▶ since the threshold used for each pixel depends on the location of the pixel in terms of the subimages, this type of thresholding is adaptive.

Example : Adaptive Thresholding

a b
c d

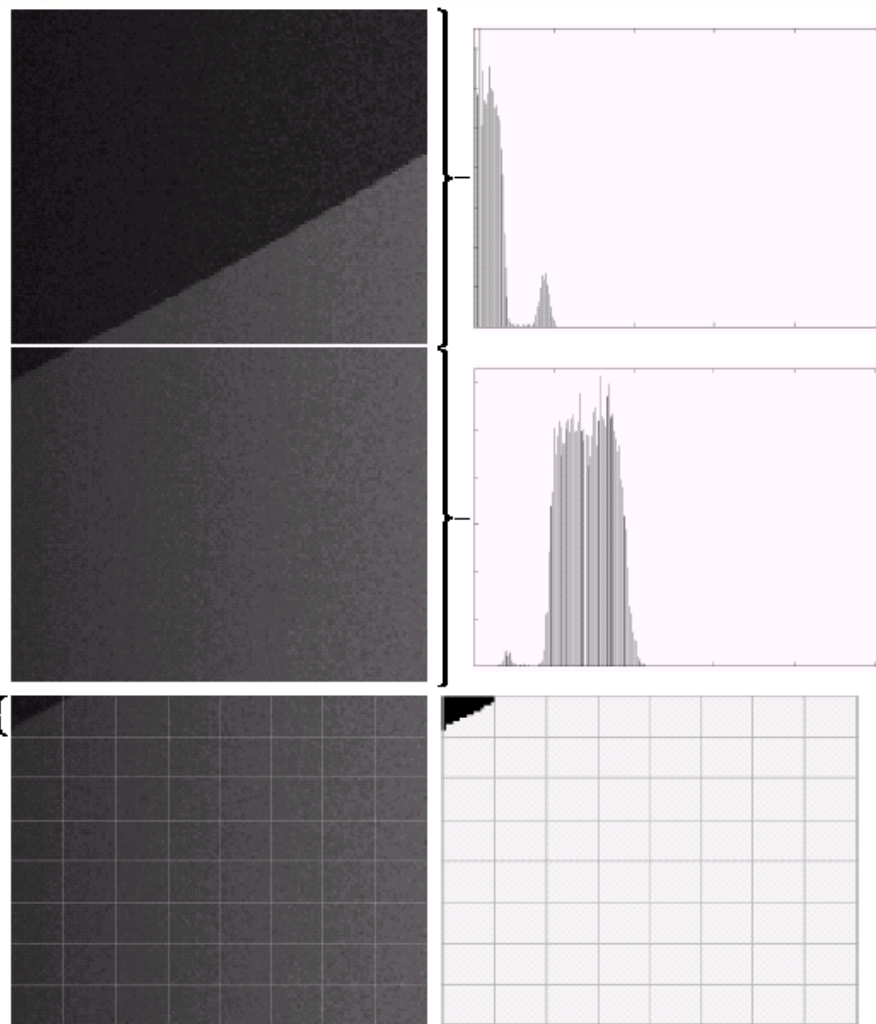
FIGURE 10.30

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



Further subdivision

- a). Properly and improperly segmented subimages from previous example
- b)-c). corresponding histograms
- d). further subdivision of the improperly segmented subimage.
- e). histogram of small subimage at top
- f). result of adaptively segmenting d).



Region-Based Segmentation

▶ Region Growing

1. Region growing is a procedure that groups pixels or subregions into larger regions.
2. 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).
3. Region growing based techniques are better than the edge-based techniques in noisy images where edges are difficult to detect.

Region-Based Segmentation

Example: Region Growing based on 8-connectivity

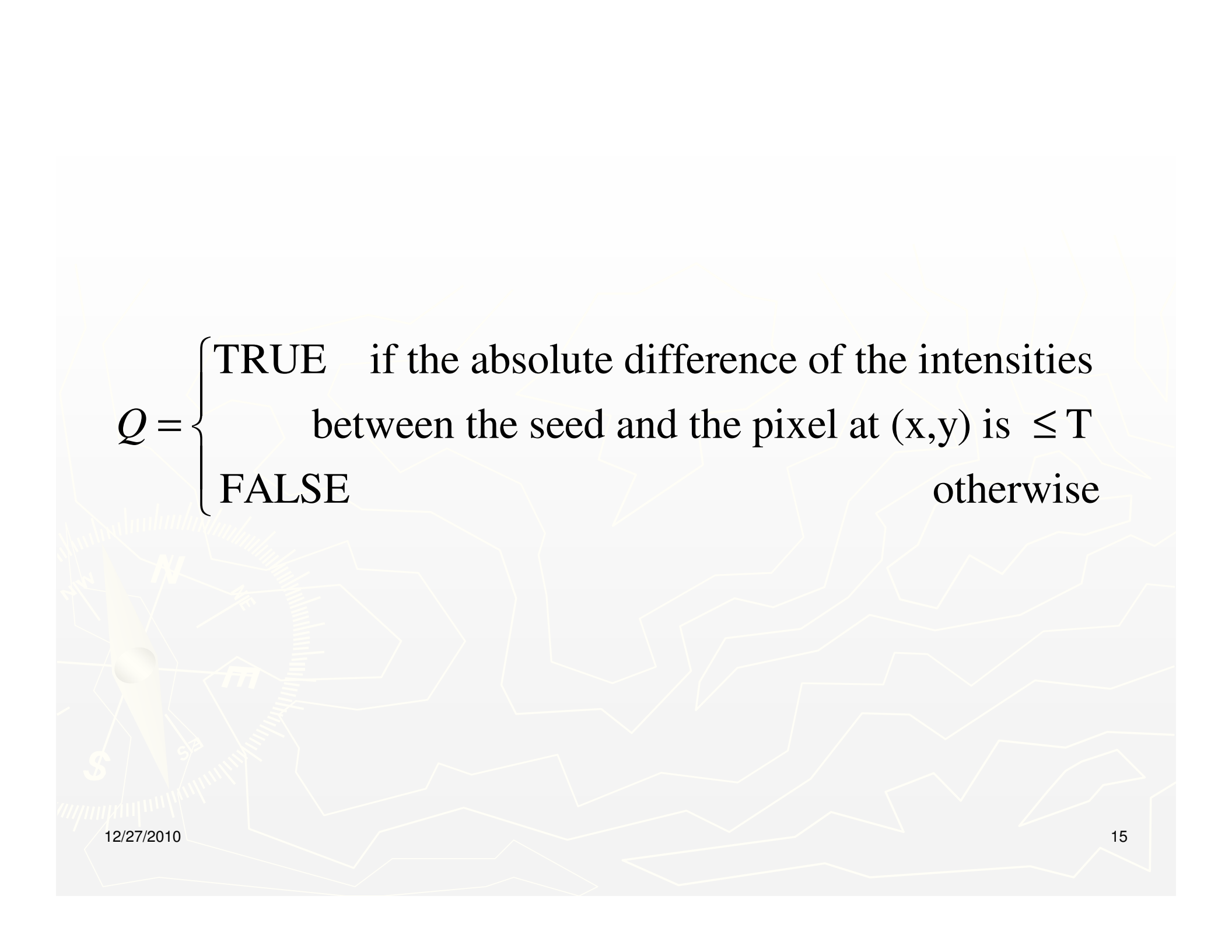
$f(x, y)$: input image array

$S(x, y)$: seed array containing 1s (seeds) and 0s

$Q(x, y)$: predicate

Region Growing based on 8-connectivity

1. Find all connected components in $S(x, y)$ and erode each connected components to one pixel; label all such pixels found as 1. All other pixels in S are labeled 0.



$Q = \begin{cases} \text{TRUE} & \text{if the absolute difference of the intensities} \\ & \text{between the seed and the pixel at } (x,y) \text{ is } \leq T \\ \text{FALSE} & \text{otherwise} \end{cases}$

Suppose that we have the image given below.

(a) Use the region growing idea to segment the object. The seed for the object is the center of the image. Region is grown in horizontal and vertical directions, and when the difference between two pixel values is less than or equal to 5.

Table 1: Show the result of Part (a) on this figure.

10	10	10	10	10	10	10
10	10	10	69	70	10	10
59	10	60	64	59	56	60
10	59	10	<u>60</u>	70	10	62
10	60	59	65	67	10	65
10	10	10	10	10	10	10
10	10	10	10	10	10	10

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10	60	59	65	67	10	65
10	10	10	10	10	10	10
10	10	10	10	10	10	10



4-connectivity

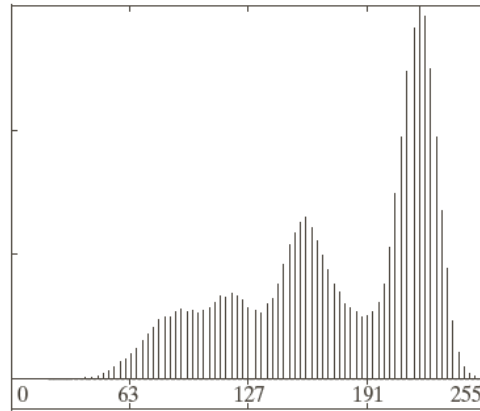
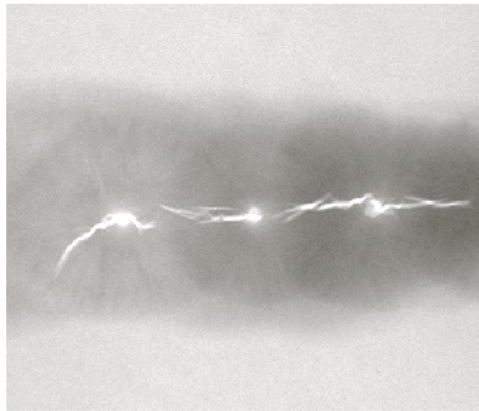
Suppose that we have the image given below.

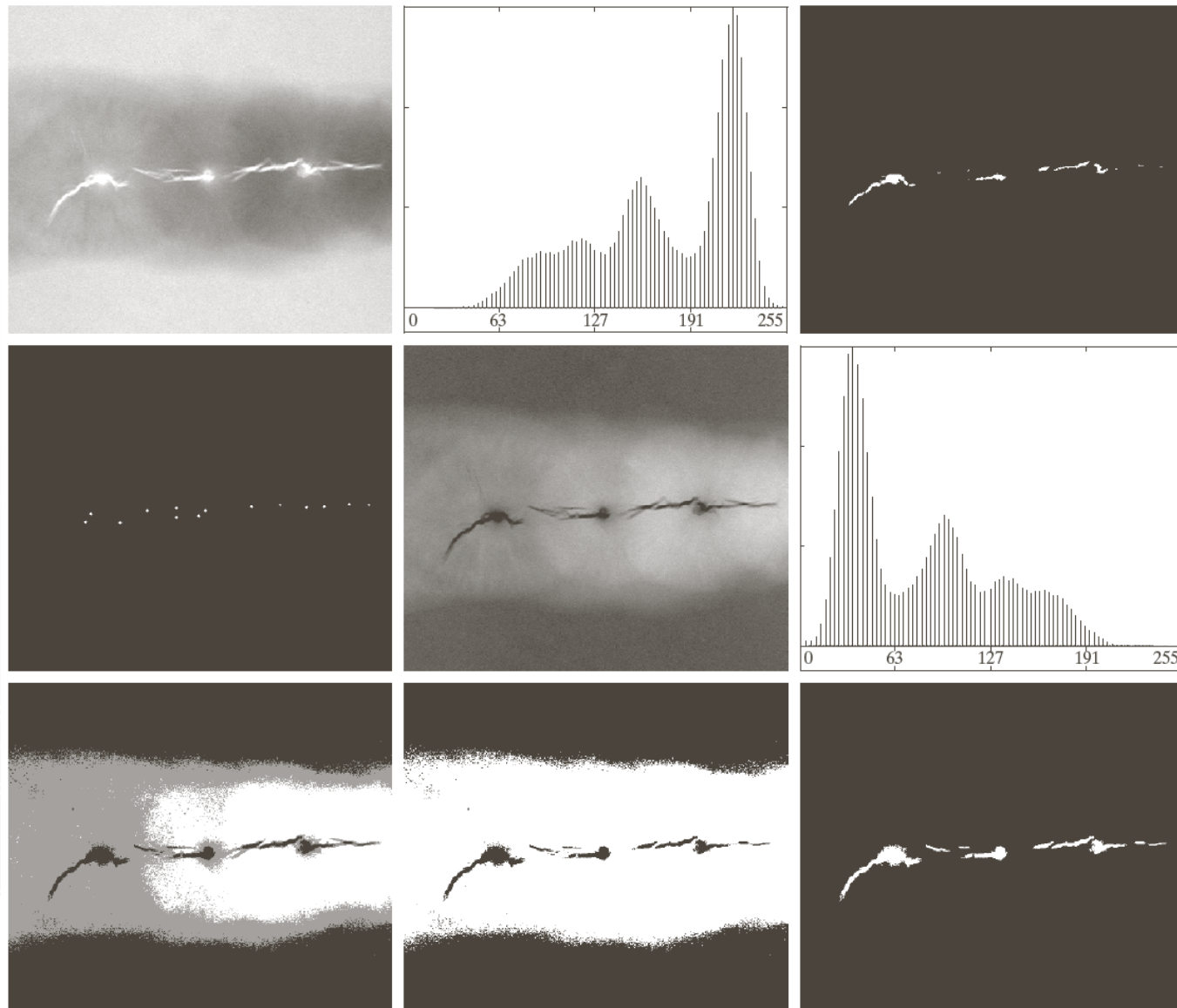
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10	60	59	65	67	10	65
10	10	10	10	10	10	10
10	10	10	10	10	10	10

8-connectivity



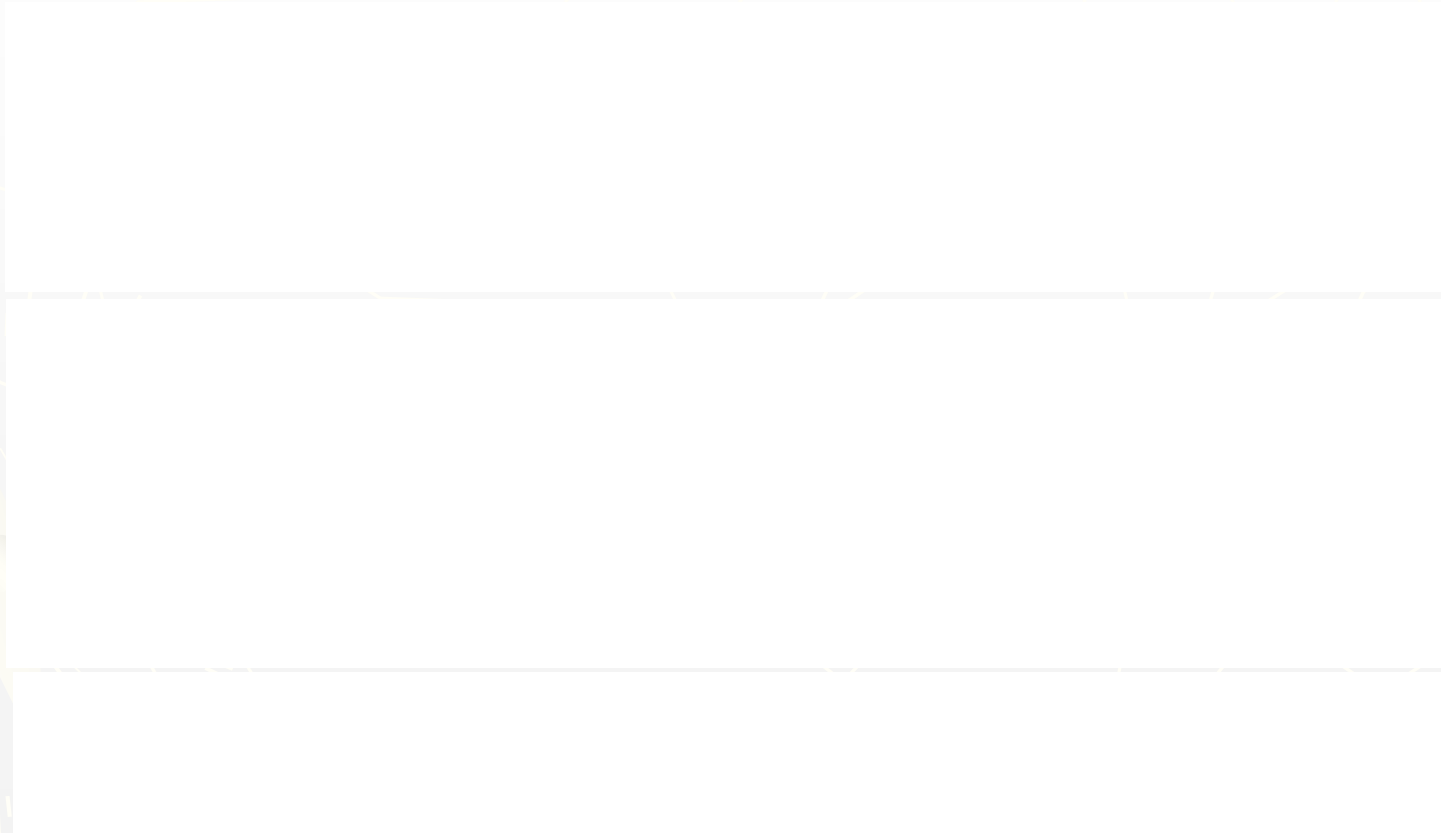


a	b	c
d	e	f
g	h	i

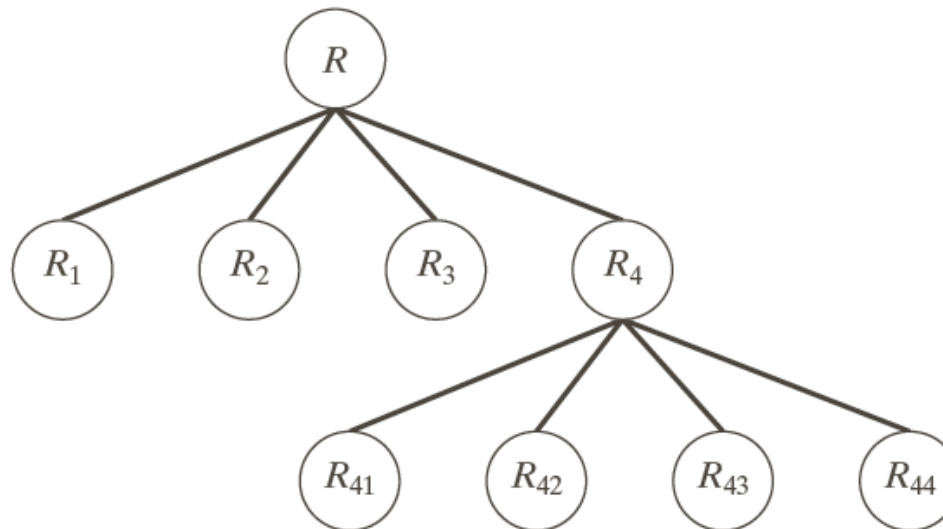
FIGURE 10.51 (a) X-ray image of a defective weld. (b) Histogram. (c) Initial seed image. (d) Final seed image (the points were enlarged for clarity). (e) Absolute value of the difference between (a) and (c). (f) Histogram of (e). (g) Difference image thresholded using dual thresholds. (h) Difference image thresholded with the smallest of the dual thresholds. (i) Segmentation result obtained by region growing. (Original image courtesy of X-TEK Systems, Ltd.)

Region Splitting and Merging

R : entire image R_i :entire image Q : predicate

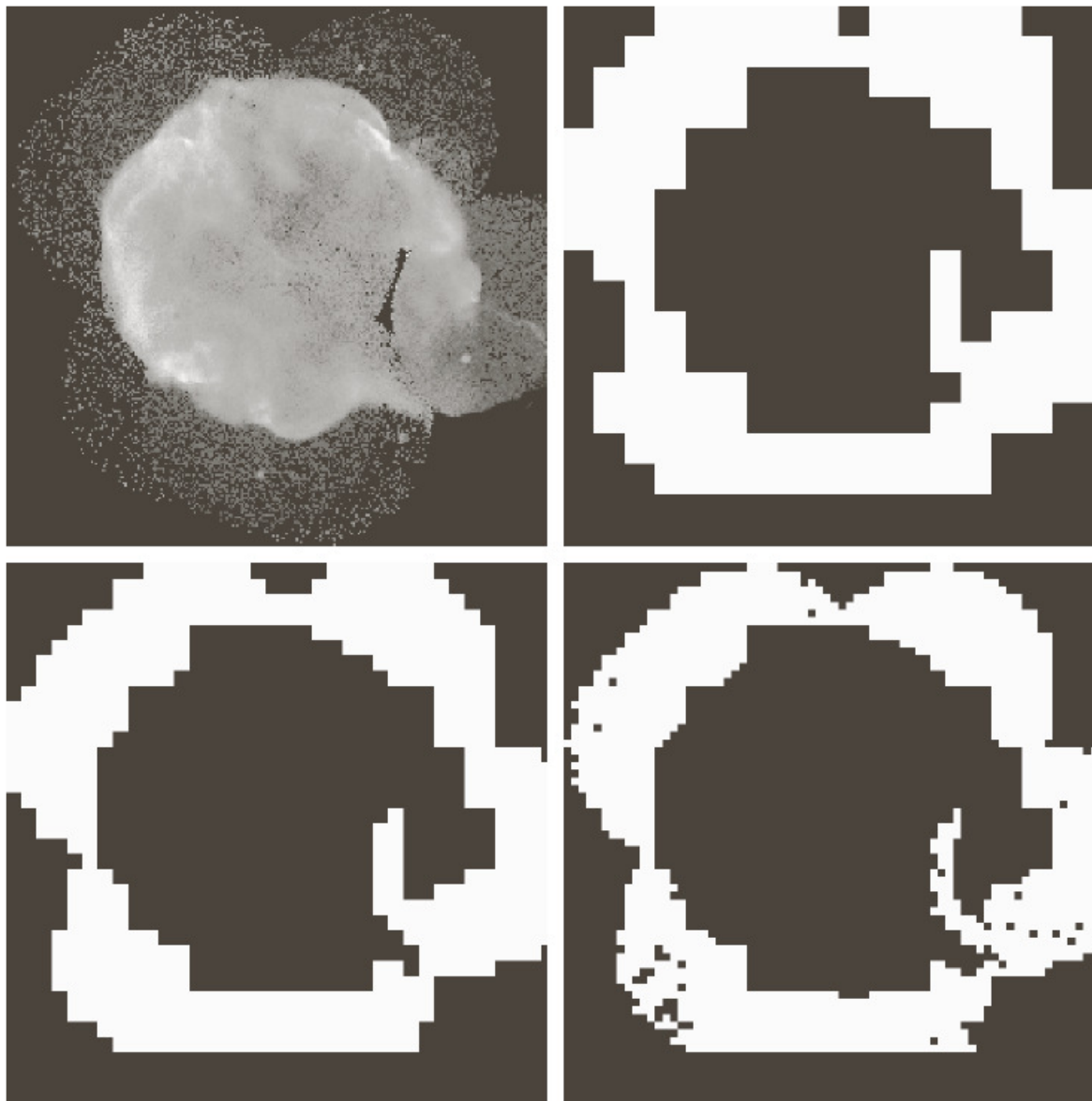


R_1	R_2	
R_3	R_{41}	R_{42}
	R_{43}	R_{44}



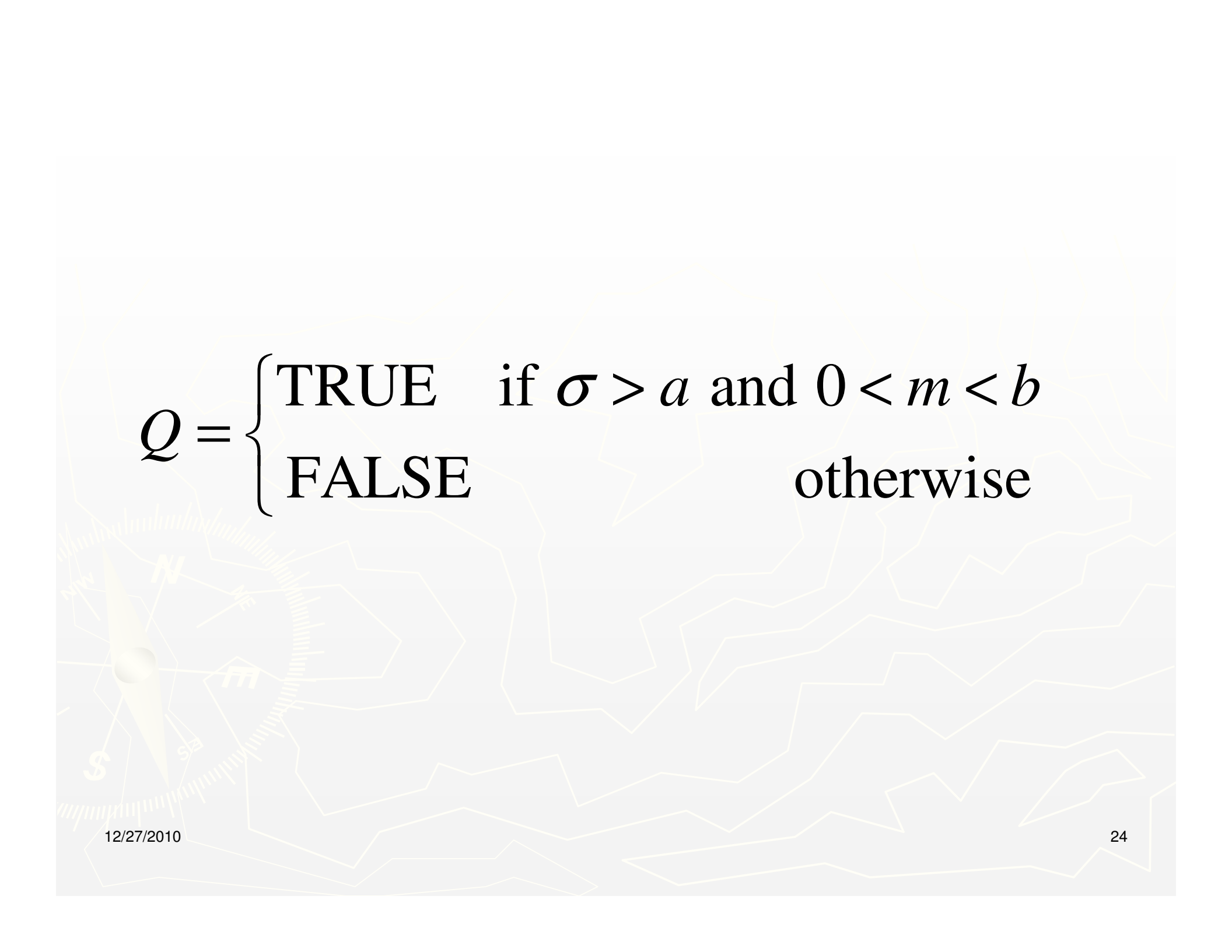
a b

FIGURE 10.52
 (a) Partitioned image.
 (b) Corresponding quadtree. R represents the entire image region.



a	b
c	d

FIGURE 10.53
(a) Image of the Cygnus Loop supernova, taken in the X-ray band by NASA's Hubble Telescope. (b)–(d) Results of limiting the smallest allowed quadregion to sizes of 32×32 , 16×16 , and 8×8 pixels, respectively. (Original image courtesy of NASA.)


$$Q = \begin{cases} \text{TRUE} & \text{if } \sigma > a \text{ and } 0 < m < b \\ \text{FALSE} & \text{otherwise} \end{cases}$$

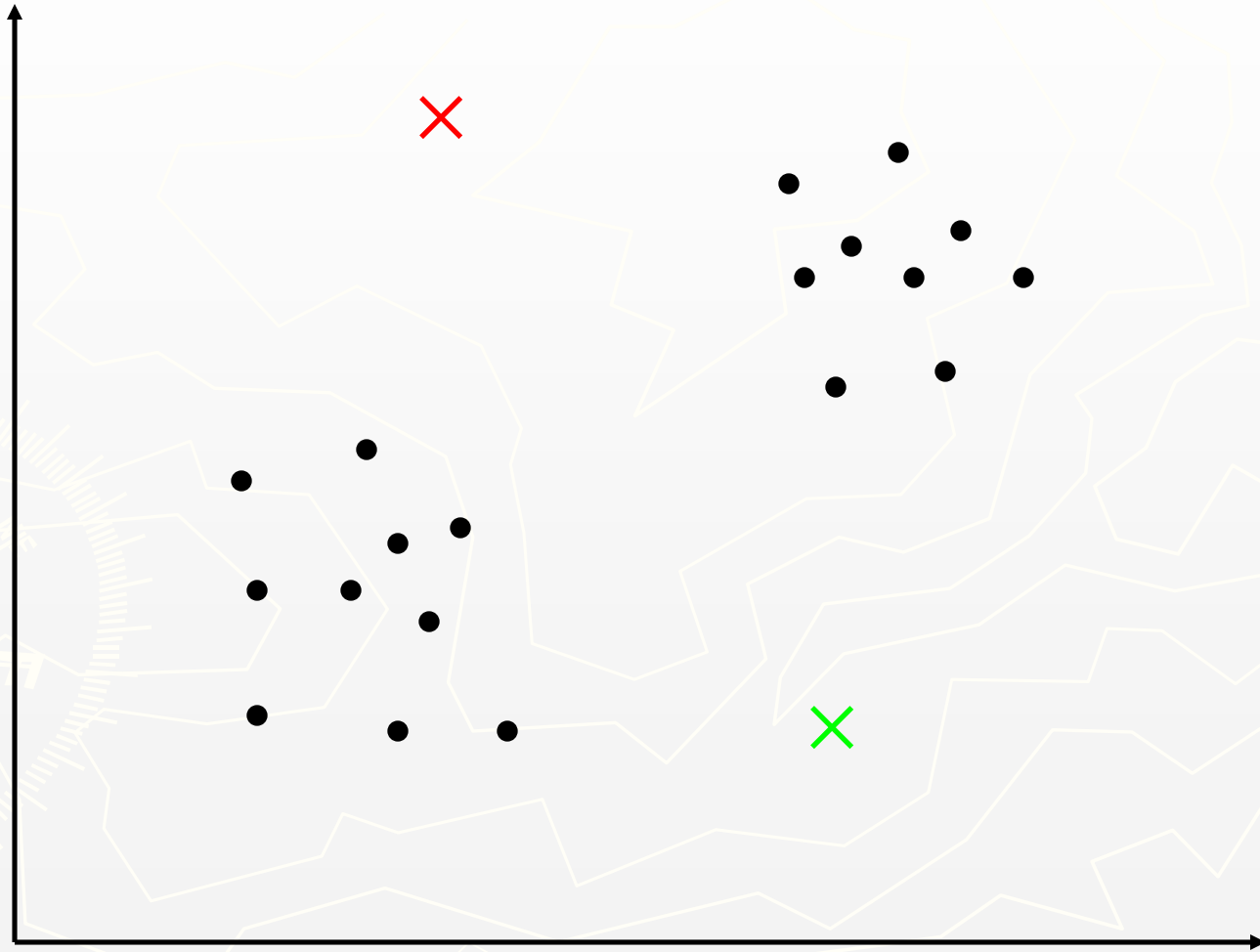
K-means Clustering

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

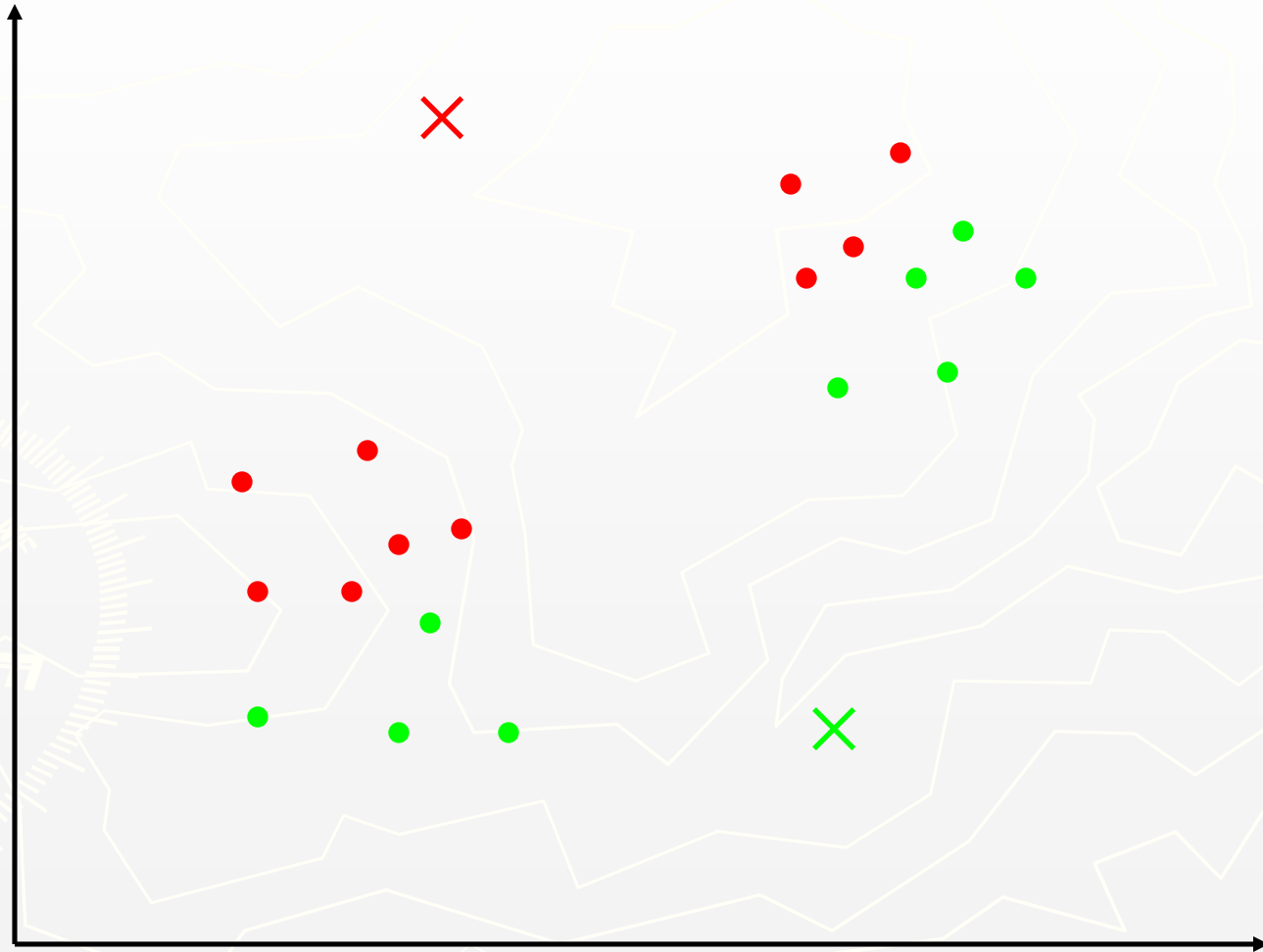
K-Means Clustering



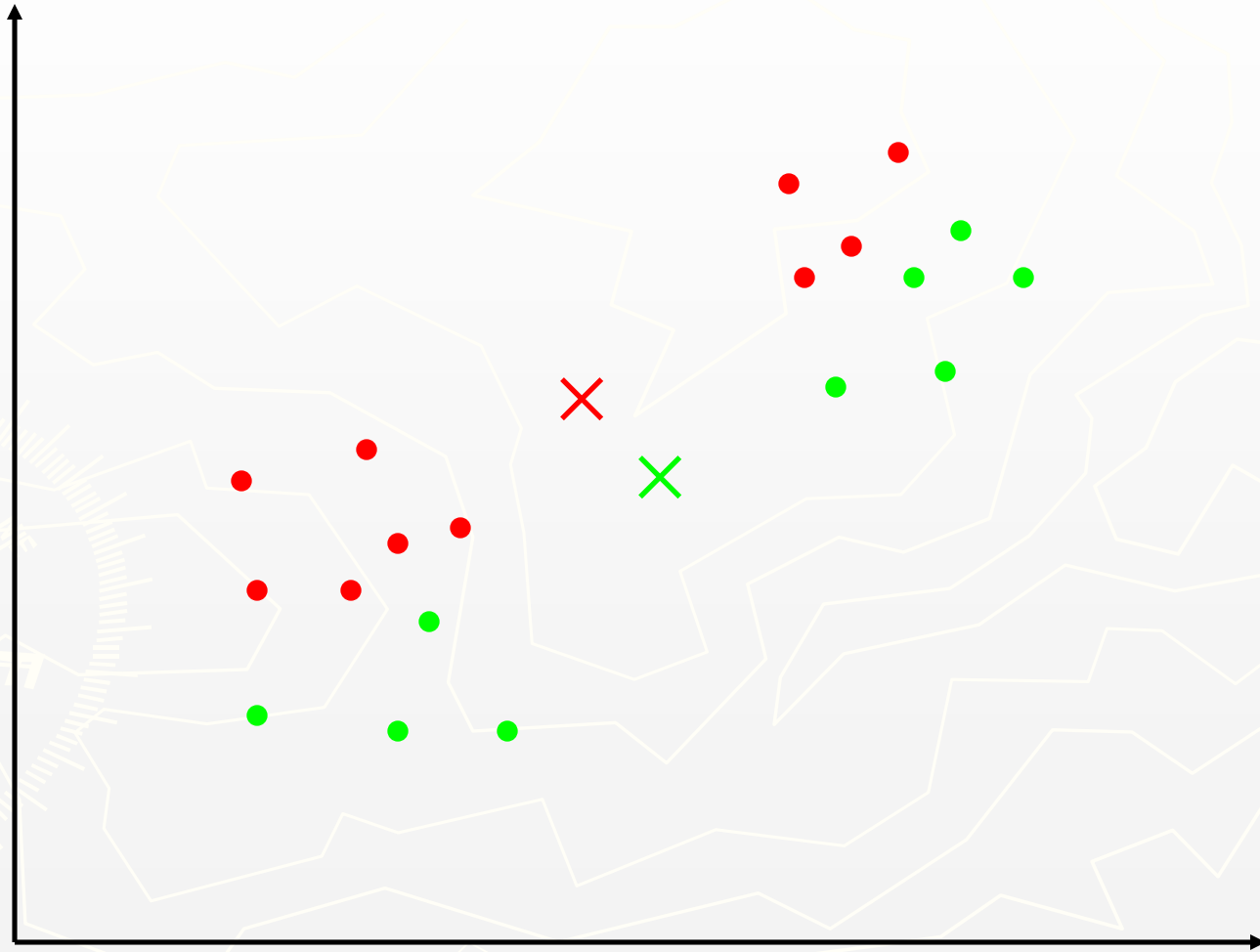
K-Means Clustering



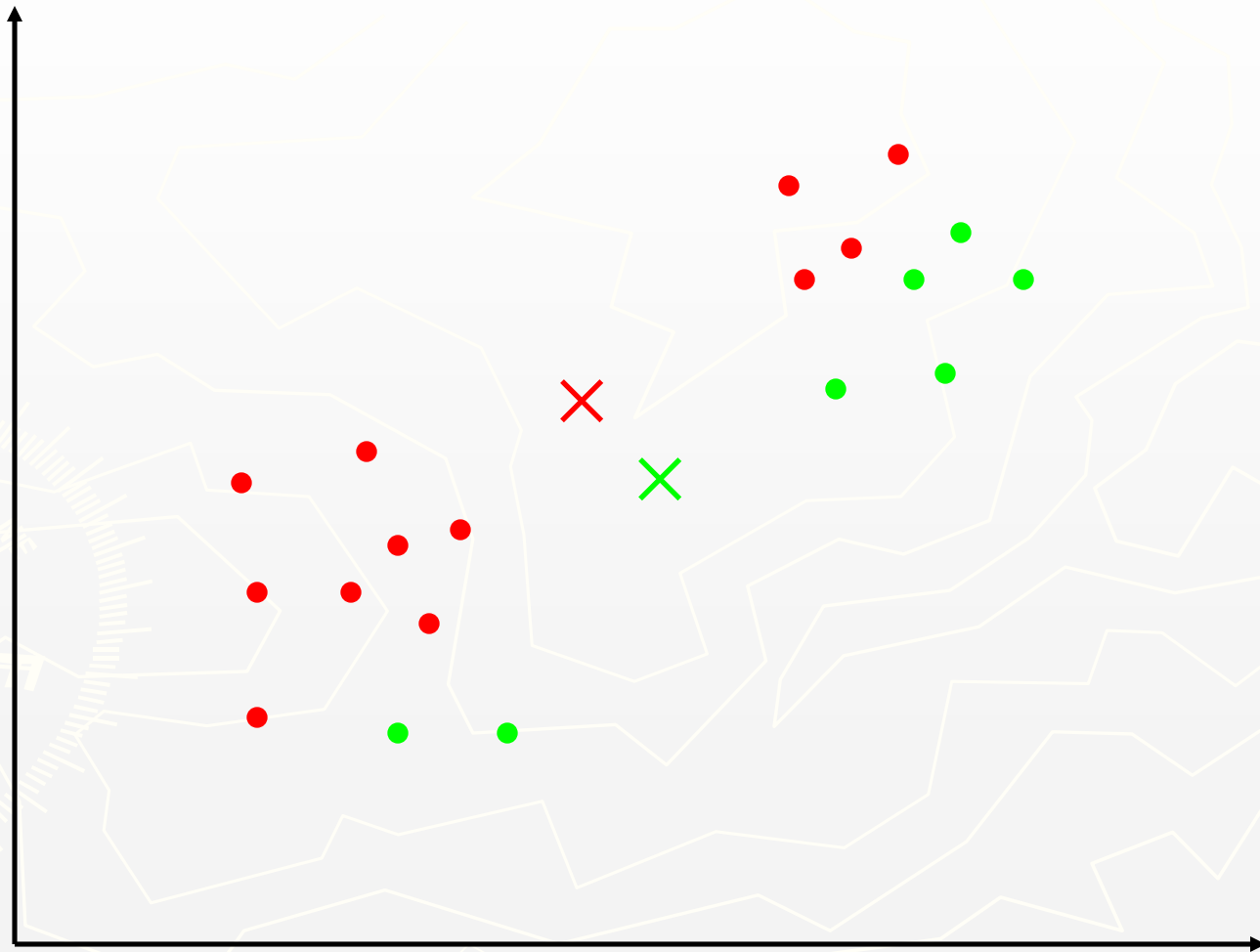
K-Means Clustering



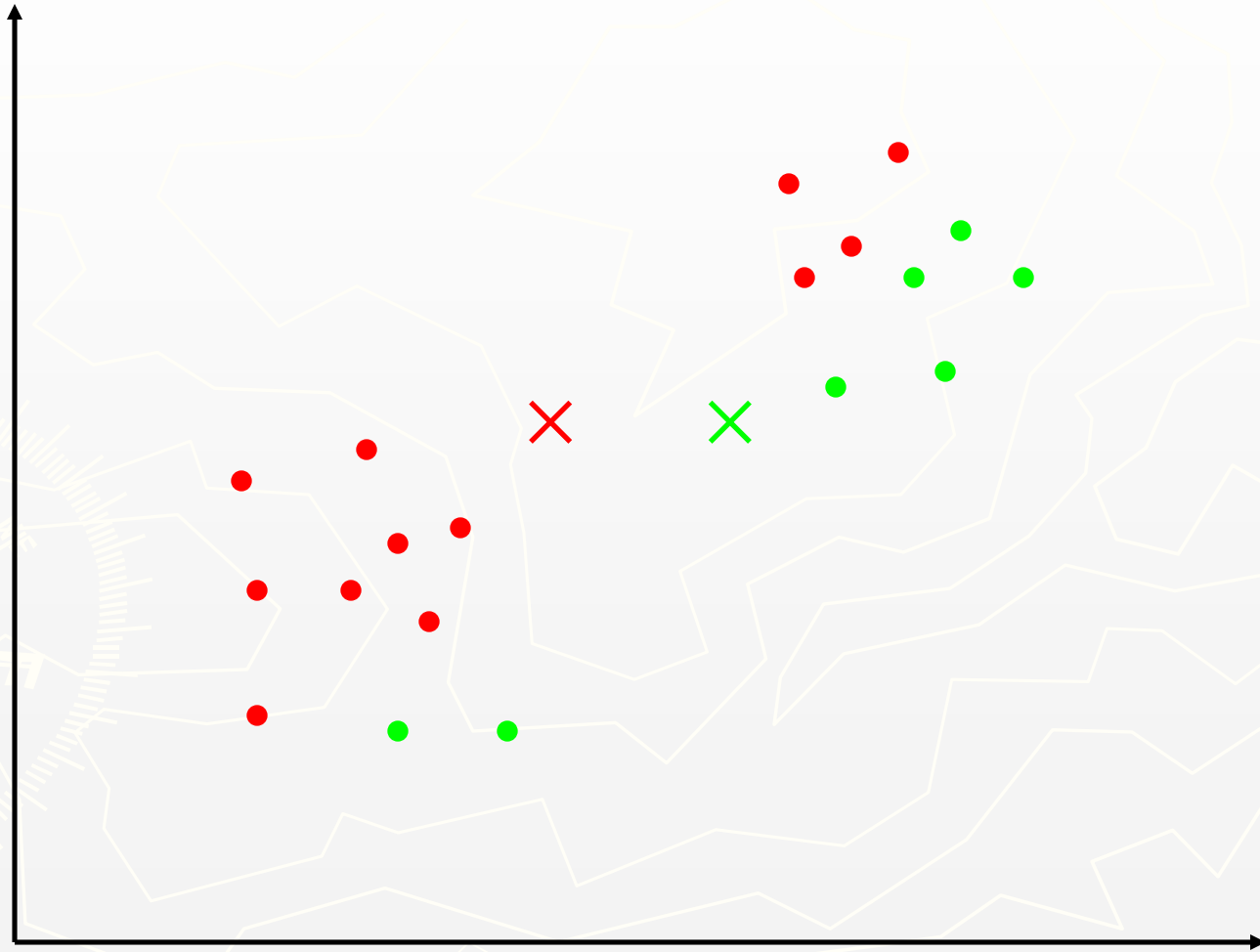
K-Means Clustering



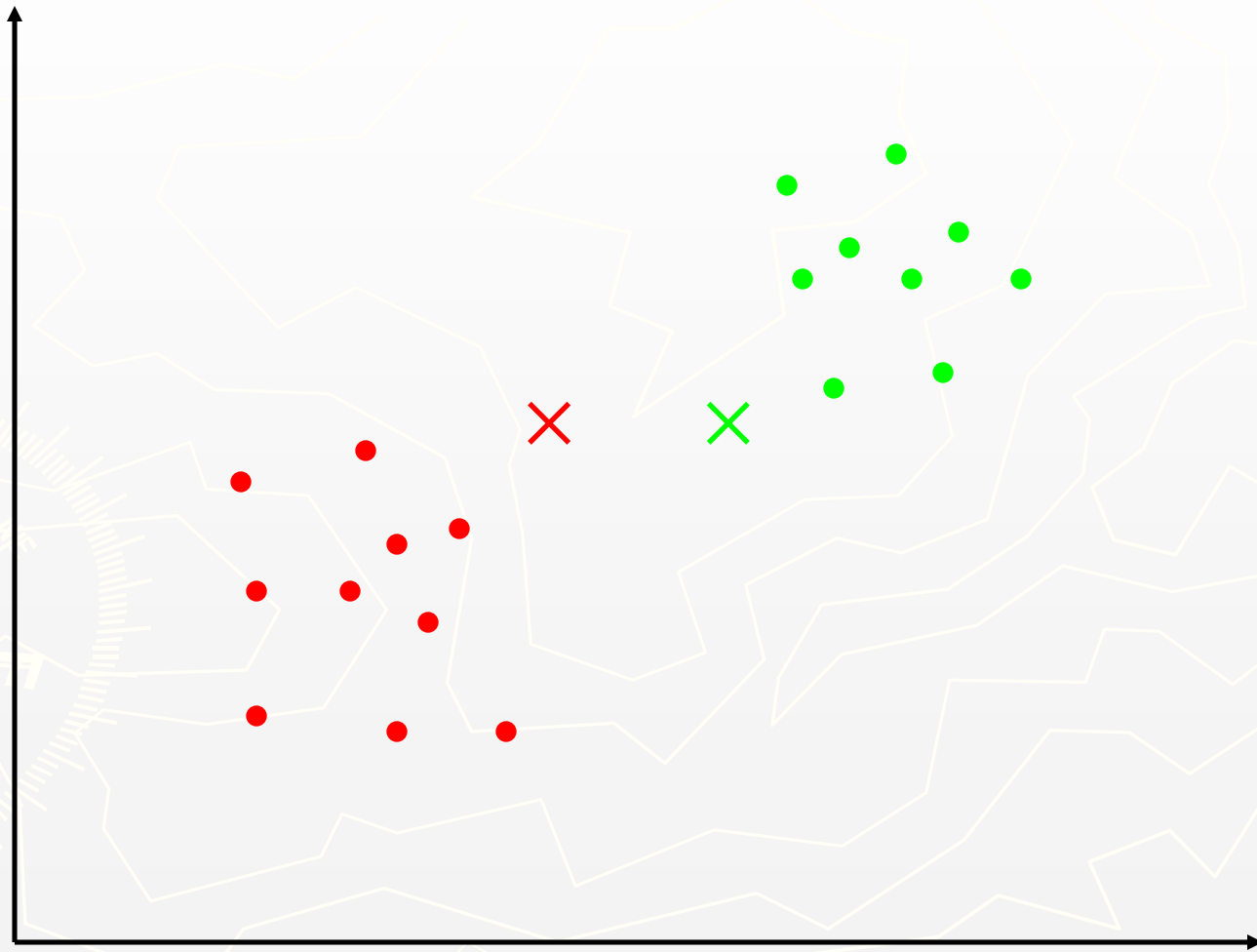
K-Means Clustering



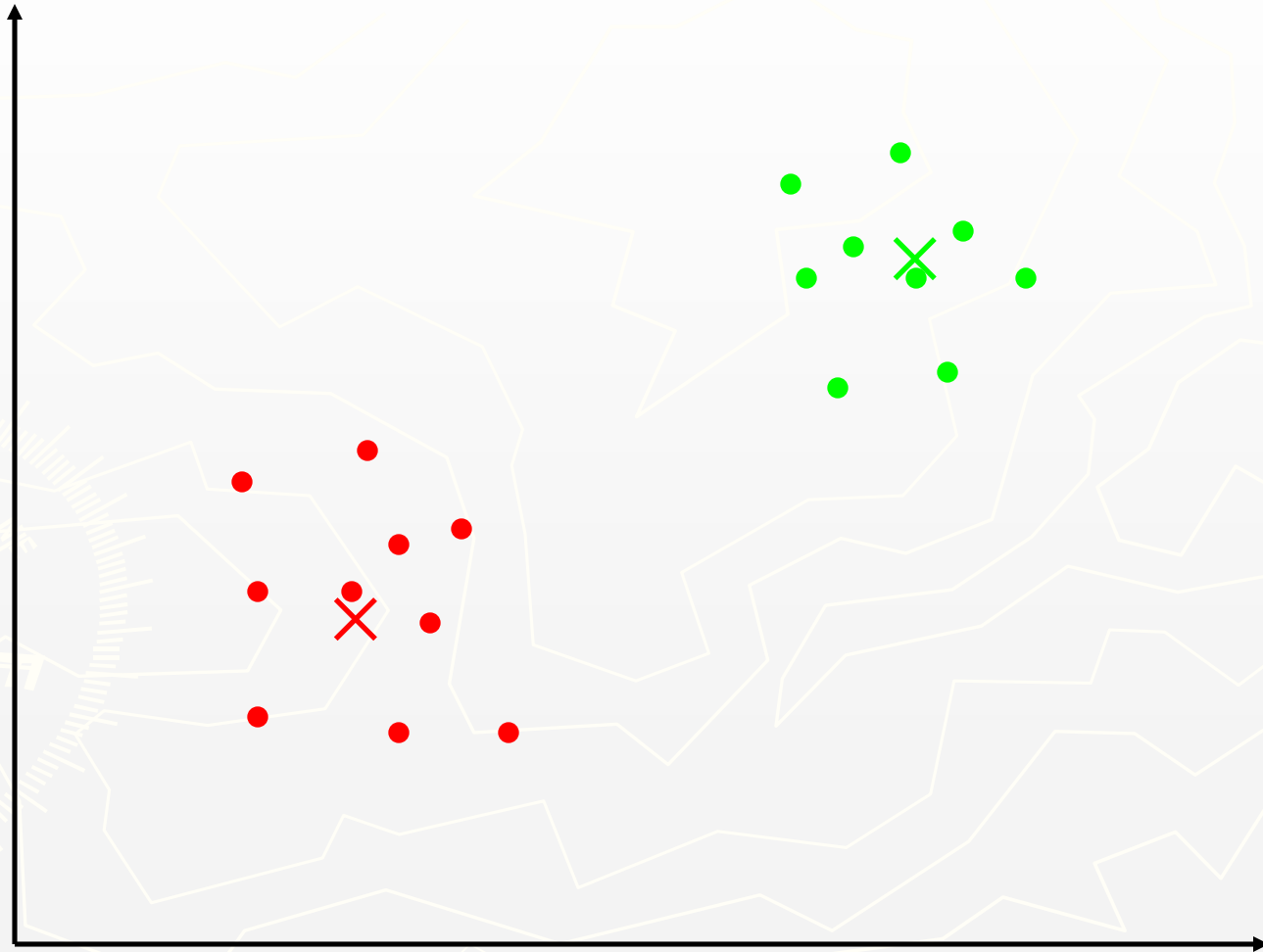
K-Means Clustering



K-Means Clustering



K-Means Clustering



Clustering

▶ Example



D. Comaniciu and P. Meer, *Robust Analysis of Feature Spaces: Color Image Segmentation*, 1997.

12/27/2010