Marwadi
University

IMAGE PROCESSING
01CE0507

Chap 8
Image Segmentation

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Outline

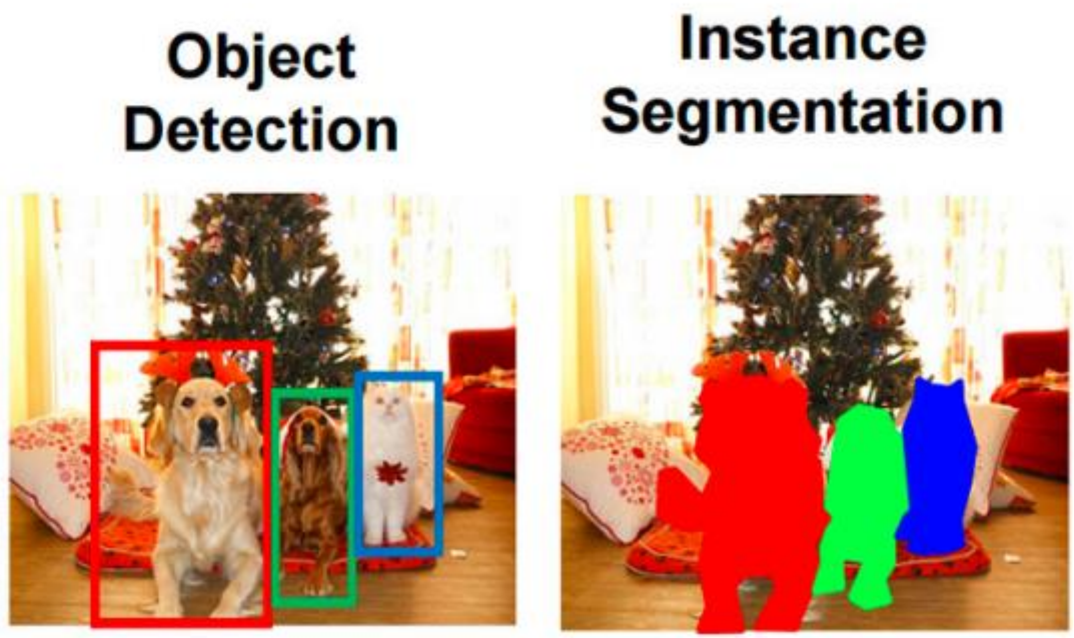
- What is Segmentation
- Application of Segmentation
- Goal of Segmentation
- Approaches of Segmentation
  - Discontinuity Approach:
    - Discontinuities Point Detection / Isolated Point Detection
    - Lines Detection
    - Edge Detection
  - Similarity Approach:
    - Threshold Based Segmentation / Histogram Based Segmentation
    - Region-Based Segmentation
    - Clustering Based Segmentation

Image Segmentation

- Segmentation in easy words is assigning labels to pixels. All picture elements or pixels belonging to the same category have a common label assigned to them.
- Image segmentation is a method in which a digital image is broken down into various subgroups called Image segments which helps in reducing the complexity of the image to make further processing or analysis of the image simpler.

Image Segmentation (Cont.)

- A common use of image segmentation is in object detection.



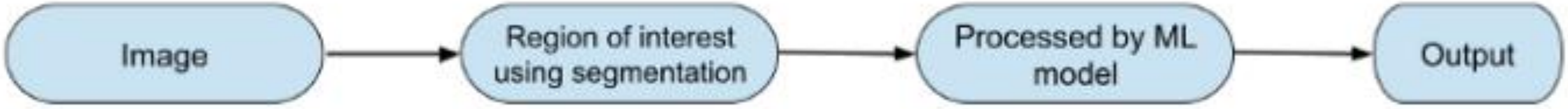
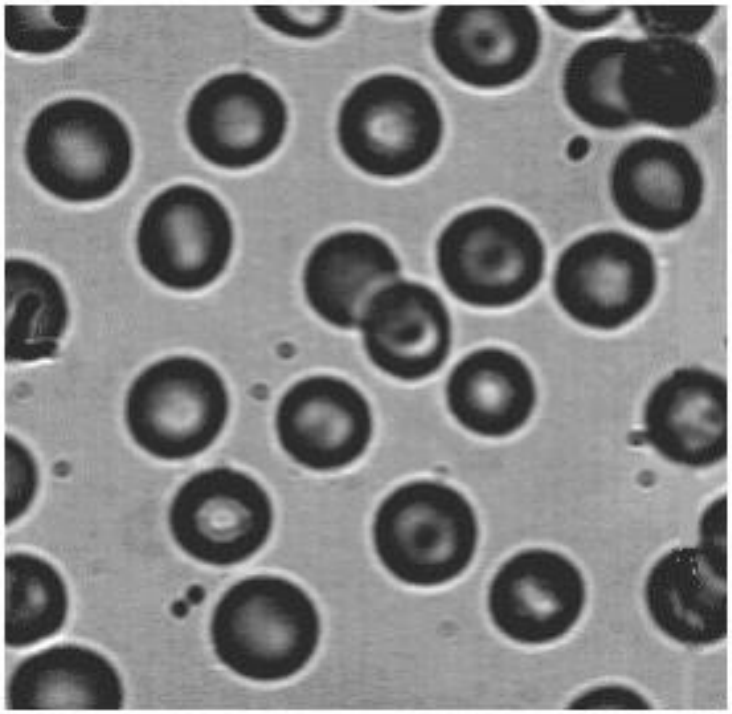
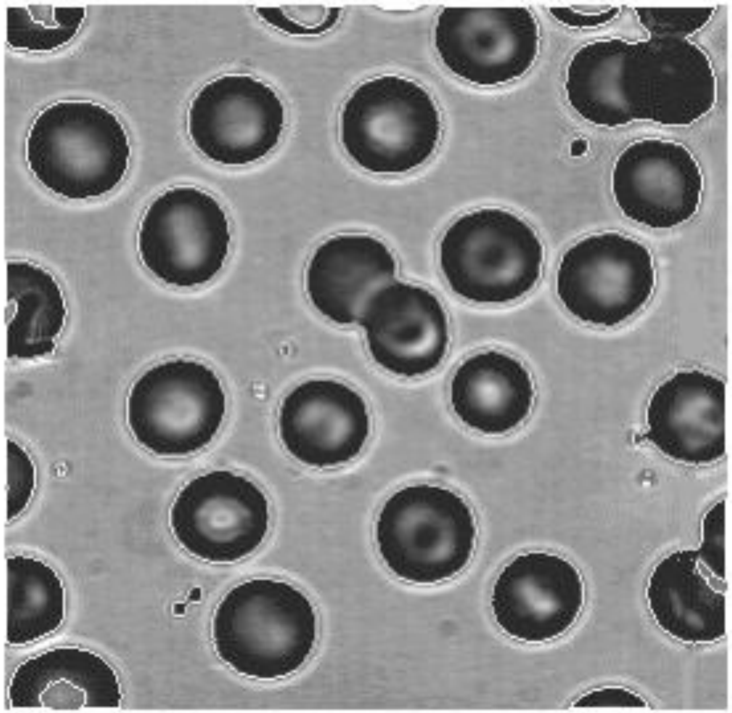


Image Segmentation (Cont.)



Given Image

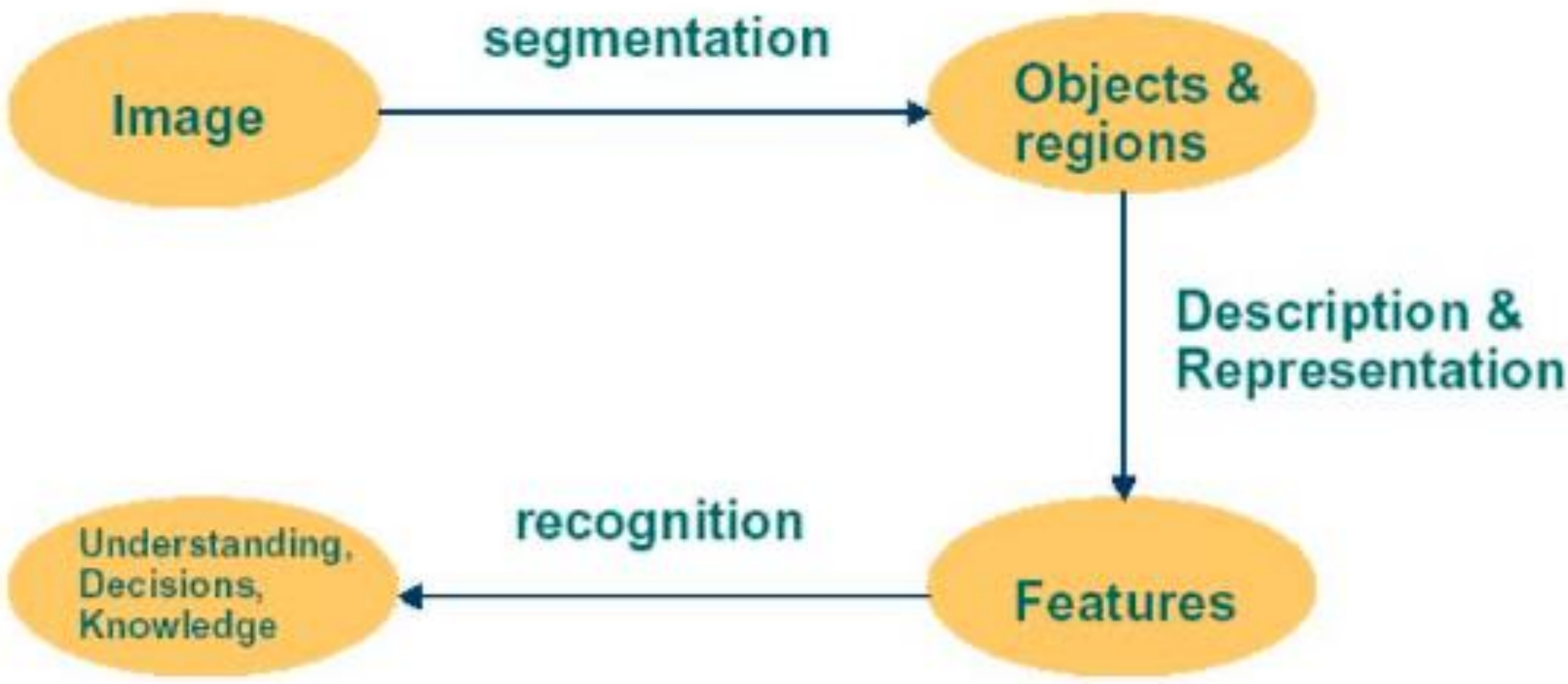


Segmented Image

Image Segmentation (Cont.)

- Instead of processing the entire image, a common practice is to first use an image segmentation algorithm to find objects of interest in the image.
- Then, the object detector can operate on a bounding box already defined by the segmentation algorithm. This prevents the detector from processing the entire image, improving accuracy and reducing inference time.

Image Segmentation (Cont.)



Application of Segmentation

- There are many other applications where Image segmentation is transforming industries:
  - Traffic Control Systems
  - Self Driving Cars
  - Locating objects in satellite images

Goal of Segmentation

- Image improvement – low level IP
  - Improvement of pictorial information for human interpretation (Improving the visual appearance of images to a human viewer)
- Image analysis – high level IP
  - Processing of scene data for autonomous machine perception (Preparing images for measurement of the features and structures present)

Approaches in Image Segmentation

- **Similarity Approach:**
  - This approach is based on detecting similarity between image pixels to form a segment, based on a threshold.
  - ML algorithms like clustering are based on this type of approach to segment an image.
- **Discontinuity Approach:**
  - This approach relies on the discontinuity of pixel intensity values of the image.
  - Line, Point, and Edge Detection techniques use this type of approach for obtaining intermediate segmentation results which can be later processed to obtain the final segmented image.

Approaches in Image Segmentation (Cont.)

- Image Segmentation
  - Discontinuity Approach:
    - Discontinuities Point Detection / Isolated Point Detection
    - Lines Detection
    - Edge Detection
  - Similarity Approach:
    - Threshold Based Segmentation / Histogram Based Segmentation
    - Region-Based Segmentation
    - Clustering Based Segmentation

Discontinuities Point Detection / Isolated Point Detection

- A point is the most basic type of discontinuity in a digital image.
- The most common approach to finding discontinuities is to run an (n*n) mask over each point in the image (Laplacian Mask)

-1	-1	-1
-1	8	-1
-1	-1	-1

Discontinuities Point Detection / Isolated Point Detection (Cont.)

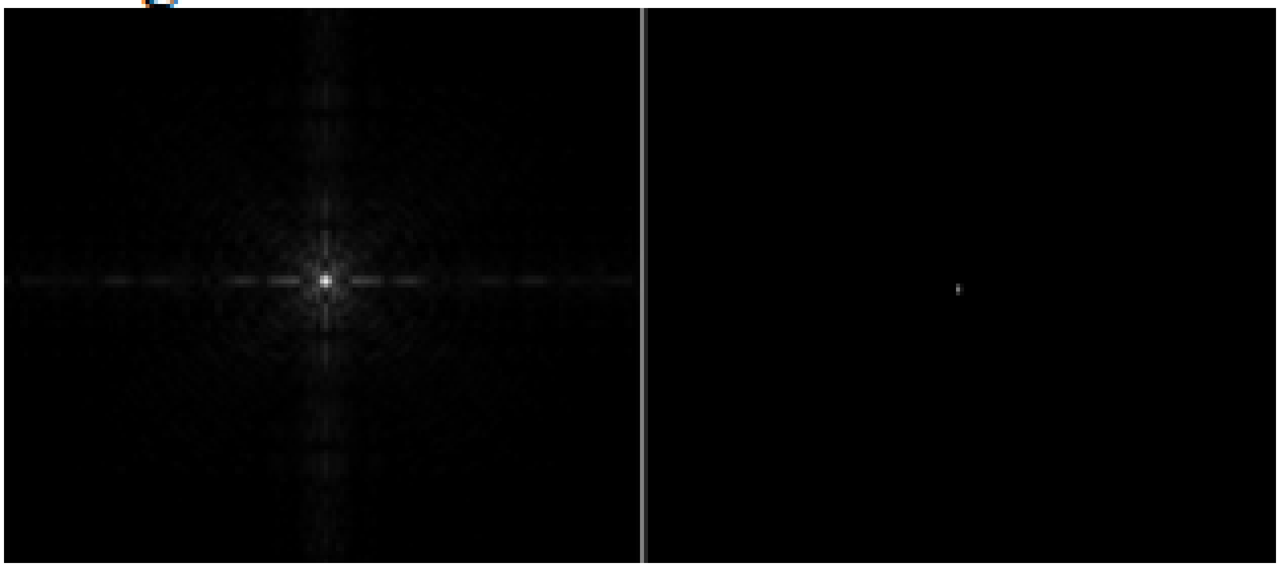
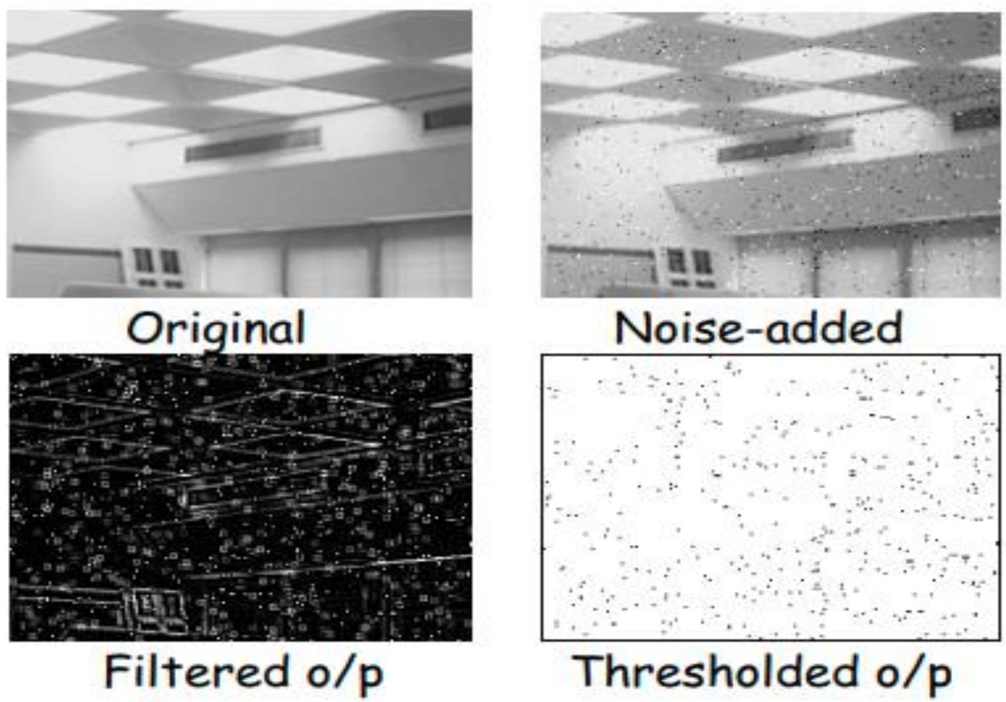


Figure 3. (a) Gray-scale image with a nearly invisible isolated black point (b) Image showing the detected point

Discontinuities Point Detection / Isolated Point Detection (Cont.)

- The idea is that the gray level of an isolated point will be quite different from the gray level of its neighbors

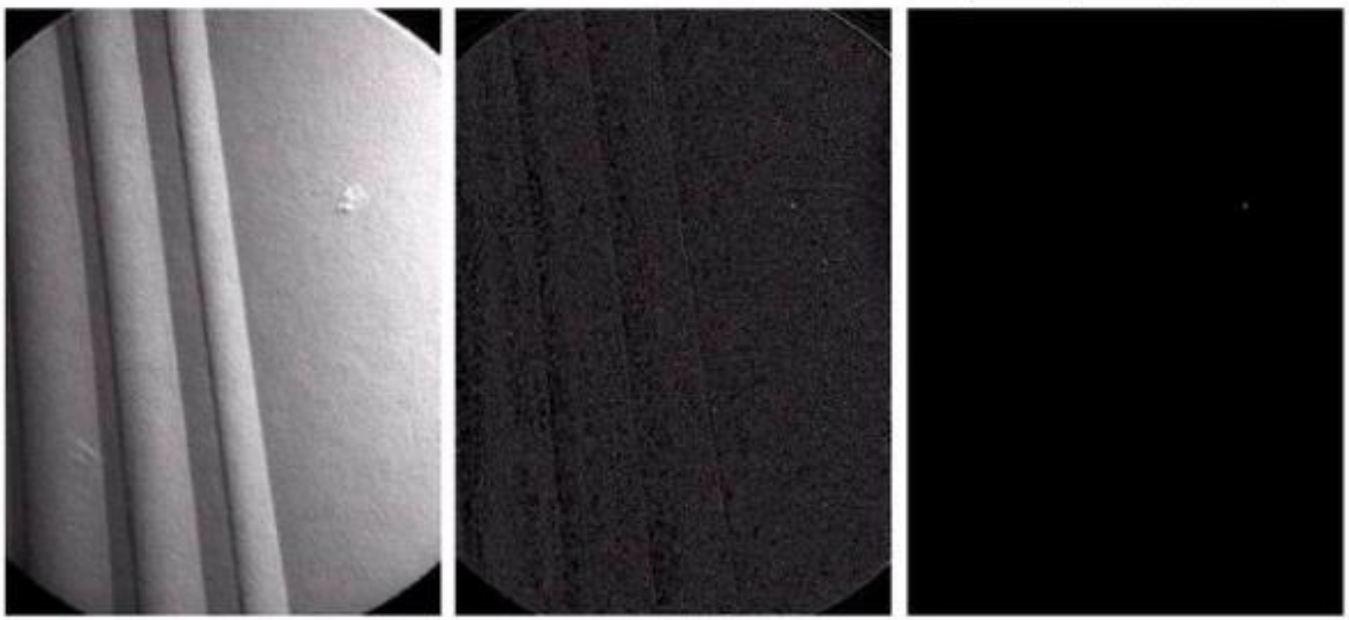


Discontinuities Point Detection / Isolated Point Detection (Cont.)

$$|R| \geq T$$

where T : a nonnegative threshold

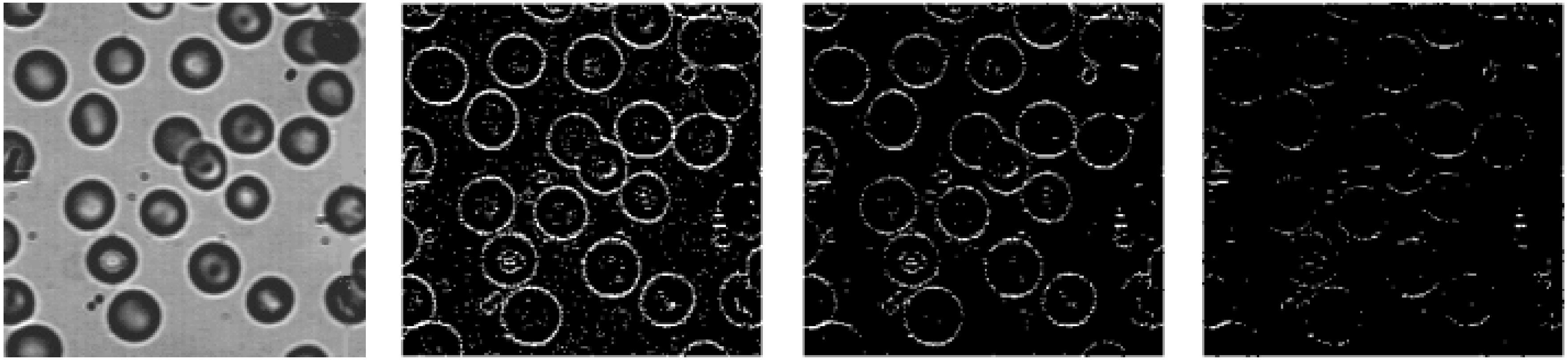
–1	–1	–1
–1	8	–1
–1	–1	–1



a
b c d

FIGURE 10.2
(a) Point detection mask.
(b) X-ray image of a turbine blade with a porosity.
(c) Result of point detection.
(d) Result of using Eq. (10.1-2).
(Original image courtesy of X-TEK Systems Ltd.)

Discontinuities Point Detection / Isolated Point Detection (Cont.)



Orig. Image $T = 0.25$ $T = 0.35$ $T = 0.5$

Discontinuities Point Detection / Isolated Point Detection in MATLAB

```
I=imread('circbw.tif');
imshow(I);
title('Original Image');

% Isolated Point Detection
IP=[-1,-1,-1;-1,8,-1;-1,-1,-1];
IP_Image=conv2(I,IP,"same");
figure;
imshow(IP_Image);
title(‘ Isolated Point Detection ');
```

Line Segmentation

- This is used to detect lines in an image.
- For digital images the only three point straight lines are only horizontal, vertical, or diagonal (+ 45° or –45°).

FIGURE 10.3 Line masks.

Horizontal:

−1	−1	−1
2	2	2
−1	−1	−1

+45°:

−1	−1	2
−1	2	−1
2	−1	−1

Vertical:

−1	2	−1
−1	2	−1
−1	2	−1

−45°:

2	−1	−1
−1	2	−1
−1	−1	2

Line Segmentation (Cont.)

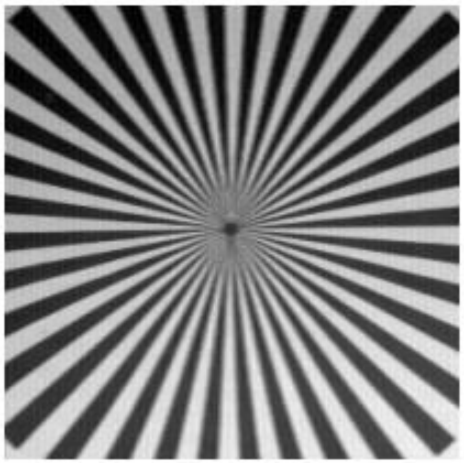
$$\mathcal{D}_{0^\circ} = \begin{bmatrix} -1 & -1 & -1 \\ 2 & 2 & 2 \\ -1 & -1 & -1 \end{bmatrix}$$ Detects horizontal lines

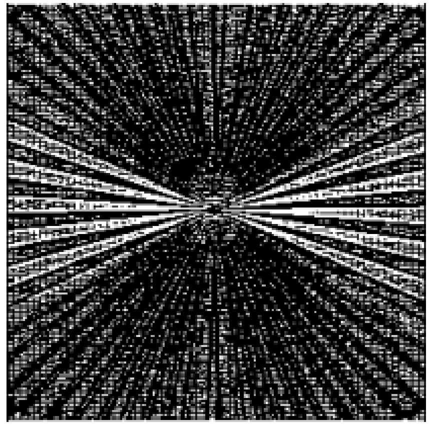
$$\mathcal{D}_{45^\circ} = \begin{bmatrix} -1 & -1 & 2 \\ -1 & 2 & -1 \\ 2 & -1 & -1 \end{bmatrix}$$ Detects 45° lines

$$\mathcal{D}_{90^\circ} = \begin{bmatrix} -1 & 2 & -1 \\ -1 & 2 & -1 \\ -1 & 2 & -1 \end{bmatrix}$$ Detects vertical lines

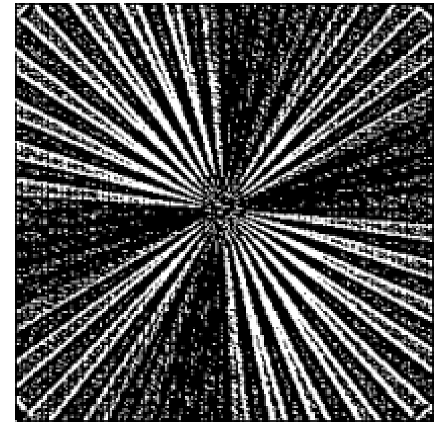
$$\mathcal{D}_{135^\circ} = \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$$ Detects 135° lines

Line Segmentation (Cont.)

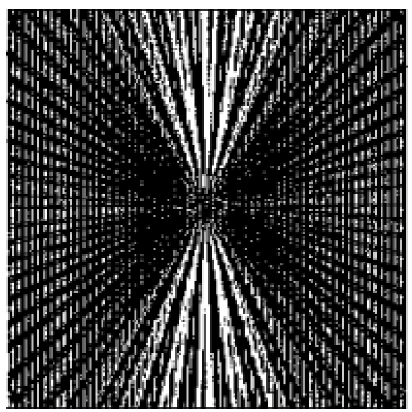




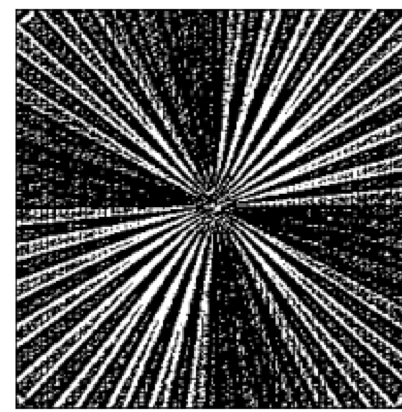
$$R_{0^\circ} = \max\{R_{0^\circ}, R_{45^\circ}, R_{90^\circ}, R_{135^\circ}\}$$



$$R_{45^\circ} = \max\{R_{0^\circ}, R_{45^\circ}, R_{90^\circ}, R_{135^\circ}\}$$



$$R_{90^\circ} = \max\{R_{0^\circ}, R_{45^\circ}, R_{90^\circ}, R_{135^\circ}\}$$



$$R_{135^\circ} = \max\{R_{0^\circ}, R_{45^\circ}, R_{90^\circ}, R_{135^\circ}\}$$

Line Segmentation (Cont.)

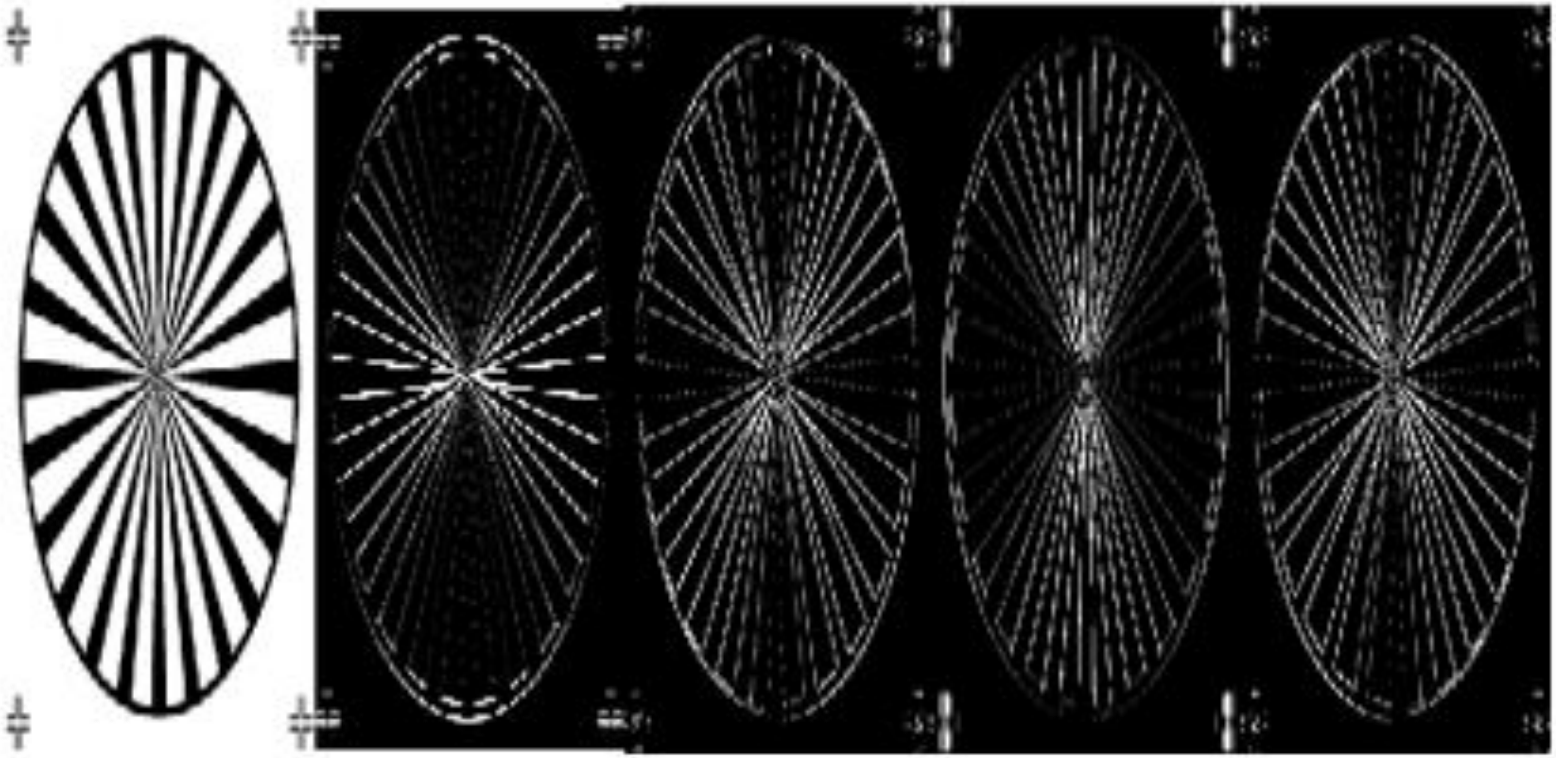
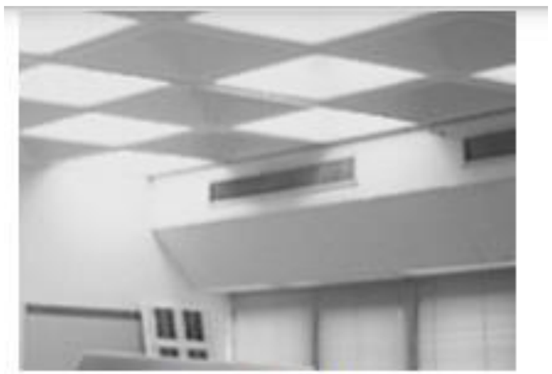


Figure 5. (a) Original Image (b) result showing with horizontal detector (c) with 45° detector (d) with vertical detector (e) with -45° detector

Line Segmentation (Cont.)

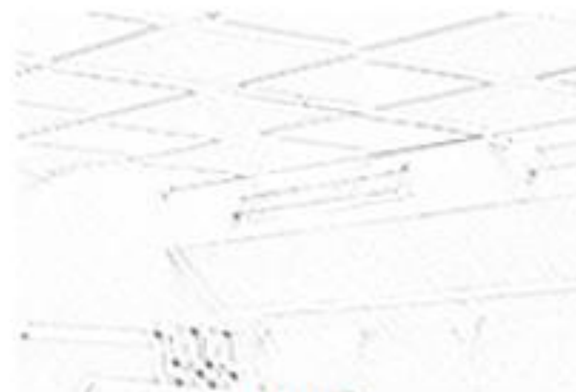


Original

Horizontal line

45° line

Vertical line



-45° line

Line Segmentation (Cont.)

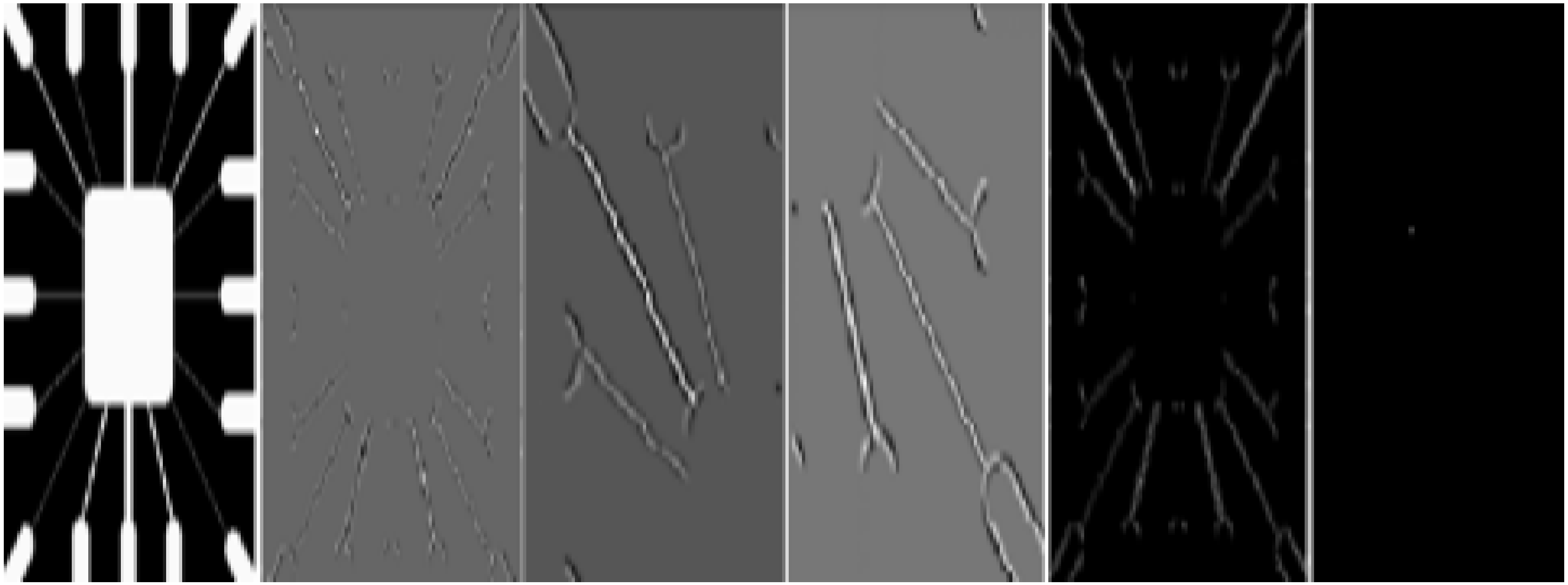
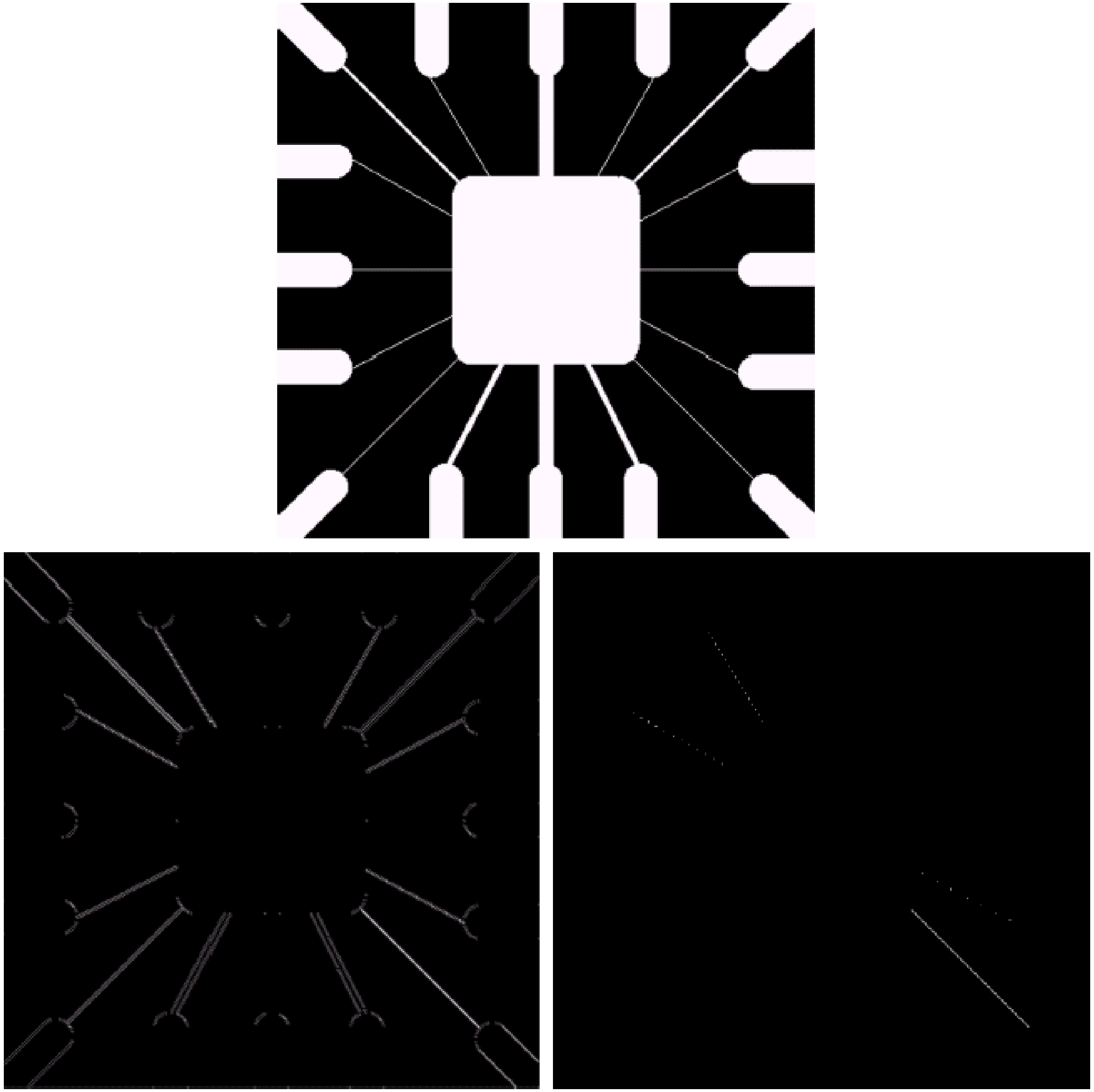


Figure 6. (a) Image of a wire-bond mask (b) Result of processing with the –45° detector (c) Zoomed view of the top, left region of –45° detector (d) Zoomed view of the bottom, right region of –45° detector (e) Absolute value of –45° detector (f) All points whose values satisfied the condition g >= T, where g is the image in (e)

Line Segmentation (Cont.)



a
b c

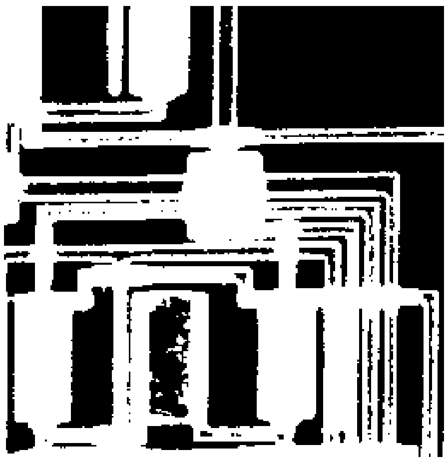
FIGURE 10.4
Illustration of line detection.
(a) Binary wire-bond mask.
(b) Absolute value of result after processing with $-45°$ line detector.
(c) Result of thresholding image (b).

Line Segmentation in MATLAB

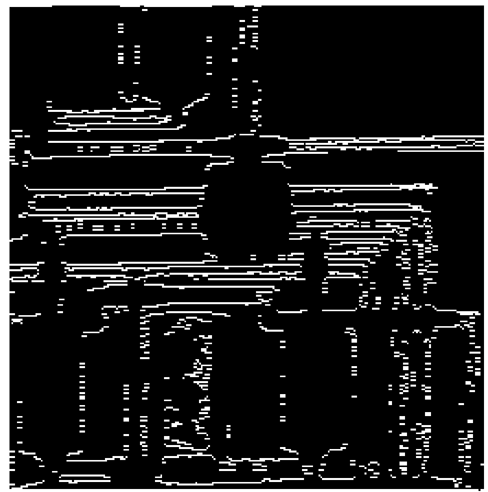
```
I=imread('circbw.tif');
%bw=imbinarize(I);
imshow(I);
title('Original Image');

%horizontal Line
HL=[-1,-1,-1;2,2,2;-1,-1,-1];
HL_Image=conv2(I,HL,"same");
figure;
imshow(HL_Image);
title('Horizontal Lines');

% Vertical Line
VL=[-1,2,-1;-1,2,-1;-1,2,-1];
VL_Image=conv2(I,VL,"same");
figure;
imshow(VL_Image);
title('Vertical Lines');

%diagonal +45
DL45=[-1,-1,2;-1,2,-1;2,-1,-1];
DL_Image1=conv2(I,DL45,"same");
figure;
imshow(DL_Image1);
title('Diagonal Lines at +45');

%diagonal -45
DL_45=[2,-1,-1;-1,2,-1;-1,-1,2];
DL_Image2=conv2(I,DL_45,"same");
figure;
imshow(DL_Image2);
title('Diagonal Lines at -45');
```

Line Segmentation in MATLAB (Cont.)

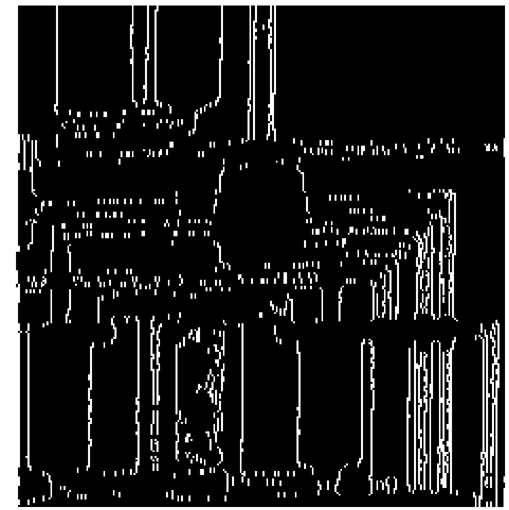
Original Image



Horizontal Lines



Vertical Lines



Diagonal Lines at +45

Diagonal Lines at -45

Edge Based Segmentation / Edge Detection

- Edge locates sharp changes in the intensity function.
- Edges are pixels where brightness changes abruptly.
- An edge is a boundary between two regions having distinct intensity level.
- It is very useful in detecting of discontinuity in an image.
- When the image changes from dark to white or vice-versa.

Edge Based Segmentation / Edge Detection (Cont.)

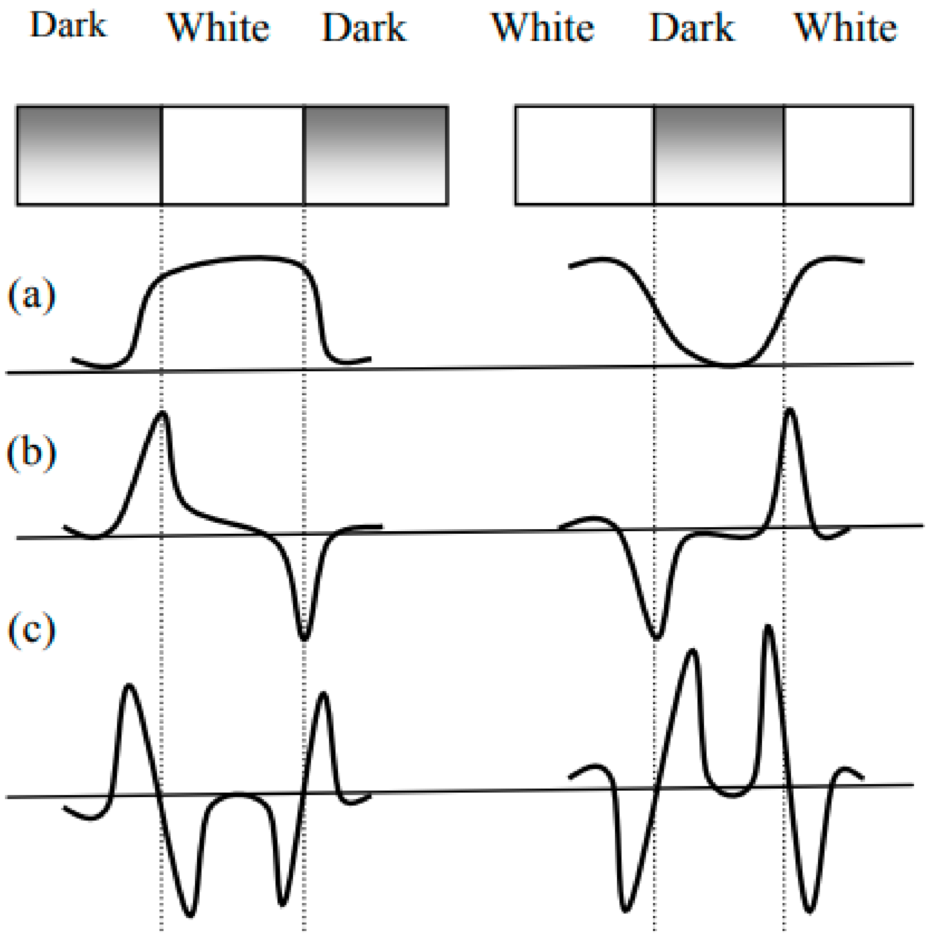
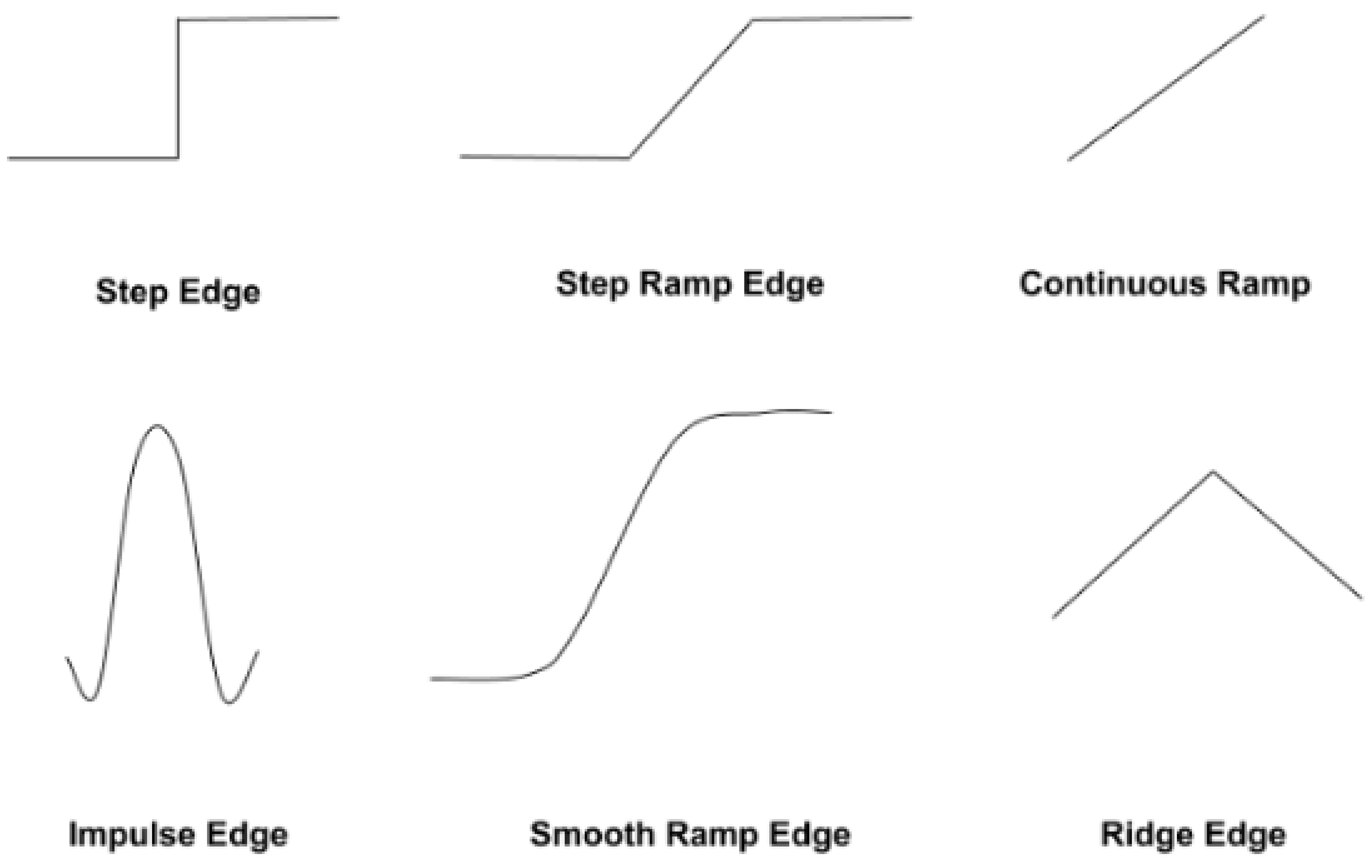


Figure 7. (a) Intensity profile (b) First-order derivatives (c) Second-order derivatives

Edge Based Segmentation / Edge Detection (Cont.)

- Types Of Edges



Edge Based Segmentation / Edge Detection (Cont.)

- Edge Detection
  - Gradient Based Operator
    - Roberts Operator
    - Prewitt Operator
    - Sobel Operator
  - Laplacian Based Operator
    - Laplacian Operator
    - Laplacian of Gaussion

Edge Based Segmentation / Edge Detection (Cont.)

- Gradient Based Operator
  - Roberts Operator
  - Prewitt Operator
  - Sobel Operator

−1	0
0	1

0	−1
1	0

Roberts

−1	−1	−1
0	0	0
1	1	1

−1	0	1
−1	0	1
−1	0	1

Prewitt

−1	−2	−1
0	0	0
1	2	1

−1	0	1
−2	0	2
−1	0	1

Sobel

Edge Based Segmentation / Edge Detection (Cont.)

- Laplacian Based Operator
  - Laplacian Operator
  - Laplacian of Gaussion

0	0	−1	0	0
0	−1	−2	−1	0
−1	−2	16	−2	−1
0	−1	−2	−1	0
0	0	−1	0	0

$$h = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

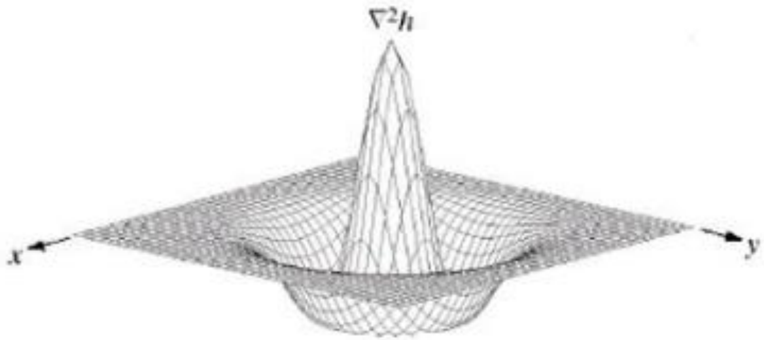
4-neighborhood

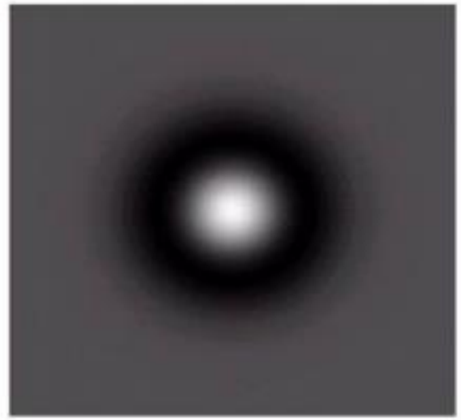
$$h = \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

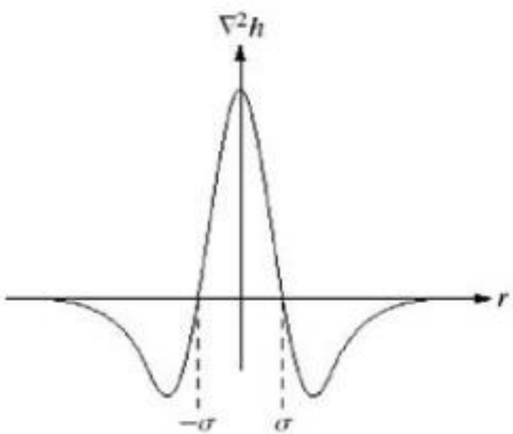
8-neighborhood

Edge Based Segmentation / Edge Detection (Cont.)

- Because of its shape, the LoG operator is commonly called a Mexican hat.







0	0	−1	0	0
0	−1	−2	−1	0
−1	−2	16	−2	−1
0	−1	−2	−1	0
0	0	−1	0	0

a b
c d

FIGURE 10.14 Laplacian of a Gaussian (LoG). (a) 3-D plot. (b) Image (black is negative, gray is the zero plane, and white is positive). (c) Cross section showing zero crossings. (d) 5 × 5 mask approximation to the shape of (a).

Edge Based Segmentation / Edge Detection (Cont.)

a b
c d

FIGURE 10.10 (a) Original image. (b) $|G_x|$, component of the gradient in the x-direction. (c) $|G_y|$, component in the y-direction. (d) Gradient image, $|G_x| + |G_y|$.

Edge Based Segmentation / Edge Detection (Cont.)

FIGURE 10.11 Same sequence as in Fig. 10.10, but with the original image smoothed with a 5 × 5 averaging filter.

Edge Based Segmentation / Edge Detection (Cont.)

Algorithm	Description	Advantages	Limitations
Edge Detection Segmentation	Makes use of discontinuous local features of an image to detect edges and hence define a boundary of the object.	It is good for images having better contrast between objects.	Not suitable when there are too many edges in the image and if there is less contrast between objects.

Threshold Based Segmentation / Histogram Based Segmentation

Marwadi University

- Thresholding is the simplest image segmentation method, dividing pixels based on their intensity relative to a given value or threshold.
- It is suitable for segmenting objects with higher intensity than other objects or backgrounds.
- It is a way to create a binary or multi-color image based on setting a threshold value on the pixel intensity of the original image.

Threshold Based Segmentation (Cont.)

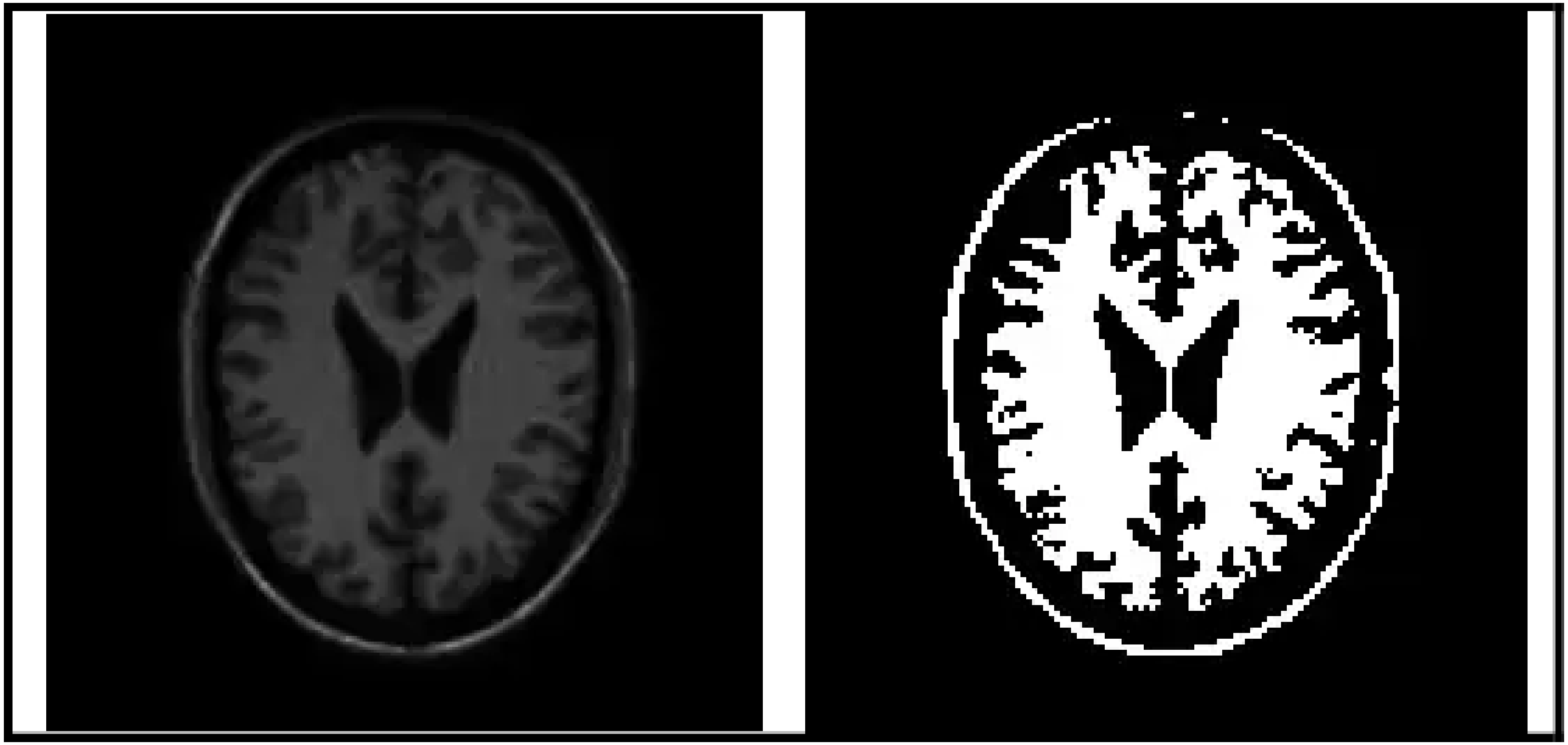
- Types of Threshold Based Segmentation
  - **Global Thresholding**
    - If we want to divide the image into two regions (object and background), we define a single threshold value. This is known as the global thresholding.
  - **Local Thresholding**
    - If we have multiple objects along with the background, we must define multiple thresholds. These thresholds are collectively known as the local thresholding.

Threshold Based Segmentation (Cont.)

- Global Thresholding
  - In this thresholding process, we will consider the intensity histogram of all the pixels in the image.
  - Then we will set a threshold to divide the image into sections.
  - For example, considering image pixels ranging from 0 to 255, we set a threshold of 60.
    - So all the pixels with values less than or equal to 60 will be provided with a value of 0(black)
    - all the pixels with a value greater than 60 will be provided with a value of 255(white).

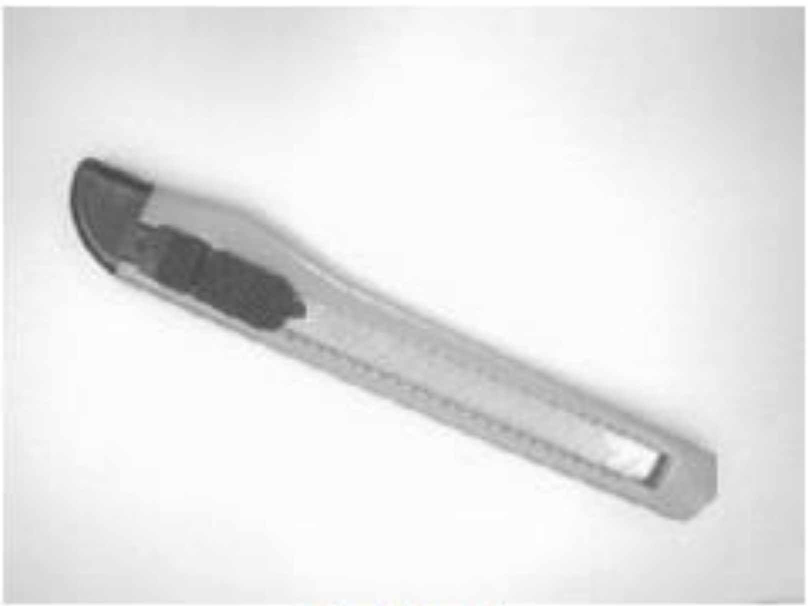
Threshold Based Segmentation (Cont.)

- Global Thresholding



Threshold Based Segmentation (Cont.)

- Global Thresholding



Original

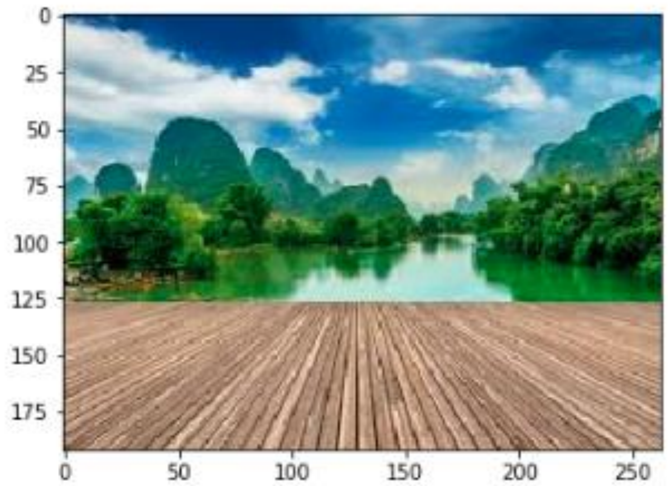
Threshold result (T=200)

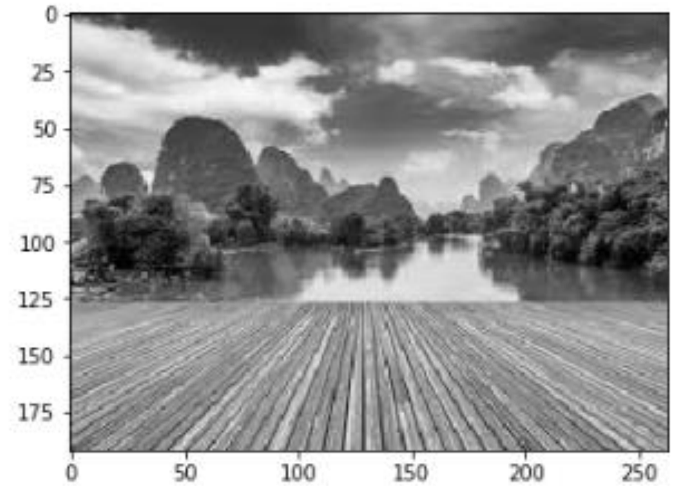
Threshold Based Segmentation (Cont.)

- Local Thresholding
  - We can define multiple thresholds as well to detect multiple objects

Threshold Based Segmentation (Cont.)

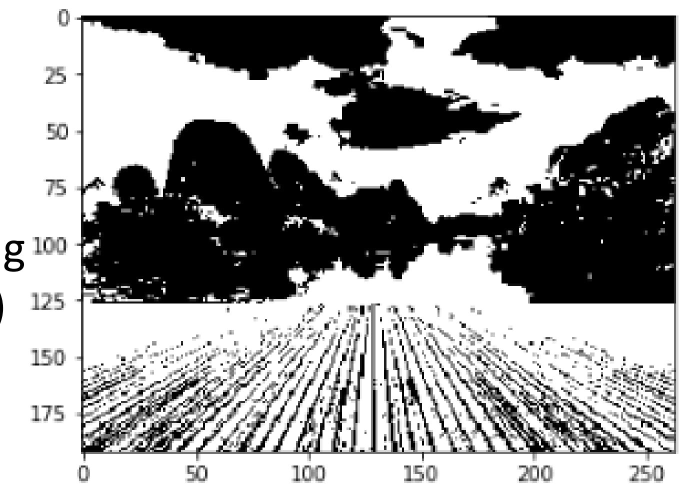
Original RGB Image

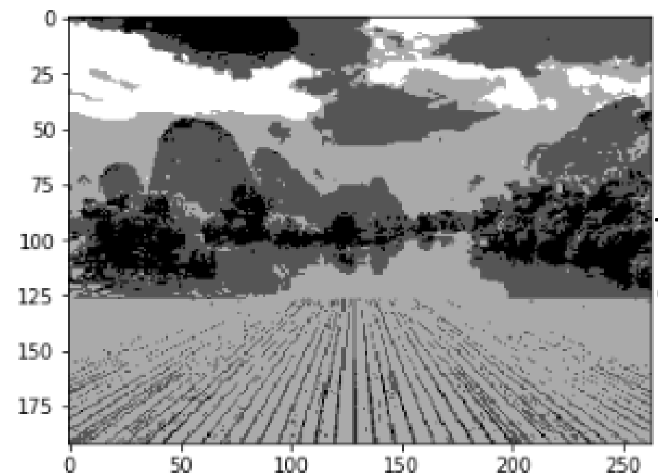




Gray Image

Global Thresholding (1 Thresold)





Local Thresholding (3 Thresold)

Threshold Based Segmentation (Cont.)

Algorithm	Description	Advantages	Limitations
Threshold Based Segmentation	Separates the objects into different regions based on some threshold value(s).	• Simple calculations • Fast operation speed • When the object and background have high contrast, this method performs really well	When there is no significant grayscale difference or an overlap of the grayscale pixel values, it becomes very difficult to get accurate segments.

Global Thresholding in MATLAB

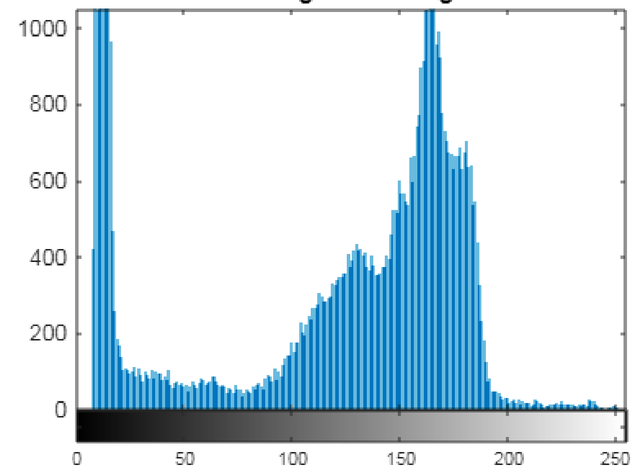
```
clc;clear;
%Load Image
A=imread('cameraman.tif');
imshow(A);
title('Original Image');

%histogram of Image
figure;
imhist(A);
title('Histogram of Image');

%Global Thresholding - Threshold = 70
output1=zeros(size(A));
for i=1:size(A,1)
        for j=1:size(A,2)
                if A(i,j)>=70
                  output1(i,j)=1;
                else
                  output1(i,j)=0;
                end
        end
end
```

```
figure;
imshow(output1);
title('Global Thresholding, Thresold=70')


%Global Thresholding - Threshold=150
output1=zeros(size(A));
for i=1:size(A,1)
        for j=1:size(A,2)
                if A(i,j)>=150
                  output1(i,j)=1;
                else
                  output1(i,j)=0;
                end
        end
end

figure;
imshow(output1);
title('Global Thresholding, Thresold=150')
```

Global Thresholding in MATLAB

Original Image

Histogram of Image



Global Thresholding, Thresold=70

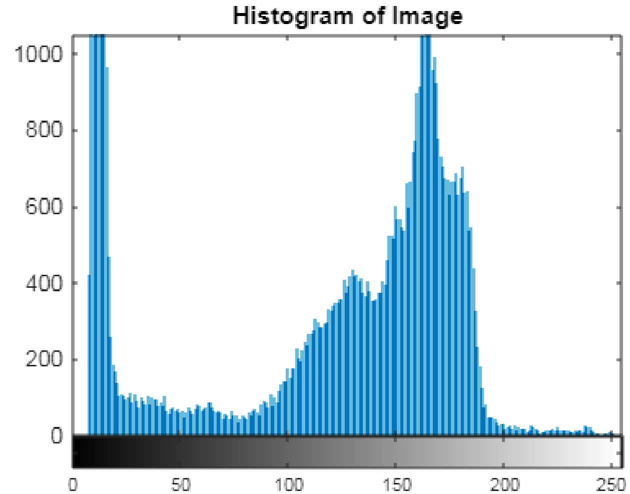
Global Thresholding, Thresold=150

Local Thresholding in MATLAB

```
clc;clear;
%Load Image
A=imread('cameraman.tif');
imshow(A);
title('Original Image');

%histogram of Image
figure;
imhist(A);
title('Histogram of Image');

%Local Thresholding - Threshold = 70, 120
output1=A;
for i=1:size(A,1)
    for j=1:size(A,2)
        if A(i,j)>=120
          output1(i,j)=255;
        elseif A(i,j)>=70
          output1(i,j)=128;
        else
          output1(i,j)=0;
        end
    end
end
figure;
imshow(output1);
title('Local Thresholding, Threshold = 70, 120')

%Local Thresholding - Thresold=50,100,150,200
output1=A;
for i=1:size(A,1)
    for j=1:size(A,2)
        if A(i,j)>=200
          output1(i,j)=255;
        elseif A(i,j)>=150
          output1(i,j)=170;
        elseif A(i,j)>=100
          output1(i,j)=100;
        else
          output1(i,j)=0;
        end
    end
end

figure;
imshow(output1);
title('Local Thresholding, Thresold=50,100,150,200')
```

Local Thresholding in MATLAB

Original Image



Local Threshold = 70, 120

Local Thresold=50,100,150,200

Region-Based Segmentation

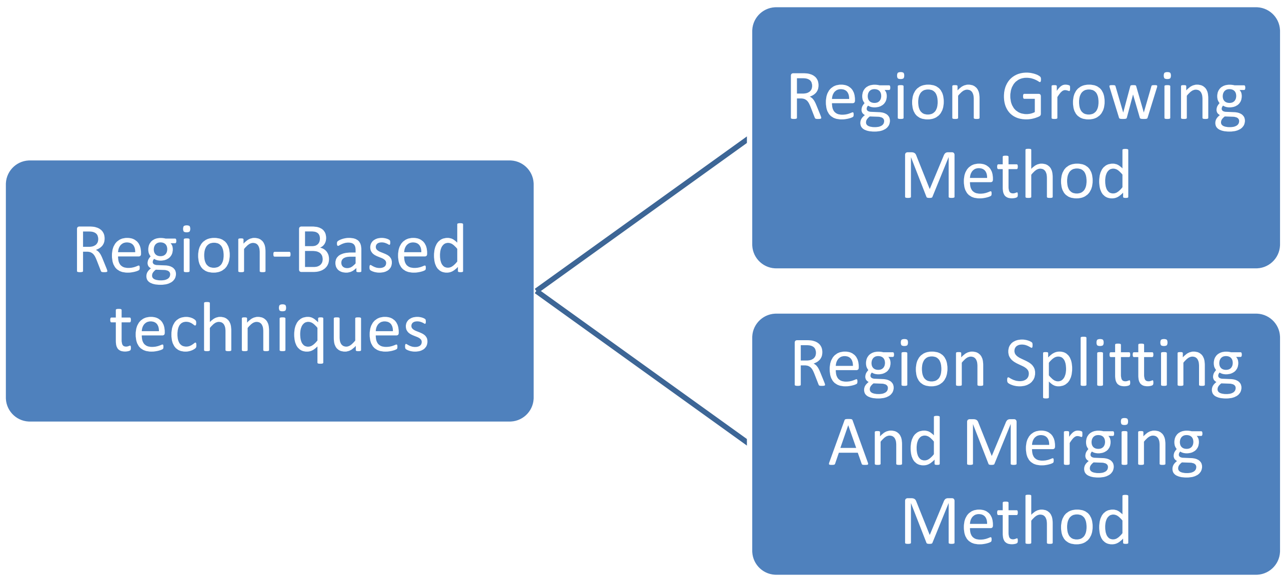
- What id Region?
  - A region can be classified as a group of connected pixels exhibiting similar properties.
  - The similarity between pixels can be in terms of intensity, color, etc. In this type of segmentation, some predefined rules are present which have to be obeyed by a pixel in order to be classified into similar pixel regions.

Region-Based Segmentation (Cont.)

- Region-based segmentation involves dividing an image into regions with similar characteristics.
- This type of Segmentation is prefered in case of a noisy image

Region-Based Segmentation (Cont.)

- Region-Based techniques are further classified into 2 types based on the approaches they follow.



Region Growing Technique

- Region growing is a procedure that groups pixels or subregions into larger regions
- we grow regions by recursively including the neighboring pixels that are similar and connected to the seed pixel.

Region Growing Technique (Cont.)

- Consider a seed pixel of 2 in the given image and a threshold value of 3,
- if a pixel has a value greater than 3 then it will be considered inside the seed pixel region.
- Otherwise, it will be considered in another region. Hence 2 regions are formed in the following image based on a threshold value of 3.

1	1	5	6	5	5
2	1	6	7	4	6
3	2	7	4	6	7
1	0	5	5	7	6
2	0	4	6	8	5
0	1	6	4	5	8

Original Image

1	1	5	6	5	5
2	1	6	7	4	6
3	2	7	4	6	7
1	0	5	5	7	6
2	0	4	6	8	5
0	1	6	4	5	8

Region growing process with 2 as the seed pixel.

R1	R1	R2	R2	R2	R2
R1	R1	R2	R2	R2	R2
R1	R1	R2	R2	R2	R2
R1	R1	R2	R2	R2	R2
R1	R1	R2	R2	R2	R2
R1	R1	R2	R2	R2	R2

Splitting image into two regions based on a threshold.

Region Growing Technique (Cont.)

0	0	5	6	7
1	1	5	8	7
0	<u>1</u>	6	<u>7</u>	7
2	0	7	6	6
0	1	5	6	5

Original intensity array

a	a	b	b	b
a	a	b	b	b
a	a	b	b	b
a	a	b	b	b
a	a	b	b	b

Result of threshold=3

a	a	a	b	b
a	a	a	b	b
a	a	b	b	b
a	a	b	b	b
a	a	a	b	?

Result of Threshold=5.5

a	a	a	a	a
a	a	a	a	a
a	a	a	a	a
a	a	a	a	a
a	a	a	a	a

Result of threshold=9

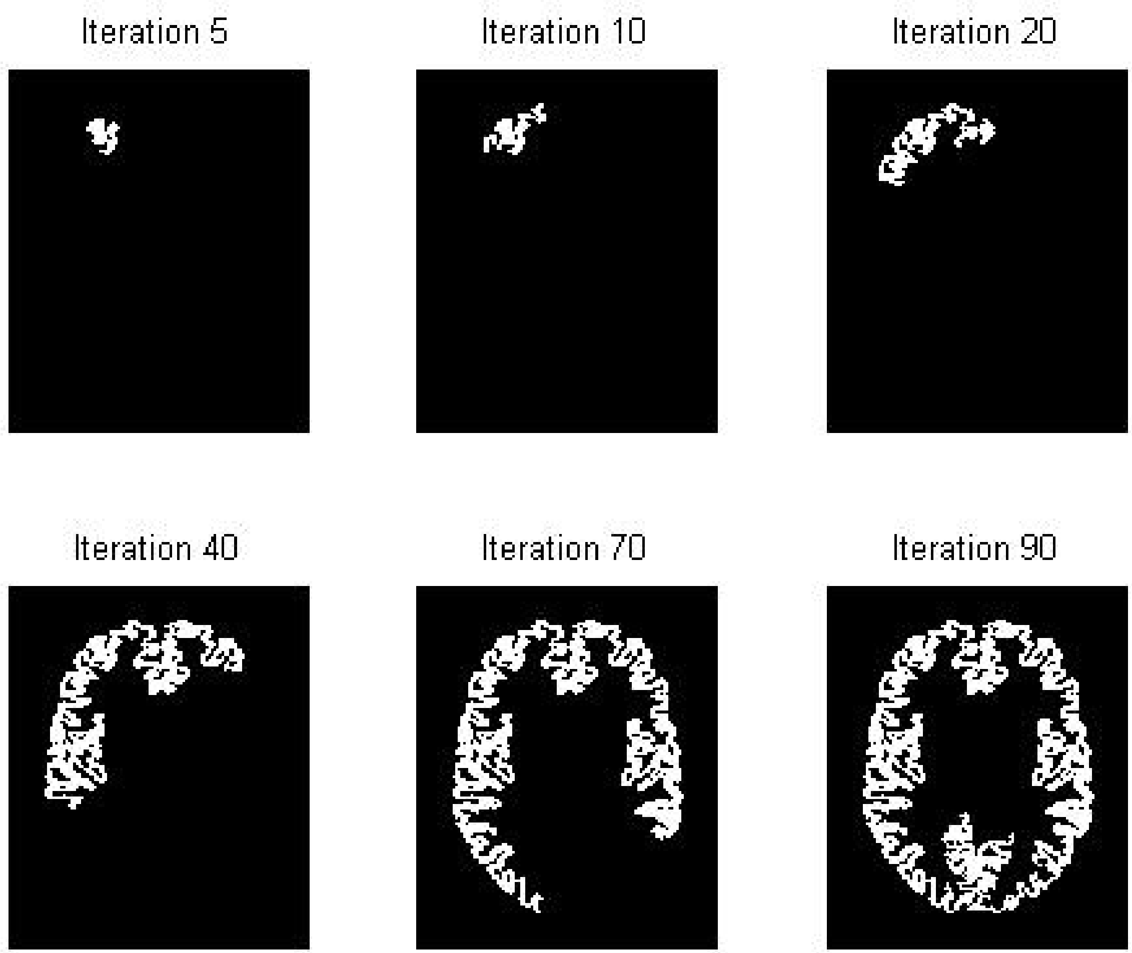
Example of region growing using known starting points

Region Growing Technique (Cont.)

Fig 7. Original image with seed point, (b) early stage of region growth, (c) final region.

- Problems have to be resolved:
  1. Selection of initial seeds that properly represent regions of interest.
  2. Selection of suitable properties for including points in the various regions during the growing process.
  3. The formulation of stopping rule.

Region Growing Technique (Cont.)

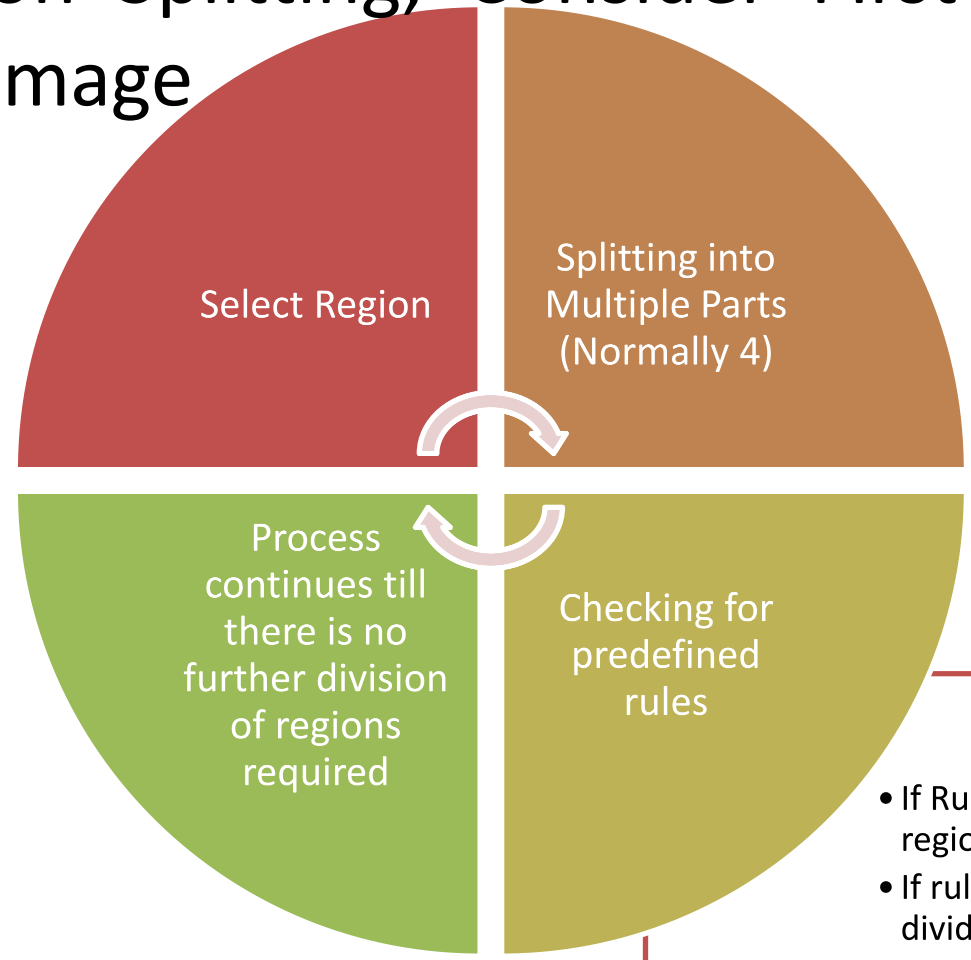


Region Growing Technique (Cont.)

- In the case of the Region growing method, we start with some pixel as the seed pixel and then check the adjacent pixels.
- If the adjacent pixels abide by the predefined rules, then that pixel is added to the region of the seed pixel and the following process continues till there is no similarity left.
- This method follows the bottom-up approach.
- In case of a region growing, the preferred rule can be set as a threshold.

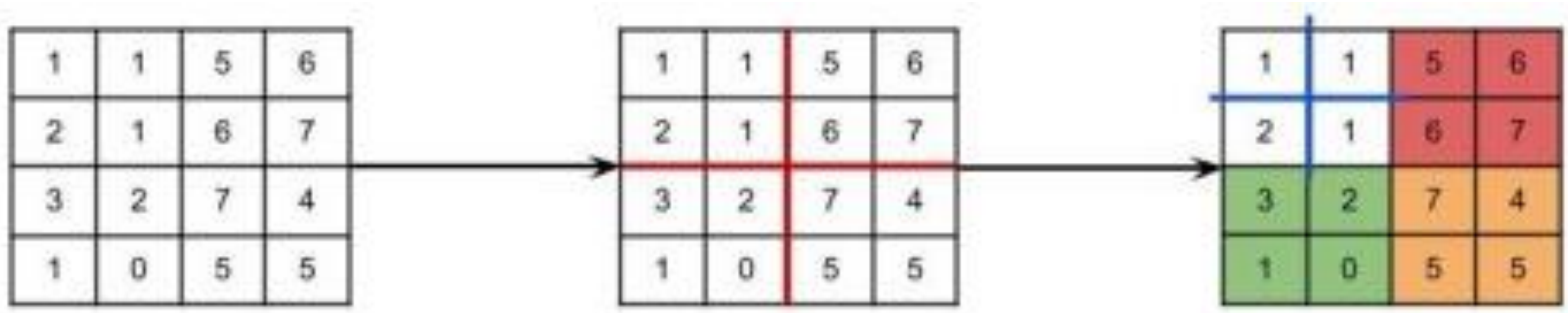
Region Splitting and Merging Technique

- In Region Splitting, Consider First Region as Whole Image



- If Rule Satisfy consider as region
- If rule not Satisfy then again divide into sub region

Region Splitting and Merging Technique (Cont.)



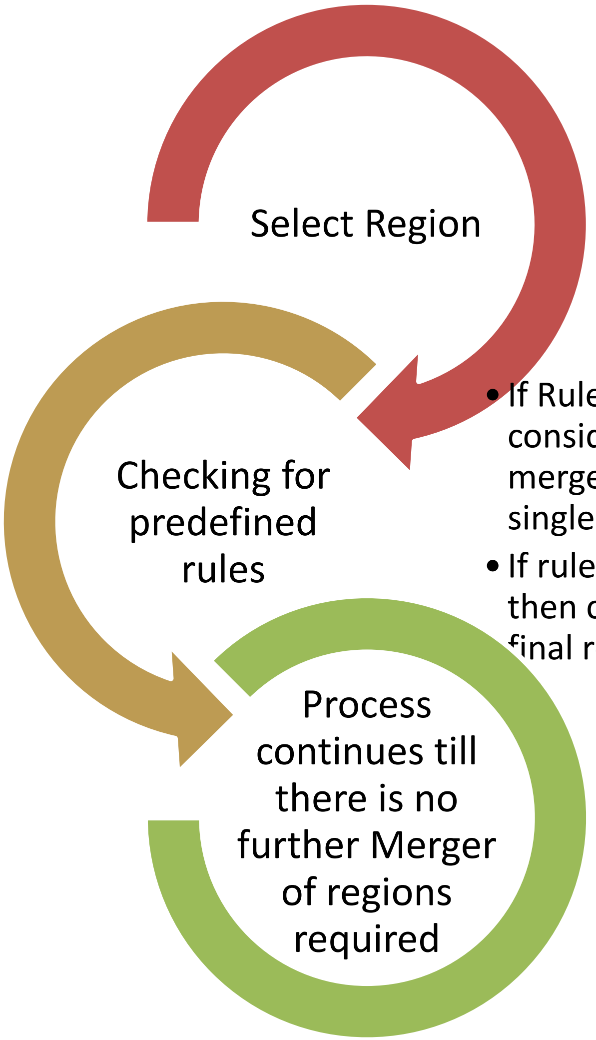
Original Image

Region splitting into 4 quadrant

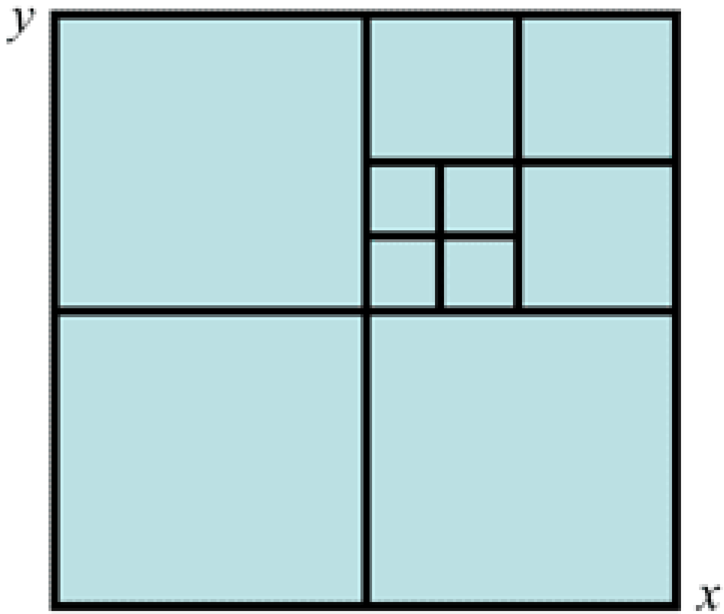
Classifying a quadrant as a region if it satisfies condition else performing further splitting

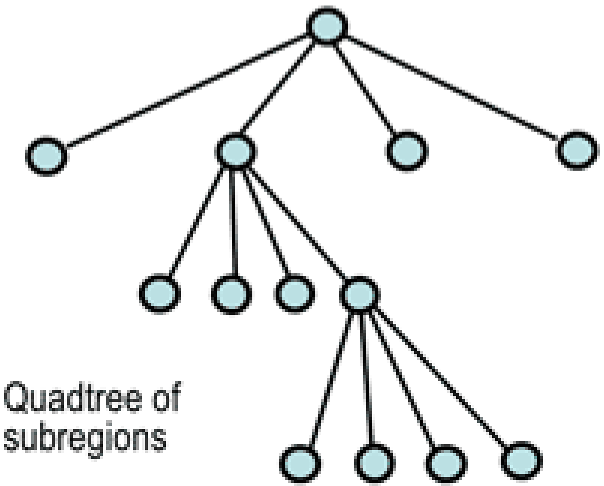
Region Splitting and Merging Technique (Cont.)

- In Region merging technique, we consider every pixel as an individual region.



Region Splitting and Merging Technique (Cont.)





Clustering Based Segmentation

- Clustering is a type of unsupervised machine learning algorithm.
- It is highly used for the segmentation of images.
- One of the most dominant clustering-based algorithms used for segmentation is KMeans Clustering.
- This type of clustering can be used to make segments in a colored image.

Clustering Based Segmentation (Cont.)

- They augment human vision by isolating clusters, shadings, and structures.
- The algorithm divides images into clusters of pixels with similar characteristics, separating data elements and grouping similar elements into clusters.

Clustering Based Segmentation (Cont.)

Algorithm	Description	Advantages	Limitations
Segmentation based on Clustering	Divides the pixels of the image into homogeneous clusters.	Works really well on small datasets and generates excellent clusters.	1. Computation time is too large and expensive. 2. k-means is a distance-based algorithm. It is not suitable for clustering non-convex clusters.


Thank
you