Lecture 5 – Image Segmentation （图像分割）

This lecture will cover:

– Morphological Image Processing （形态学图像处理）

- Morphological operation
- Morphological algorithm

– Image Segmentation（图像分割）

- Point, Line and Edge Detection（点、线和边缘检测）
- **Thresholding（阈值处理）**
- **Region-based Segmentation（区域分割）**
- Segmentation using Morphological Watersheds（形态学分水岭分割）

Thresholding

➢ Global thresholding (全局阈值处理)

- Basic global thresholding
- Optimum global thresholding using Otsu’s method
- Improve global thresholding by using image smoothing
- Improve global thresholding by using edges
- Multiple thresholds

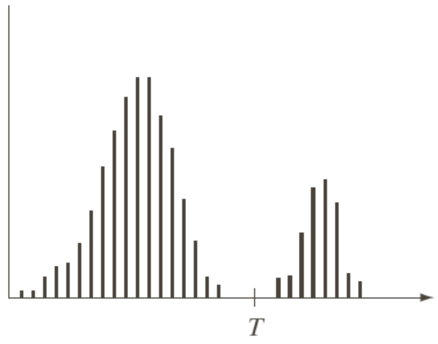
➢ Variable thresholding（可变阈值处理）

- Image partitioning（图像分块）
- Variable thresholding based on local image properties
- Using moving average（移动平均）

Foundation

➢ **Definition**

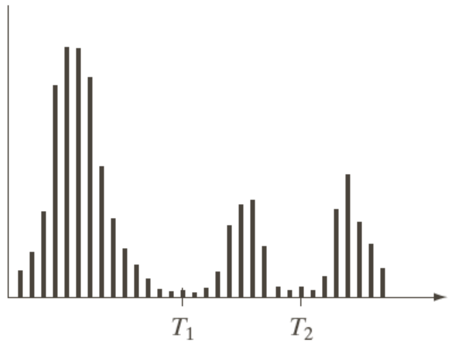
$$g(x,y) = \begin{cases} 1, & f(x,y) > T \quad \text{(object points)} \\ 0, & f(x,y) \le T \quad \text{(background points)} \end{cases}$$



Where

- *Global Thresholding* **(全局阈值处理)** if T is constant over an entire image
- *Variable/Local/Regional Thresholding* **(可变/局域/区域阈值处理)** if T changes over an image
- *Dynamic/Adaptive Thresholding* **(动态/自适应阈值处理)** if T depends on spatial coordinates (x,y)
- *Multiple Thresholding* **(多阈值处理)**

$$g(x,y) = \begin{cases} a, & f(x,y) > T_2 \\ b, & T_1 < f(x,y) \le T_2 \\ c, & f(x,y) \le T_1 \end{cases}$$



➢ **Matlab function:** BW = im2bw(I,level)

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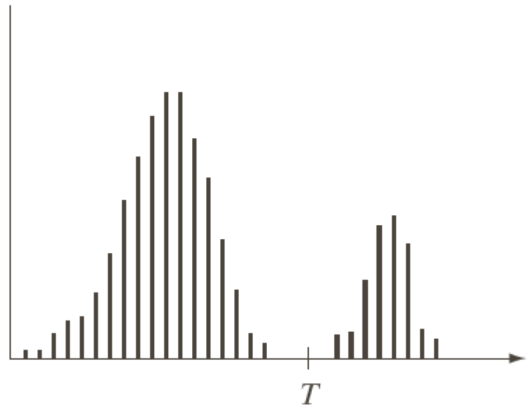
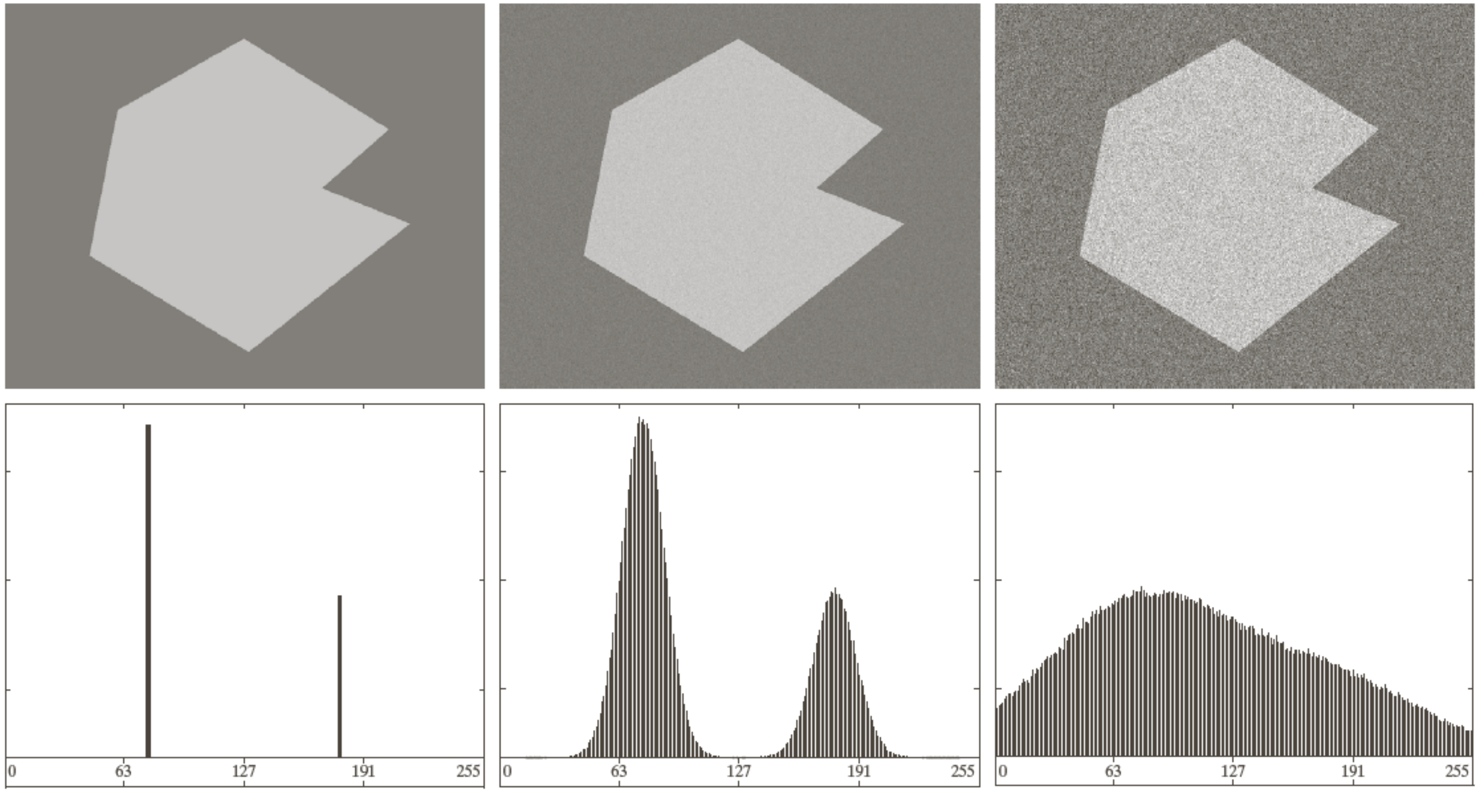
Intensity Valley

Key factors affecting the properties of the valley which separate the histogram modes

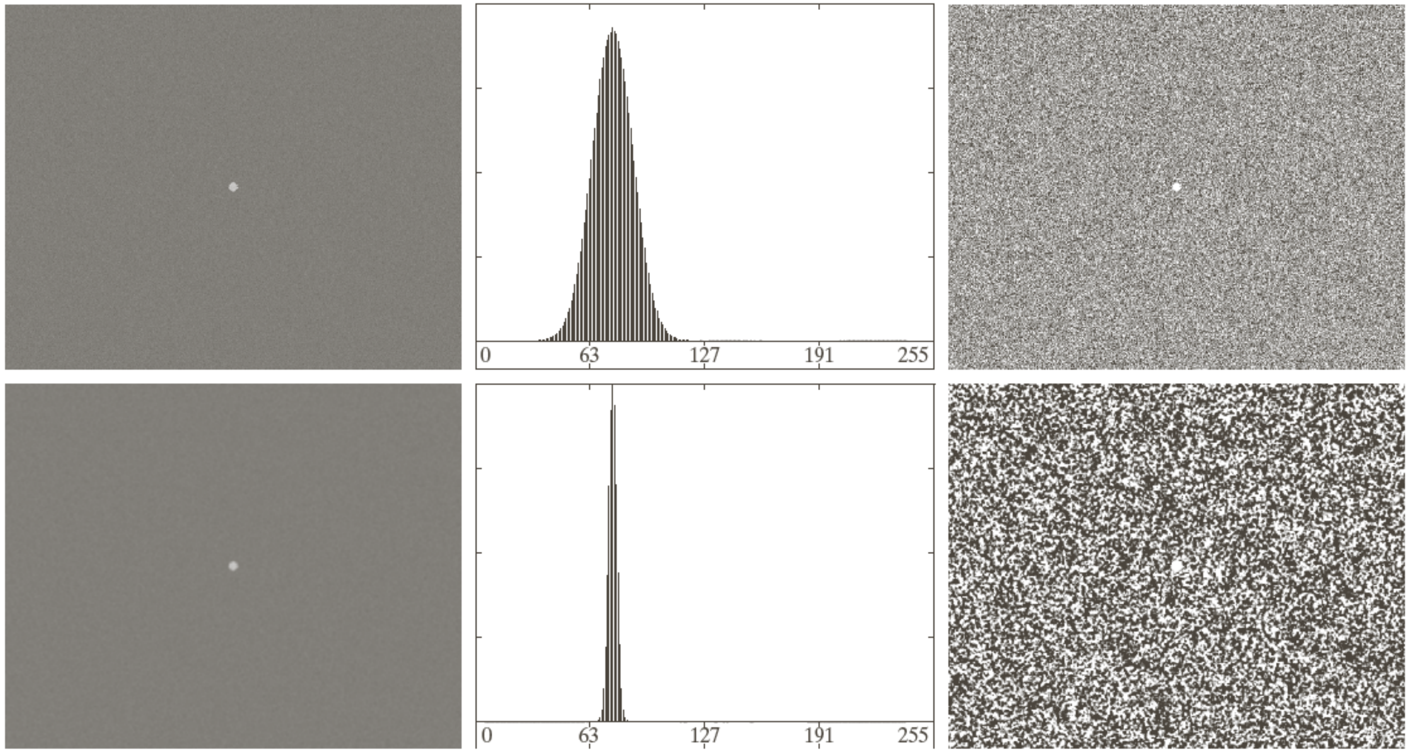
- The separation between peaks
- The noise content in the image
- The relative sizes of objects and background
- The uniformity of illumination source
- The uniformity of reflectance properties of the image



Influence of Noise



Influence of objects and background sizes



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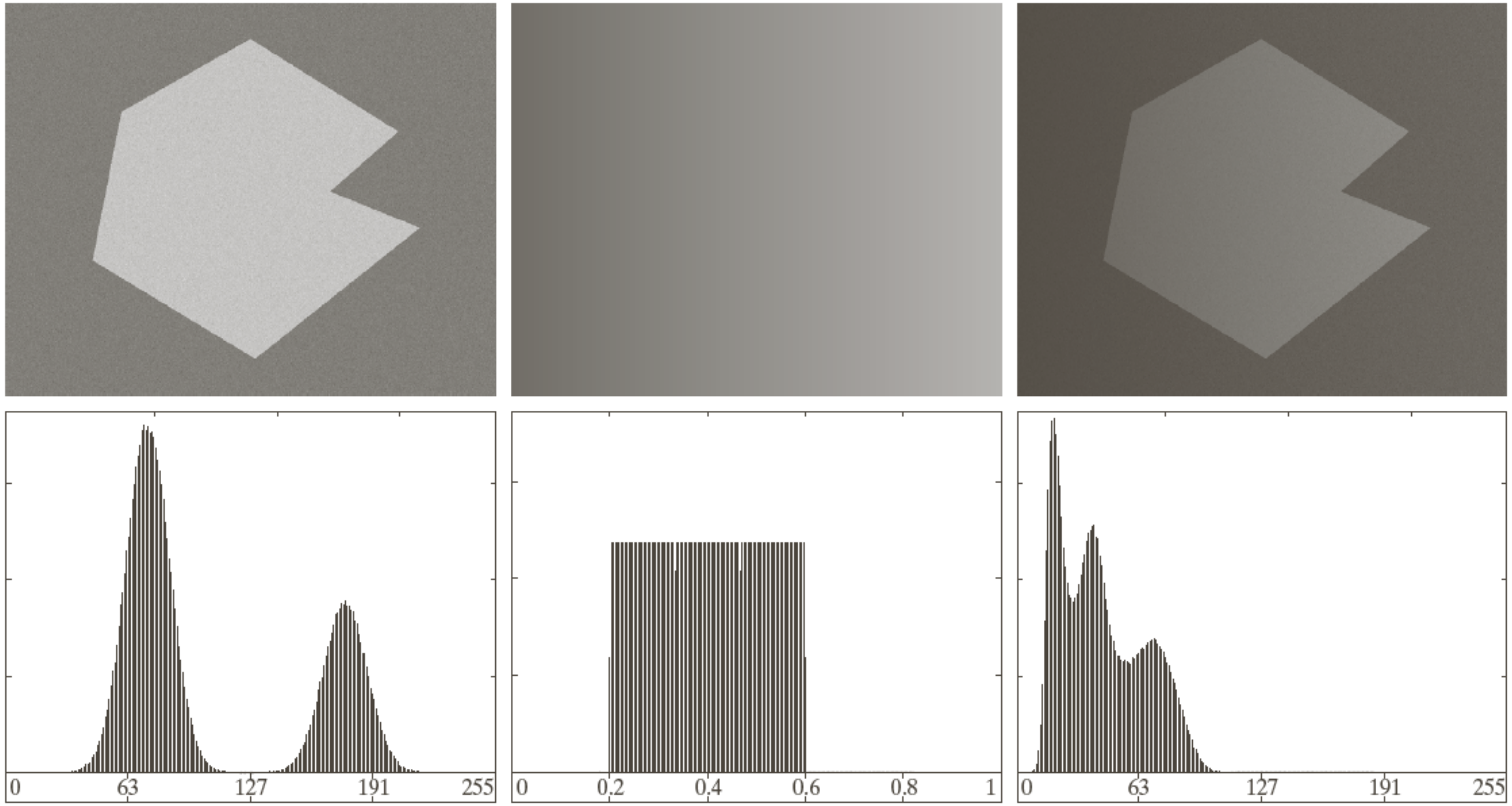
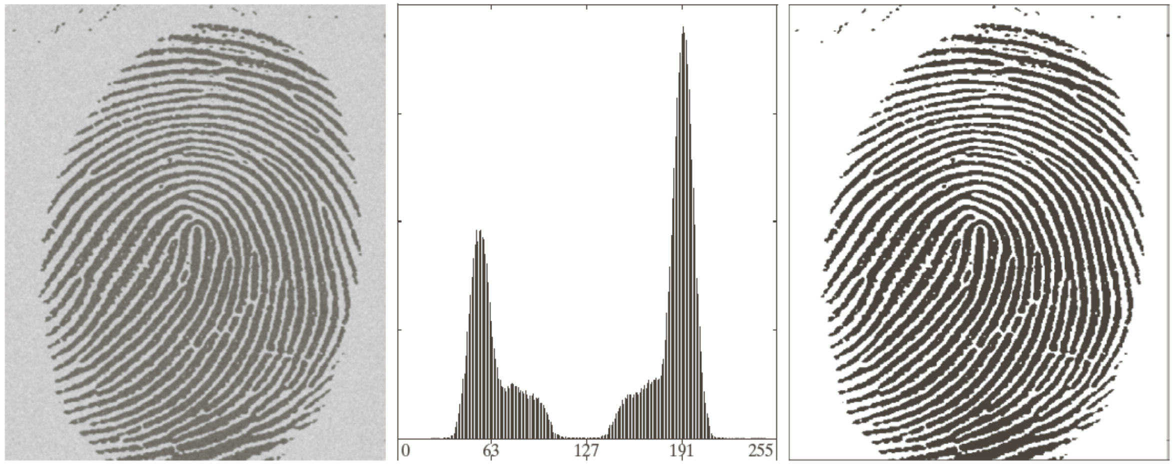
Influence of Illumination and Reflection



Basic Global Thresholding

- **Steps:**

1. Select an initial estimate of the global threshold **T**;
2. Segment the image using **T** to two groups $G_1(>T)$ and $G_2(\leqslant T)$;
3. Compute average intensity m_1 and m_2 for G_1 and G_2 respectively;
4. Compute new threshold **T**$=(m_1 + m_2)/2$;
5. Repeat 2-4 until the difference between **T** in successive iteration is smaller than requirement.



Otsu's Method

- **Between-class variance (类间方差):**

$$\sigma_B^2 = \frac{(m_G P_1 - m)^2}{P_1(1 - P_1)}$$

Where

m_G: average intensity of entire image

P_1: the cumulative probability of all pixels in the intensity range [0,*k*]

m: the average intensity up to level *k*

- **Matlab function:**

[level,EM] = graythresh(I)

Otsu's Method

- **Algorithm summary:**

1. compute the normalized histogram of the input image p_i;

2. compute the cumulative sums $P_1(k) = \sum_{i=0}^{k} p_i$;

3. compute the cumulative means $m(k) = \sum_{i=0}^{k} ip_i$

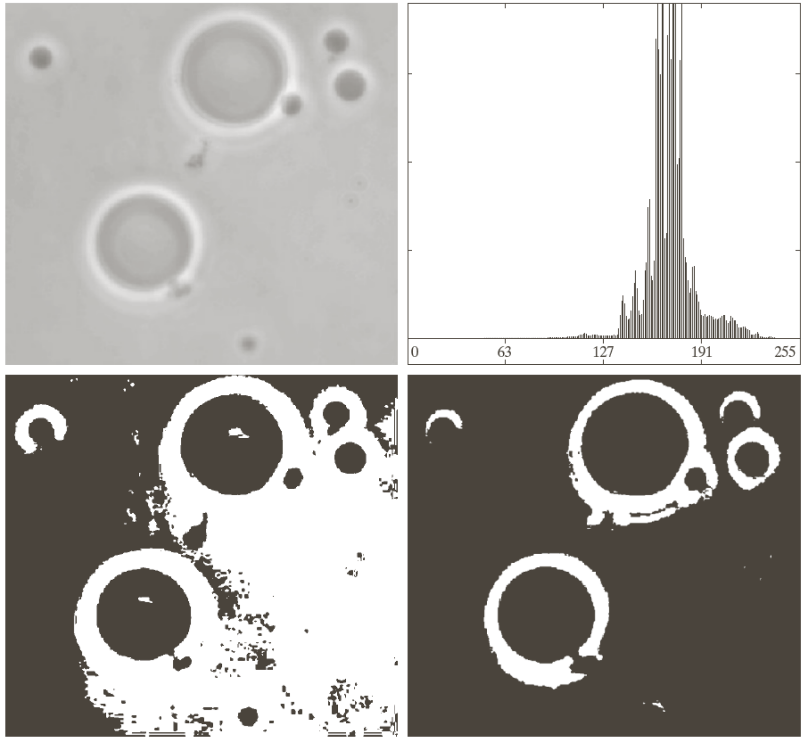
4. compute the global intensity mean $m_G = \sum_{i=0}^{L-1} ip_i$

5. compute between-class variance σ_B^2 for $k = 0,1,\cdots,L-1$;

$$\sigma_B^2 = \frac{(m_G P_1 - m)^2}{P_1(1-P_1)}$$

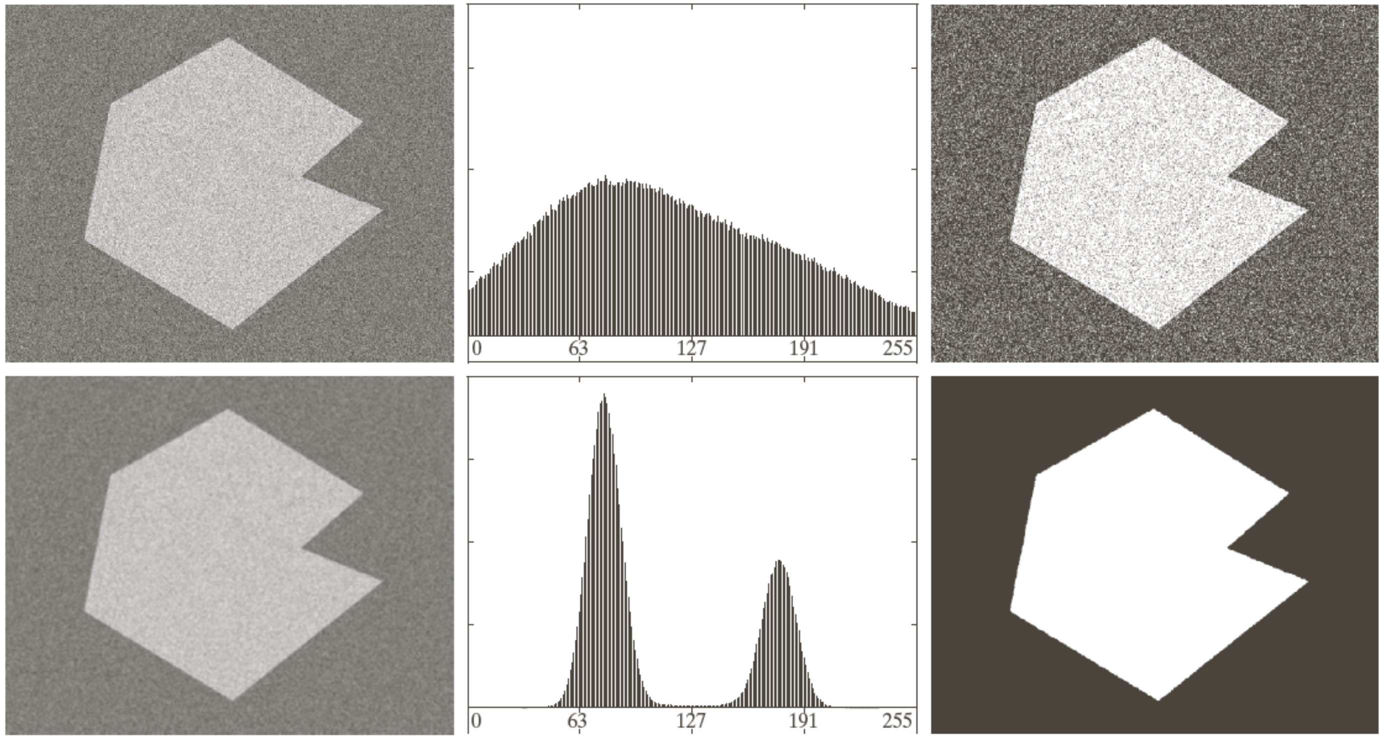
6. Obtain the Otsu threshold k^* when $\sigma_B^2(k^*)$ is the maximum of all k value

7. Obtain the separability measure $\eta^* = \frac{\sigma_B^2(k^*)}{\sigma_G^2}$



Improve Global Thresholding

- **Using image smoothing:**



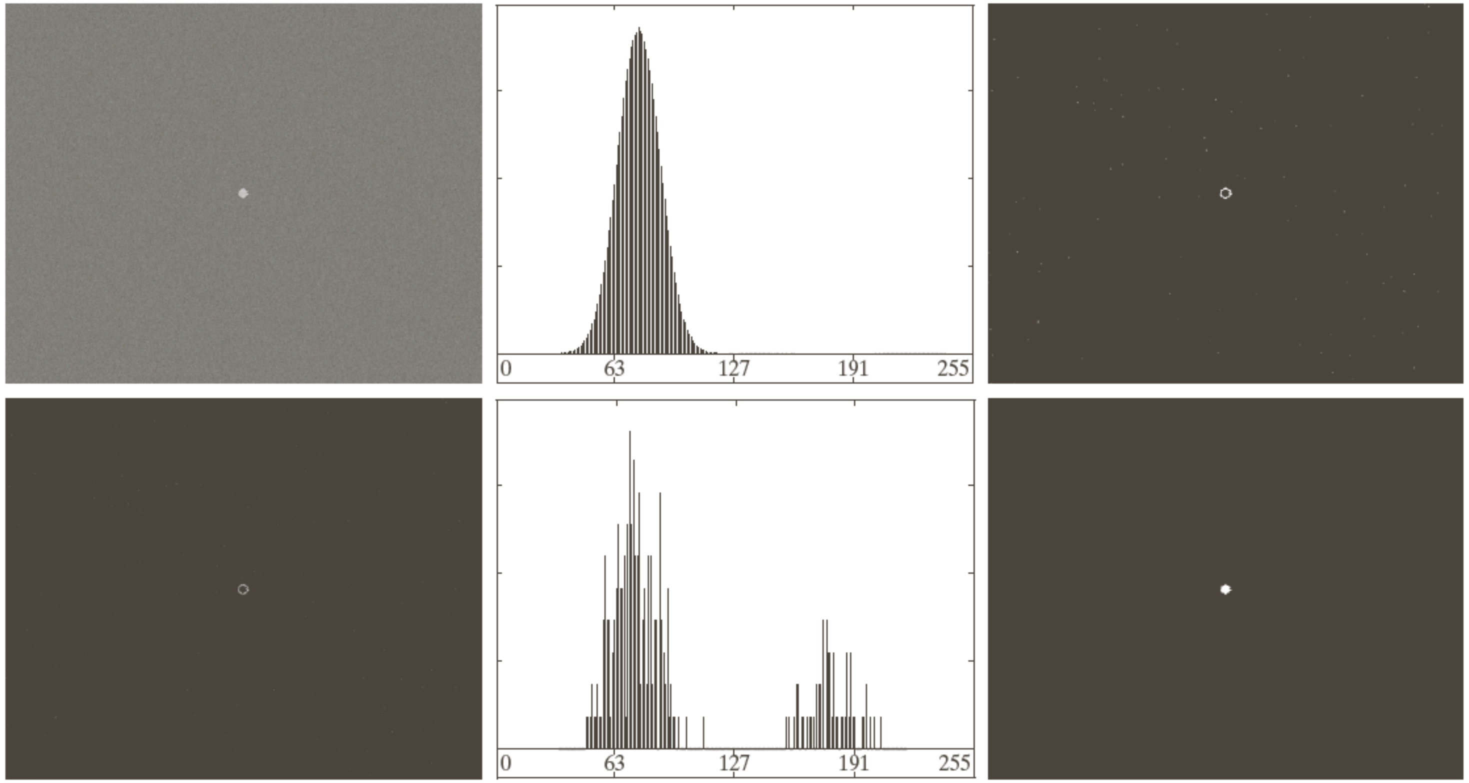
Improve Global Thresholding

➢ **Using edges:**

1. compute an edge image from the input image $f(x, y)$ using any edge detector;
2. specify a threshold value T;
3. Threshold the edge image using T to produce a binary image $g_T(x, y)$
4. compute a histogram using only the pixels in $f(x, y)$ that correspond to the locations of the 1-valued pixels in $g_T(x, y)$
5. use the histogram to segment $f(x, y)$;

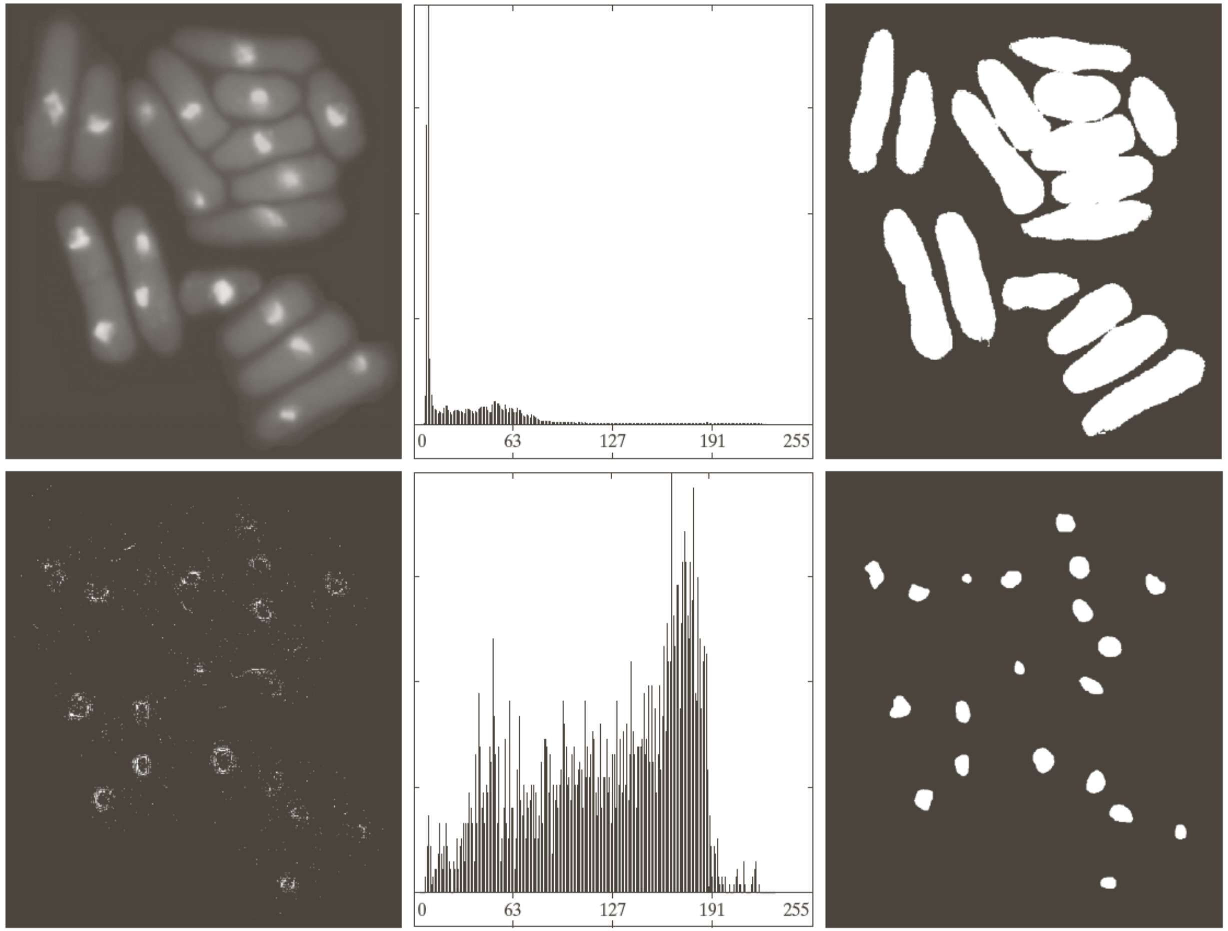
Improve Global Thresholding

- Using edges:



Improve Global Thresholding

- **Using edges:**



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Multiple thresholds

➢ **Between-class variance (类间方差):**

$$\sigma_B^2 = P_1(m_1 - m_G)^2 + P_2(m_2 - m_G)^2 + P_3(m_3 - m_G)^2$$

Where

$$P_1 = \sum_{i=0}^{k_1} p_i \qquad P_2 = \sum_{i=k_1+1}^{k_2} p_i \qquad P_3 = \sum_{i=k_2+1}^{L-1} p_i$$

$$m_1 = \sum_{i=0}^{k_1} ip_i \qquad m_2 = \sum_{i=k_1+1}^{k_2} ip_i \qquad m_3 = \sum_{i=k_2+1}^{L-1} ip_i$$

$$P_1 m_1 + P_2 m_2 + P_3 m_3 = m_G \qquad P_1 + P_2 + P_3 = 1$$

The two optimum thresholds k_1^* and k_2^* are the values that maximize $\sigma_B^2(k_1, k_2)$, then

$$g(x,y) = \begin{cases} a, & f(x,y) \le k_1^* \\ b, & k_1^* < f(x,y) \le k_2^* \\ c, & f(x,y) > k_2^* \end{cases} \quad \text{and} \quad \eta(k_1^*, k_2^*) = \frac{\sigma_B^2(k_1^*, k_2^*)}{\sigma_G^2}$$

Multiple thresholds

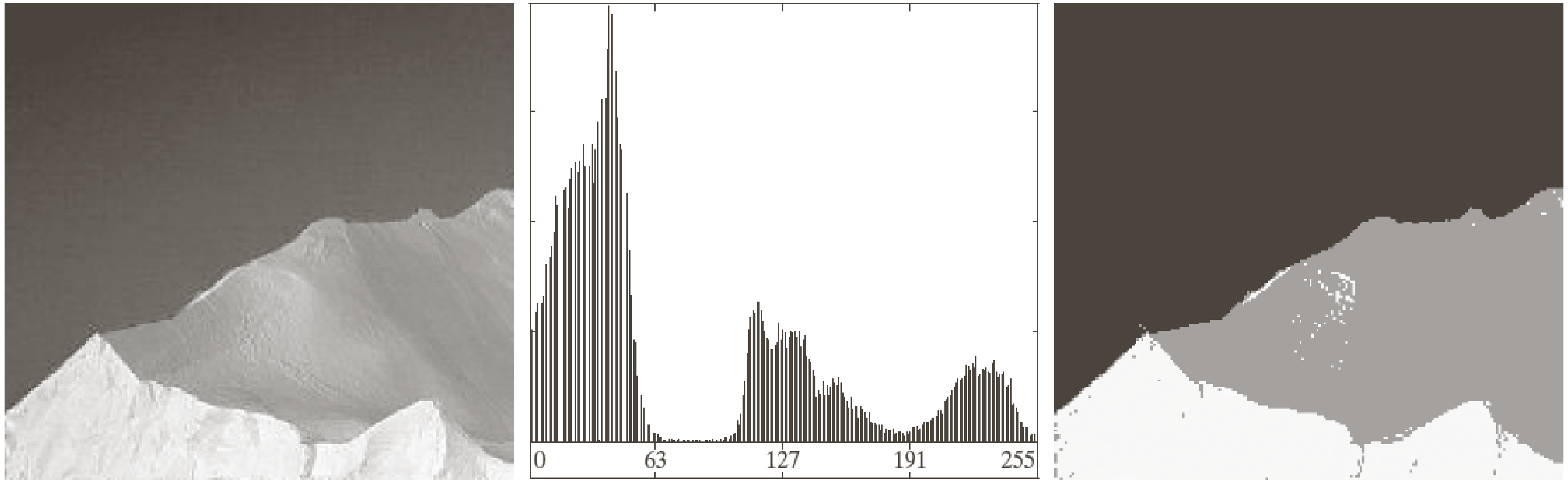
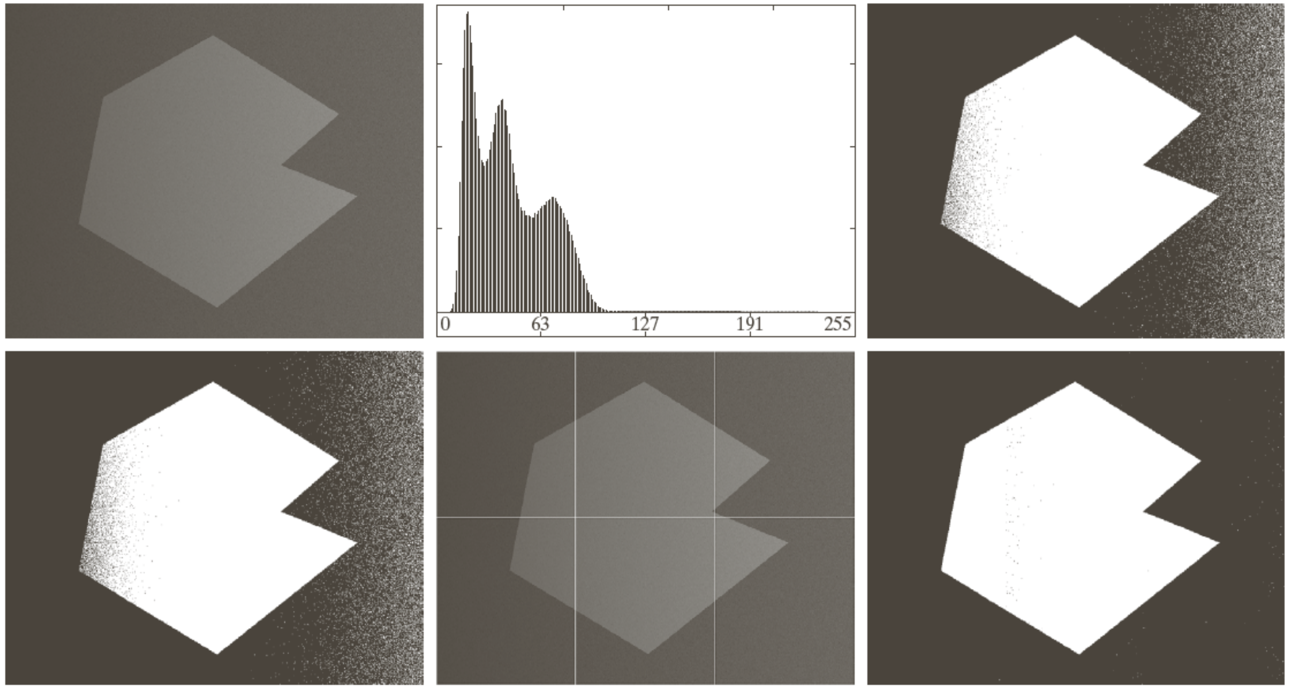
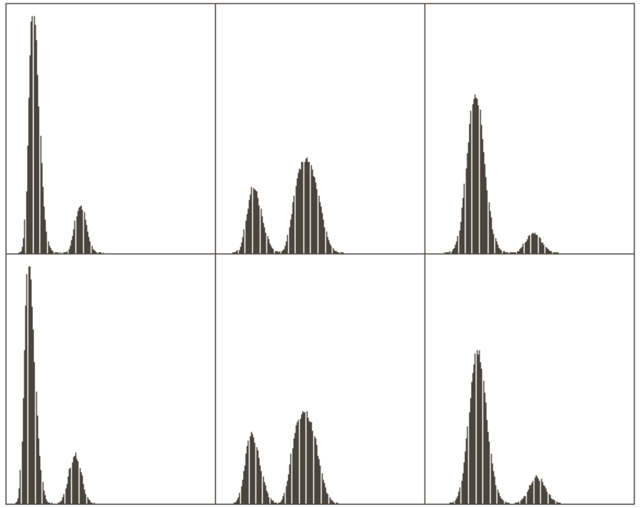


Image partitioning（图像分块）





Variable thresholding based on local image properties

- **Algorithm:**

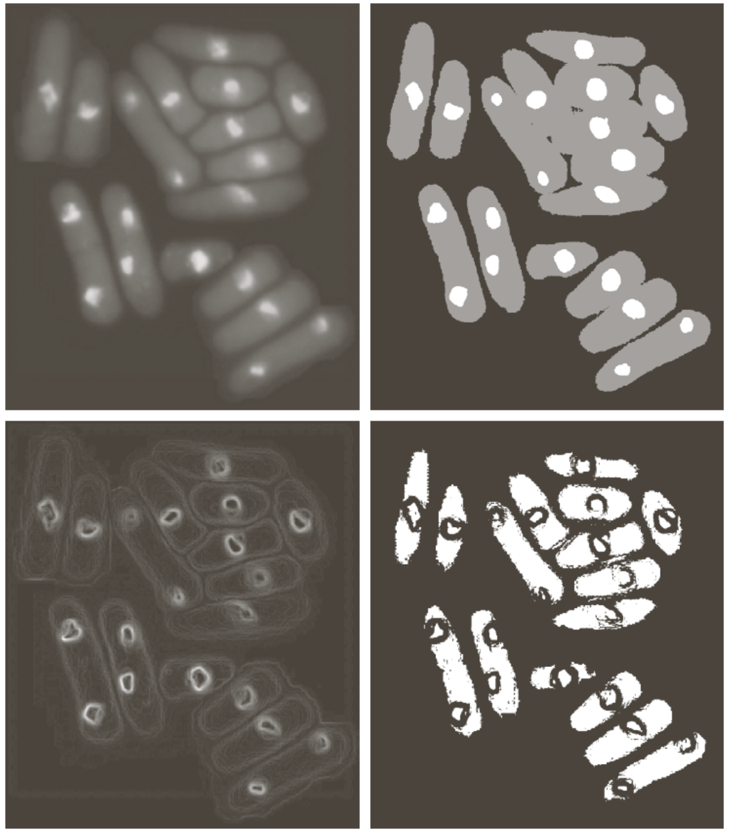
$$T_{xy} = a\sigma_{xy} + bm_{xy}$$

or

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

- **Matlab function:**

```
g = stdfilt(f, nhood);
```



Moving average（移动平均）

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

Region Growing (区域生长)

➢ Algorithm based on 8-connectivity:

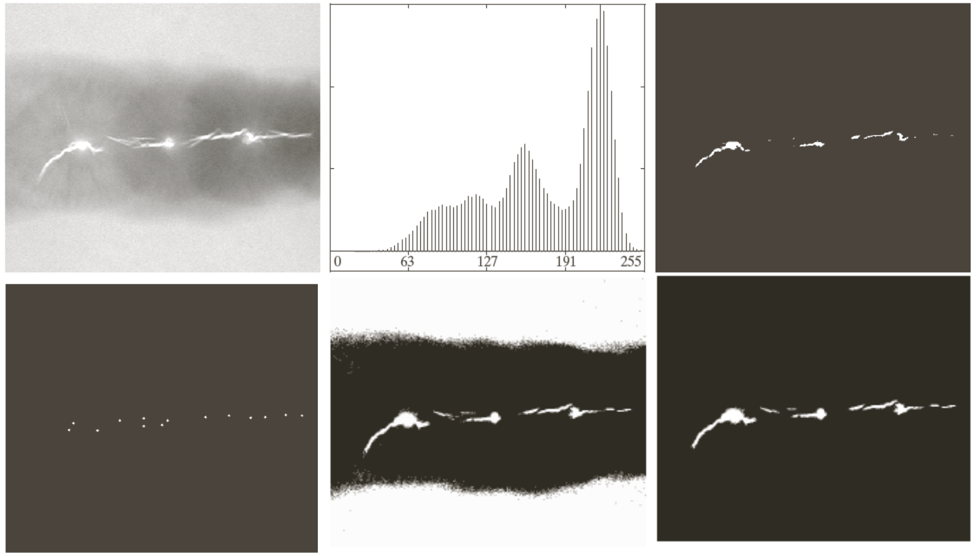
Where

$f(x, y)$: input image

$S(x, y)$: a seed array

Q: a predicate to be applied at each location

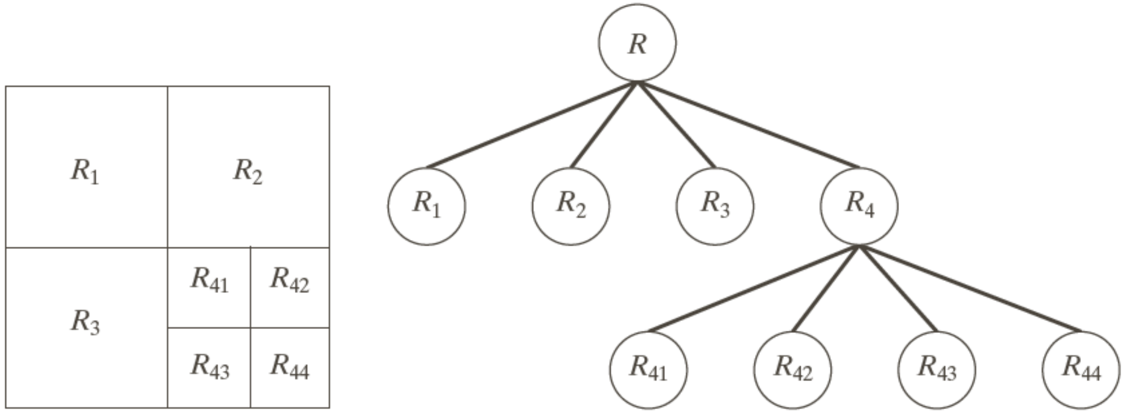
1. Find all connected components in $S(x, y)$ and erode each component to one pixel;
2. Form an image f_Q based on if satisfying Q
3. In f_Q, find all the 1-valued points which 8-connected to each seed point in S, and form an image g;
4. Label each connected component in g, and this is the segmented image obtained by region growing.



Region Splitting and Merging(区域分裂与聚合)

➢ Steps

1. Split into four disjoint quadrants any region R_i for which $Q(R_i) = False$ (need to specify a minimum quadregion size beyond which no further splitting is carried out;
2. Merge any adjacent regions R_j and R_k for which $Q(R_j \cup R_k) = True$;
3. Stop when no further merging is possible.



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Region Splitting and Merging(区域分裂与聚合)