DIGITAL IMAGE PROCESSING

IMAGE SEGMENTATION

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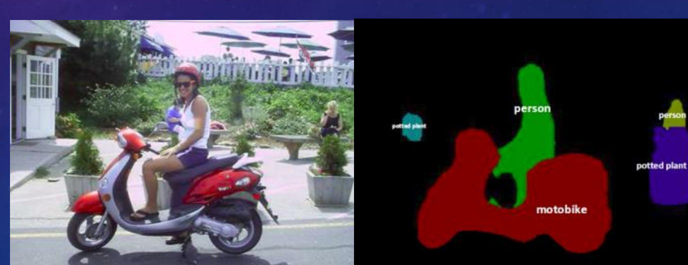
IMAGE SEGMENTATION

- Image segmentation is the process of *separating* or *grouping* an image into different parts
- The segmentation process is based on various features found in the image:
  - Color
  - Edges or boundaries
  - Texture



(Dai, He and Sun, 2016)

IMAGE SEGMENTATION

- Goal
- Connectivity
- Segmentation Methods
  - Amplitude
  - Region
  - Clustering
- Edge Detection

IMAGE SEGMENTATION

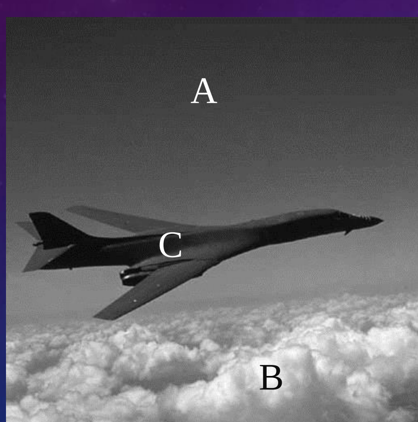


IMAGE SEGMENTATION

IMAGE SEGMENTATION

- Goal
- Connectivity (n-adjacency)
- Segmentation Methods
  - Amplitude
  - Region
  - Clustering
- Edge Detection

IMAGE SEGMENTATION

4-adjacency

- A pixel p at coordinates (x, y) has four horizontal and vertical neighbors whose coordinates are given by

$$(x+1, y), (x-1, y), (x, y+1), (x, y-1)$$

  - This set of pixels, called the 4-neighbors of p, is denoted by $N_4(p)$
  - If q is in the set $N_4(p)$, p and q are 4-adjacent.

8-adjacency

  - Four diagonal neighbors of p are denoted by $N_D(p)$. These points together with the 4-neighbors are called the 8-neighbors of p and denoted by $N_8(p)$
  - If q is in the set $N_8(p)$, p and q are 8-adjacent

1	1	1
1	1	1
1	1	1

1	1	1
1	1	1
1	1	1

1	1	1
1	1	1
1	1	1

IMAGE SEGMENTATION

m-adjacency

- Two pixels p and q are m-adjacent if
  - q is in $N_4(p)$, or
  - q is in $N_D(p)$, and the set $N_4(p) \cap N_4(q)$ has no pixels whose values are the values used to define adjacency.

1	1	1
1	1	1
1	1	1

1	0	1
0	1	0
1	0	1

1	0	1
0	1	0
1	1	1

IMAGE SEGMENTATION

- A path from pixel (x_0,y_0) to pixel (x_n,y_n) is a sequence of distinct pixels $(x_0,y_0), (x_1,y_1)\ldots (x_i,y_i)\ldots (x_n,y_n)$, where (x_{i-1},y_{i-1}) and (x_i,y_i) are adjacent for $1 \le i \le n$.
- We can define 4-, 8-, or *m*-paths depending on the type of adjacency specified.
- Question: find the shortest path from p to q, and determine the length of the path.

Using 4-adjacency:

Using 8-adjacency: $n = 4$

Using m-adjacency: $n = 7$

$$\begin{matrix} p & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & q \end{matrix} \qquad \begin{matrix} p & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & q \end{matrix} \qquad \begin{matrix} p & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & q \end{matrix}$$

IMAGE SEGMENTATION

- The foreground and background must have different definition of connectivity, or there will be ambiguity

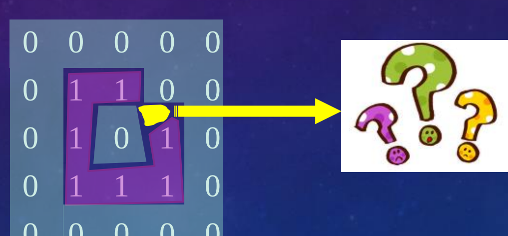


IMAGE SEGMENTATION

S --- a subset of pixels in an image;.

- Two pixels p and q are said to be connected in S if there exists a path between them consisting entirely of pixels in S.
- S is a connected set if it only has one connected component, it is also called a region of the image.
- Two regions R_i and R_j are said to be adjacent if $R_i \cup R_j$ is a connected set. Regions that are not adjacent are said to be disjoint.
- We consider 4- and 8-adjacency when referring to regions.

IMAGE SEGMENTATION

```
BW = [1 1 1 0 0 0 0 0;
      1 1 1 0 1 1 0 0;
      1 1 1 0 1 1 0 0;
      1 1 1 0 0 0 1 0;
      1 1 1 0 0 0 1 0;
      1 1 1 0 0 0 1 0;
      1 1 1 0 0 1 1 0;
      1 1 1 0 0 0 0 0]
```

```
L4 = 1 1 1 0 0 0 0 0
     1 1 1 0 2 2 0 0
     1 1 1 0 2 2 0 0
     1 1 1 0 0 0 3 0
     1 1 1 0 0 0 3 0
     1 1 1 0 0 0 3 0
     1 1 1 0 0 3 3 0
     1 1 1 0 0 0 0 0
```

```
L8 = 1 1 1 0 0 0 0 0
     1 1 1 0 2 2 0 0
     1 1 1 0 2 2 0 0
     1 1 1 0 0 0 2 0
     1 1 1 0 0 0 2 0
     1 1 1 0 0 0 2 0
     1 1 1 0 0 2 2 0
     1 1 1 0 0 0 0 0
```

L4 = bwlabel(BW,4)

L8 = bwlabel(BW,8)

IMAGE SEGMENTATION

- R represents the entire spatial region，we may view image segmentation as a process that partitions R into N subregions, such that :

predicate

- （1） $\bigcup_{i=1}^{N} R_i = R$
- （2） R_i is a connected set, $i = 1, 2, \ldots, N$
- （3） $R_i \cap R_j = \varnothing$ ， for all i and j ，$i \neq j$ ，
- （4） $Q(R_i)$ = TRUE, for $i = 1, 2, \ldots, N$ ，
- （5） $Q(R_i \cup R_j)$ = FALSE, for any adjacent regions R_i and R_j ，

IMAGE SEGMENTATION

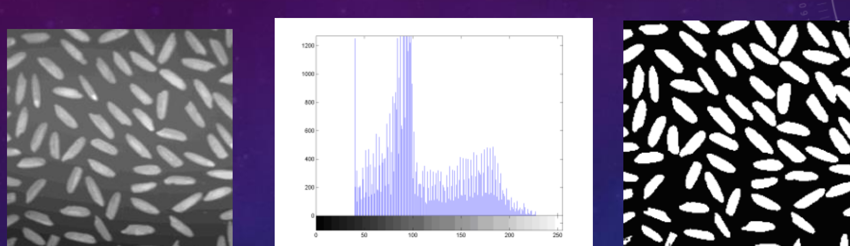
- Goal
- Connectivity
- Segmentation Methods
  - Amplitude thresholding
  - Region
  - Clustering
- Edge Detection

Threshold

IMAGE SEGMENTATION

- Bilevel Luminance Thresholding
- If an image is composed of light objects on a dark background, the intensity values can be grouped into two dominant modes. We can select a threshold T that separates these modes.
- The segmented image $g(x, y)$, is given by：

$$g(x,y)=\begin{cases}1 & f(x,y)\geq T\\ 0 & f(x,y)<T\end{cases}$$



（a） Original　　（b） Histogram　　（c） Segmented

Fig. Bilevel Luminance Thresholding

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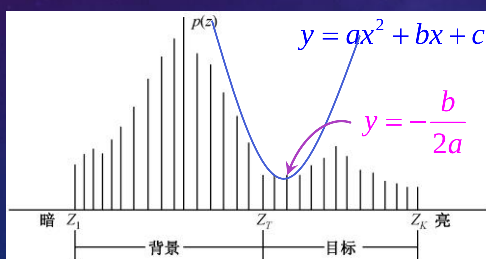
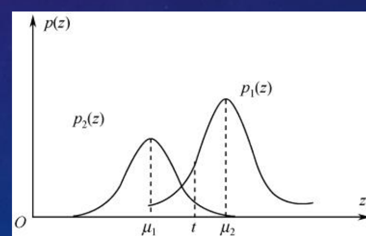
IMAGE SEGMENTATION

between class variance

- Basic global thresholding
  - A single threshold applicable over the entire image

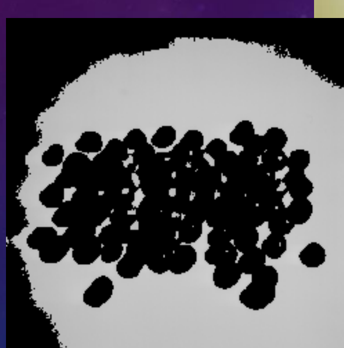


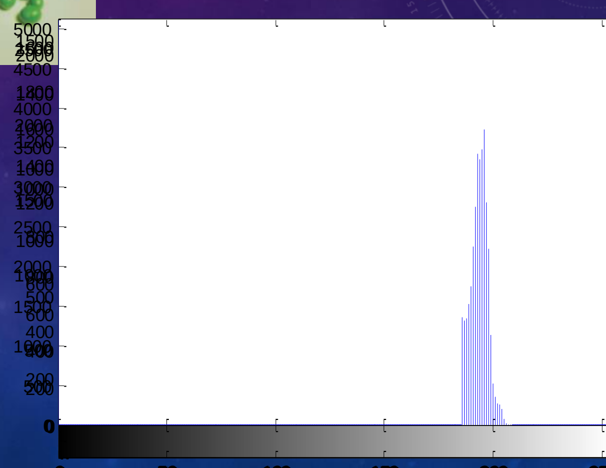


Ostu's method

IMAGE SEGMENTATION

- Multilevel Luminance Thresholding





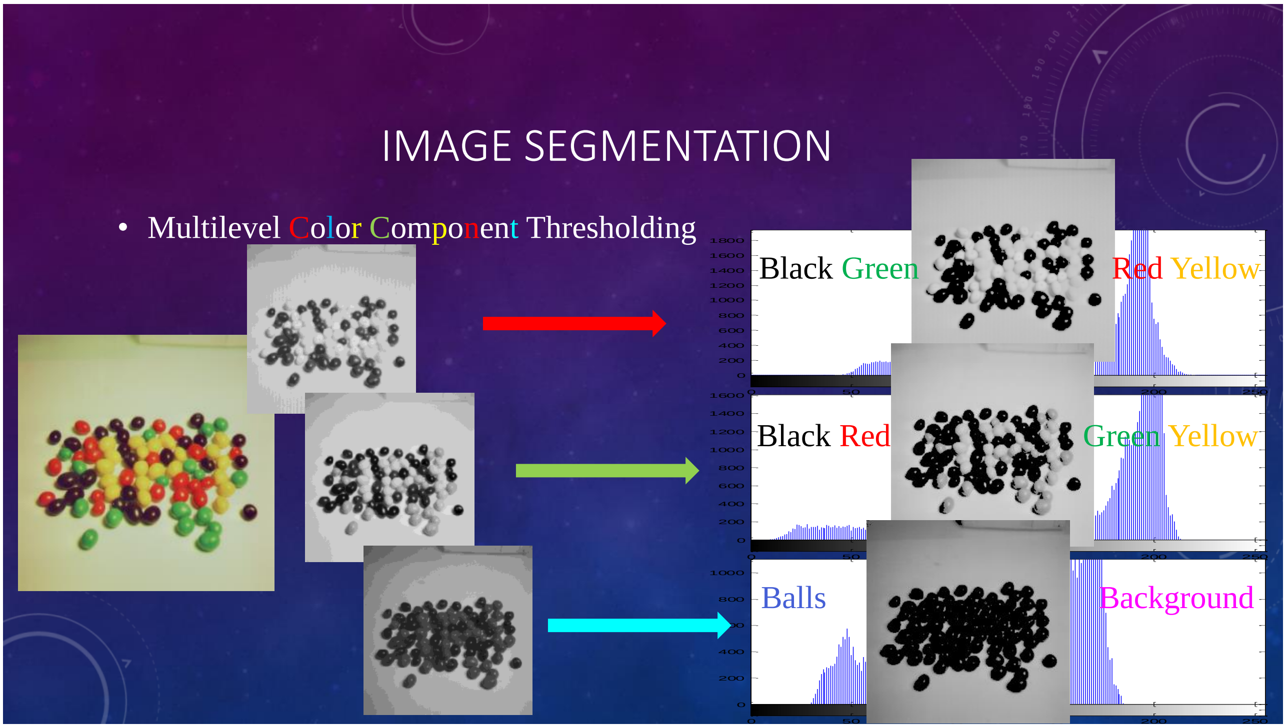


IMAGE SEGMENTATION
• Multilevel Color Component Thresholding
Black Green
Red Yellow
Black Red
Green Yellow
Balls
Background

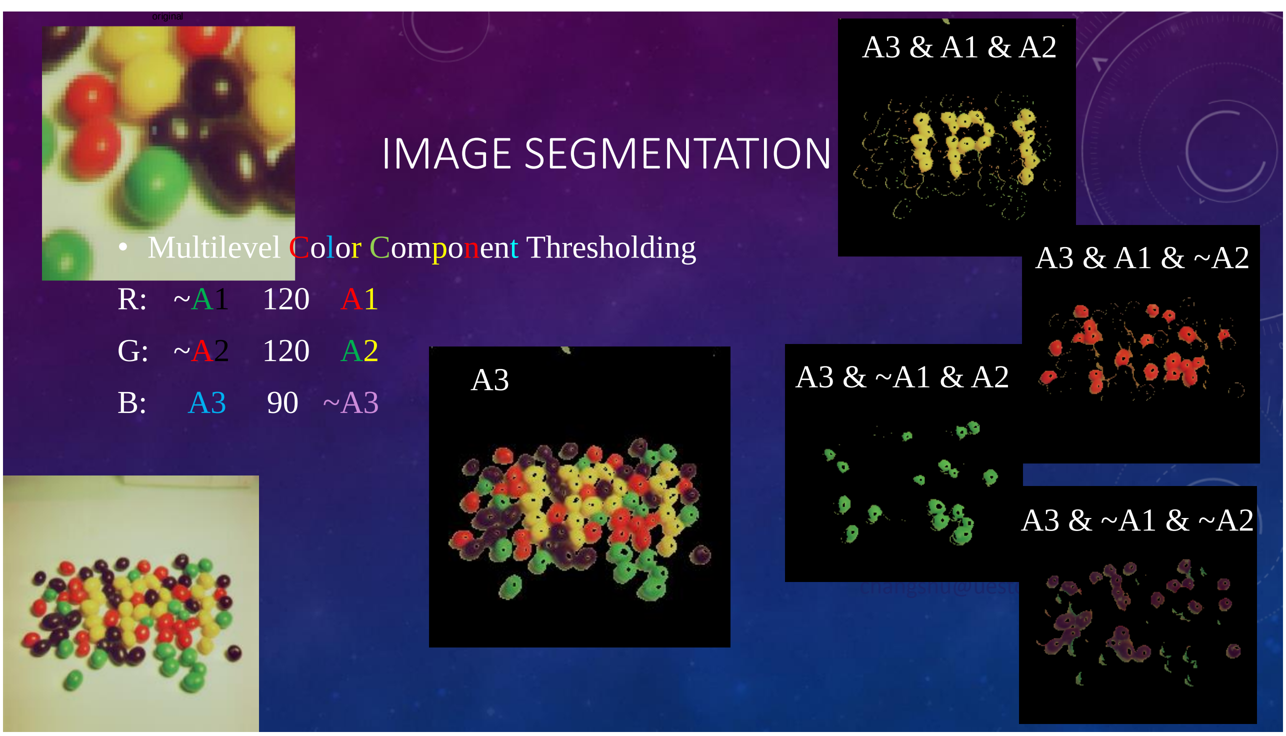


IMAGE SEGMENTATION
• Multilevel Color Component Thresholding
R: ~A1 120 A1
G: ~A2 120 A2
B: A3 90 ~A3
A3
A3 & A1 & A2
A3 & A1 & ~A2
A3 & ~A1 & A2
A3 & ~A1 & ~A2

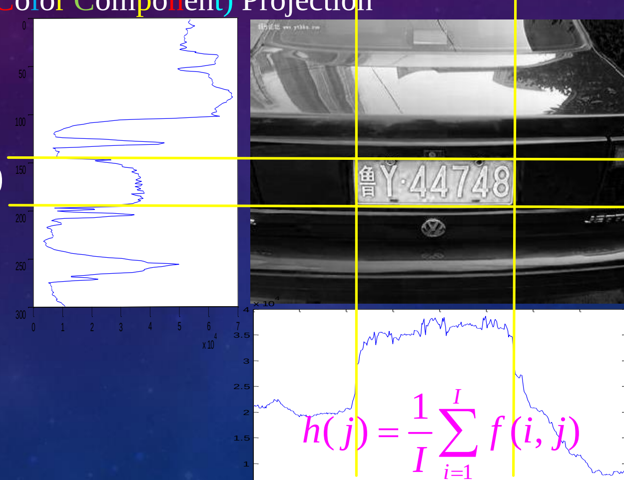
IMAGE SEGMENTATION

- Most graphics packages come with some form of thresholding segmentation. “Magic Wand” is such a tool, and is included in Adobe Photoshop 7. With this tool the user will select a seed or multiple seed pixels and set some form of tolerance level. The segmentation is then performed by testing all pixels against the set tolerance level(INCORP, 2002). This technique is easy to use, but the results are most often unsatisfactory and finding the correct tolerance level can be cumbersome, and sometimes even impossible (Rother et al., 2004).

IMAGE SEGMENTATION

- Amplitude(Color Component) Projection

$$v(i) = \frac{1}{J}\sum_{j=1}^{J} f(i, j)$$



$$h(j) = \frac{1}{I}\sum_{i=1}^{I} f(i, j)$$

IMAGE SEGMENTATION

- Amplitude(Color Component) Projection

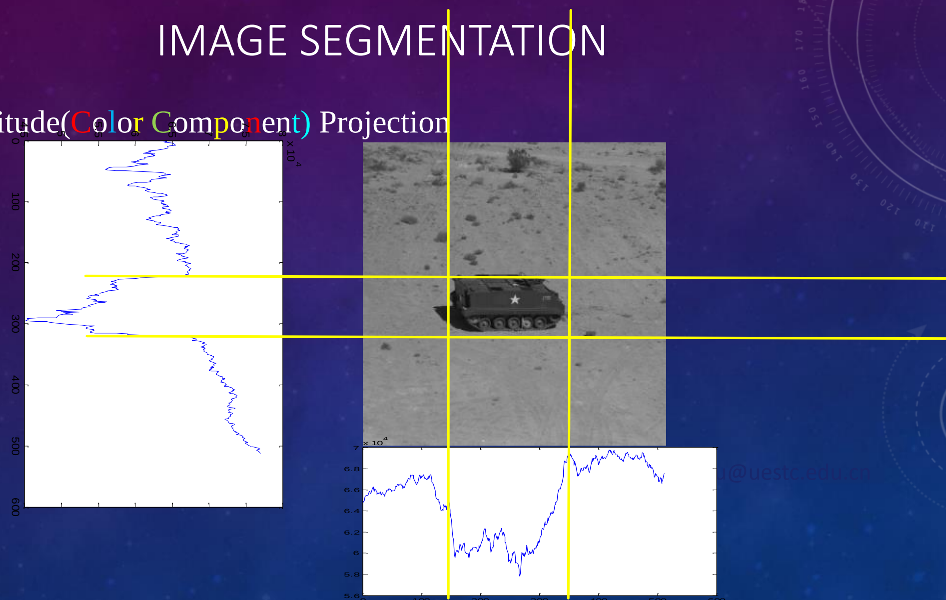
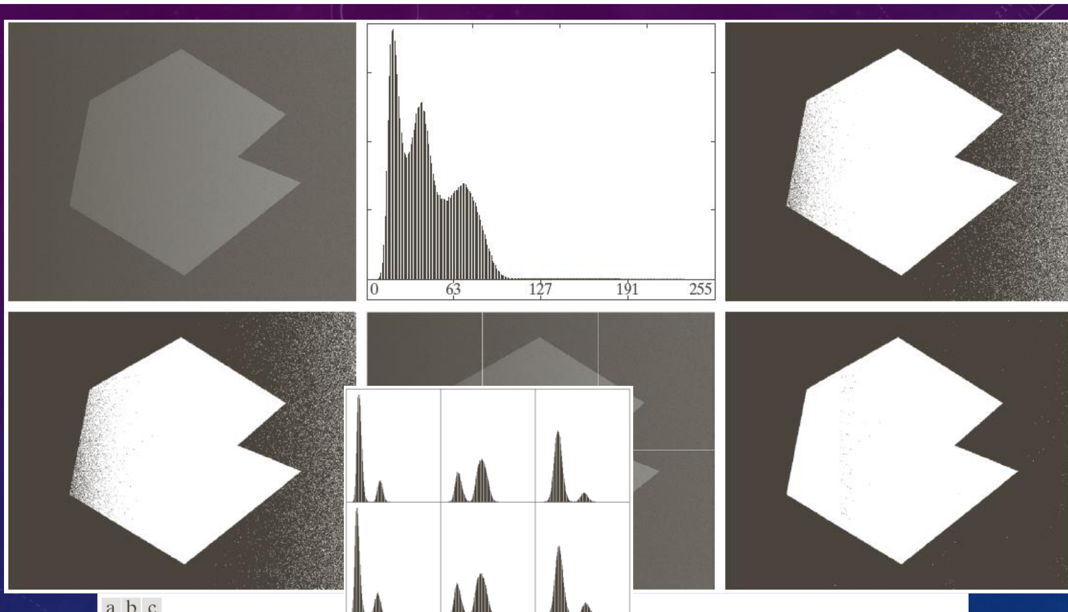


IMAGE SEGMENTATION

- Global thresholding v.s. Variable thresholding
  - Noise and nonuniform illumination play a major role in the performance of a thresholding algorithm
- Variable thresholding
  - Image partitioning



a b c
d e f

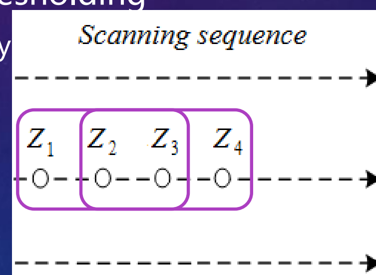
FIGURE 10.46 (a) Noisy, shaded image and (b) its histogram. (c) Segmentation of (a) using the iterative global algorithm from Section 10.3.2. (d) Result obtained using Otsu's method. (e) Image subdivided into six subimages. (f) Result of applying Otsu's method to each subimage individually.

IMAGE SEGMENTATION

- Global thresholding v.s. Variable thresholding
  - Noise and nonuniform illumination play a major role in the performance of a thresholding algorithm
- Variable thresholding
  - Image partitioning
  - Moving averages

IMAGE SEGMENTATION

- Global thresholding v.s. Variable thresholding
  - Noise and nonuniform illumination play … nce of a thresholding algorithm
- Variable thresholding
  - Image partitioning
  - Moving averages



$$m(k+1) = \frac{1}{n}\sum_{i=k+2-n}^{k+1} z_i = m(k) + \frac{1}{n}(z_{k+1} - z_{k+1-n}) \qquad m(1) = \frac{1}{n} z_1$$

IMAGE SEGMENTATION

- Global thresholding v.s. Variable thresholding
  - Noise and nonuniform illumination play a major role in the performance of a thresholding algorithm
- Variable thresholding
  - Image partitioning
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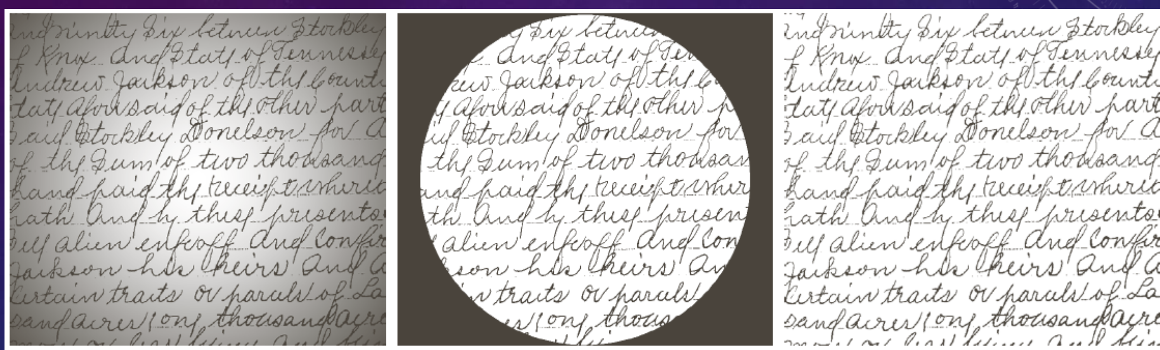
$$T_{xy} = bm_{xy}$$

$$T_{xy} = a\sigma_{xy} + bm_{xy}$$

$$T_{xy} = a\sigma_{xy} + bm_G$$

$$g(x,y) = \begin{cases} 1 & if \;\; f(x,y) > T_{xy} \\ 0 & if \;\; f(x,y) \le T_{xy} \end{cases}$$

IMAGE SEGMENTATION



a b c

FIGURE 10.49 (a) Text image corrupted by spot shading. (b) Result of global thresholding using Otsu's method. (c) Result of local thresholding using moving averages.

IMAGE SEGMENTATION

a b c

FIGURE 10.50 (a) Text image corrupted by sinusoidal shading. (b) Result of global thresholding using Otsu's method. (c) Result of local thresholding using moving averages.

IMAGE SEGMENTATION

- Goal
- Connectivity
- Segmentation Methods
  - Amplitude
  - Region
  - Clustering
- Edge Detection

IMAGE SEGMENTATION

- Region-growing
  - Seeds
  - Similar criteria -→ connectivity properties
  - Stopping rule

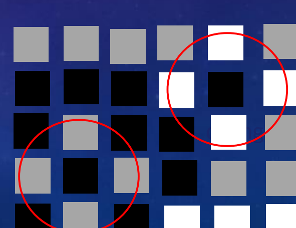


IMAGE SEGMENTATION

(a)

1	0	4	7	5
1	0	4	7	7
0	*1*	5	*5*	5
2	0	5	6	5
2	2	5	6	4

(b)

1	1	5	5	5
1	1	5	5	5
1	1	5	5	5
1	1	5	5	5
1	1	5	5	5

(c)

1	1	5	7	3
1	1	5	7	7
1	1	5	5	5
1	1	5	5	5
1	1	5	5	5

(a)Seeds on the original image (b)Result of applying the similar criteria $T<3$ (c) Result of applying the similar criteria $T<=1$