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

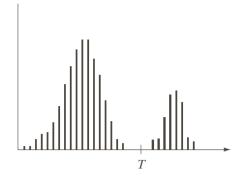
$$g(x,y) = \begin{cases} 1, & f(x,y) > T \text{ (object points)} \\ 0, & f(x,y) \le T \text{ (background points)} \end{cases}$$

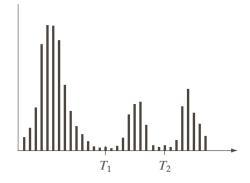
Where

- 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)



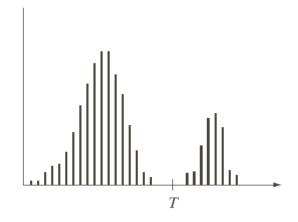




Intensity Valley

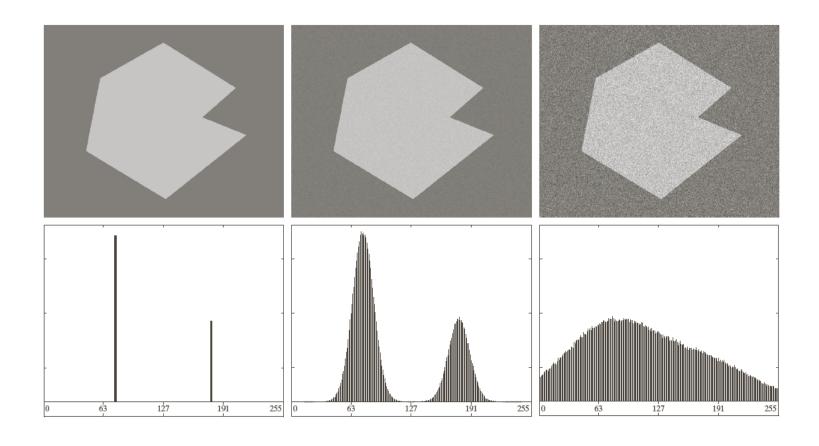
Key factors affecting the properties of the valley which separate the histogram modes

- 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



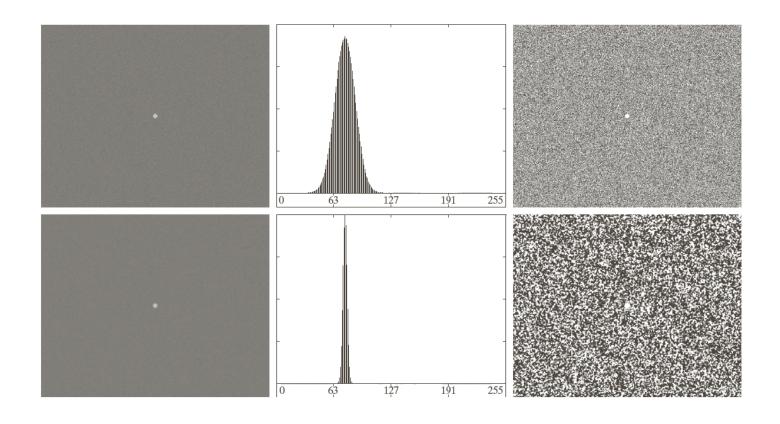


Influence of Noise



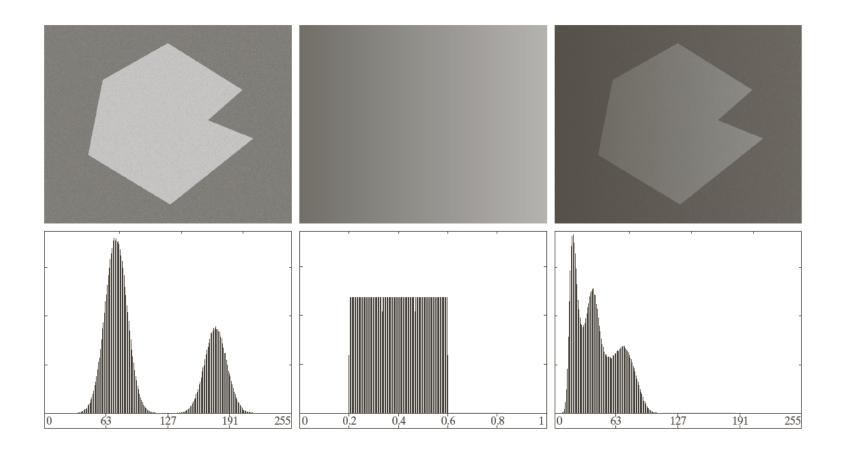


Influence of objects and background sizes





Influence of Illumination and Reflection

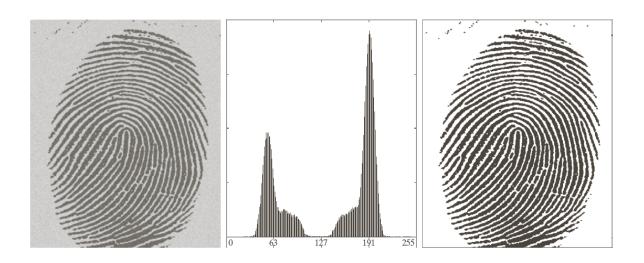




Basic Global Thresholding

Steps:

- 1. Select an initial estimate of the global threshold **T**;
- 2. Segment the image using **T** to two groups $G_1(>T)$ and $G_2(\leq T)$;
- 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(l)



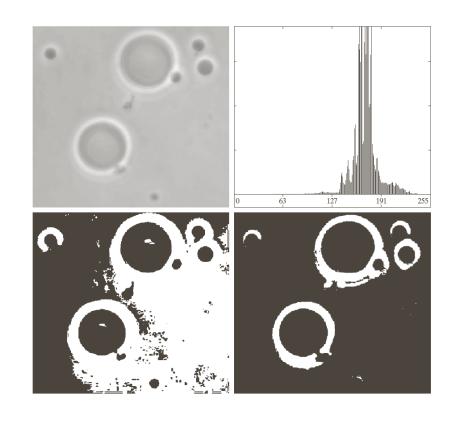
Otsu's Method

> 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 $m(k) = \sum_{i=0}^{k} i p_i$
- 4. compute the global intensity mean $m_G = \sum_{i=0}^{L-1} i p_i$
- 5. compute between-class variance σ_B^2 for $k=0,1,\cdots,L-1$;

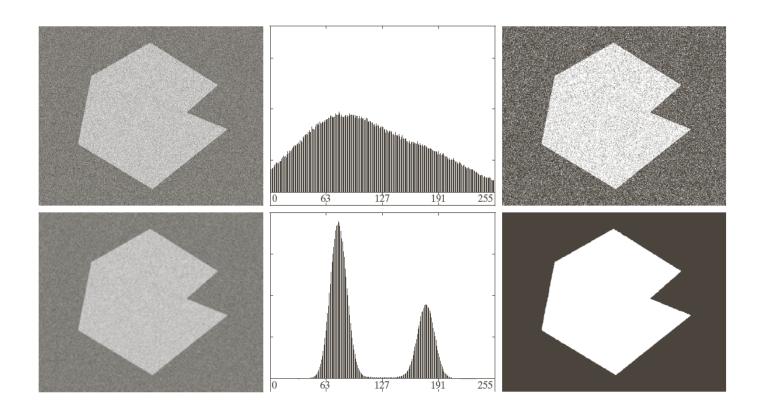
$$\sigma_B^2 = \frac{(m_G P_1 - m)^2}{P_1 (1 - P_1)}$$

- 6. Obtain the Otsu threshold k^* when $\sigma_B^2(k^*)$ is the maximum of all k value
- 7. Obtain the separability measure $\eta^* = \frac{\sigma_B^2(k^*)}{\sigma_G^2}$





> Using image smoothing:



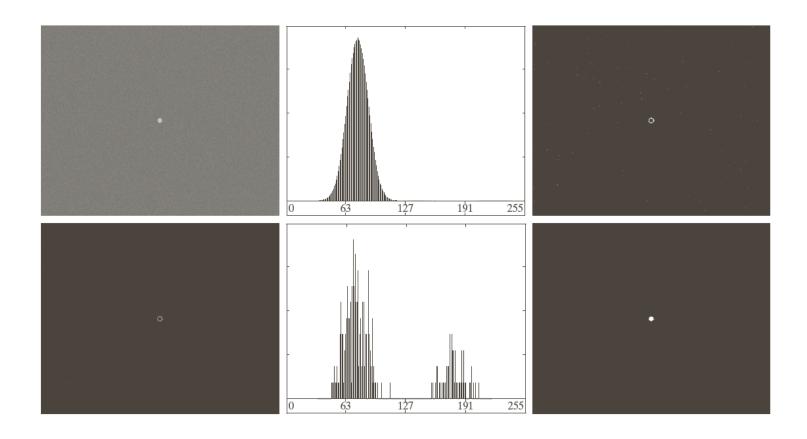


Using edges:

- 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);

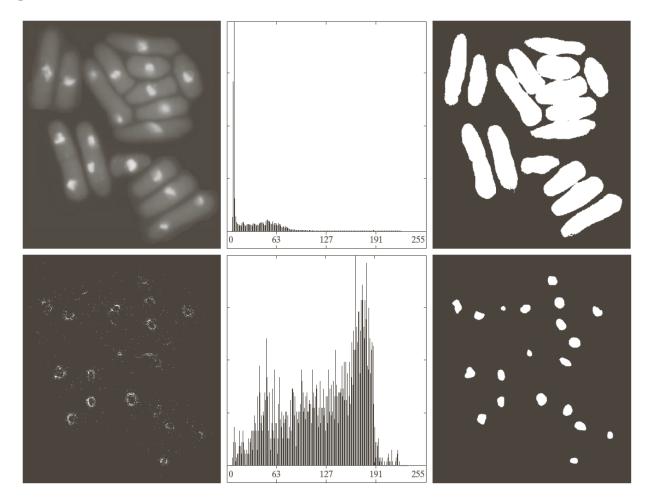


Using edges:





Using edges:





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

$$P_{1} = \sum_{i=0}^{k_{1}} p_{i} \qquad P_{2} = \sum_{i=k_{1}+1}^{k_{2}} p_{i} \qquad P_{3} = \sum_{i=k_{2}+1}^{L-1} p_{i}$$

$$m_{1} = \sum_{i=0}^{k_{1}} i p_{i} \qquad m_{2} = \sum_{i=k_{1}+1}^{k_{2}} i p_{i} \qquad m_{3} = \sum_{i=k_{2}+1}^{L-1} i p_{i}$$

$$P_{1} m_{1} + P_{2} m_{2} + P_{3} m_{3} = m_{G} \qquad P_{1} + P_{2} + P_{3} = 1$$

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

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



Multiple thresholds

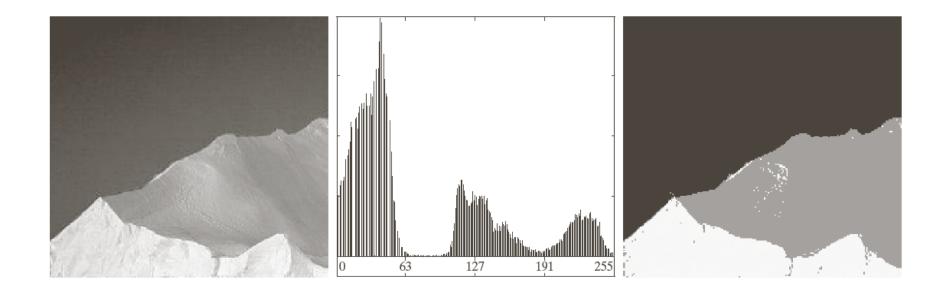
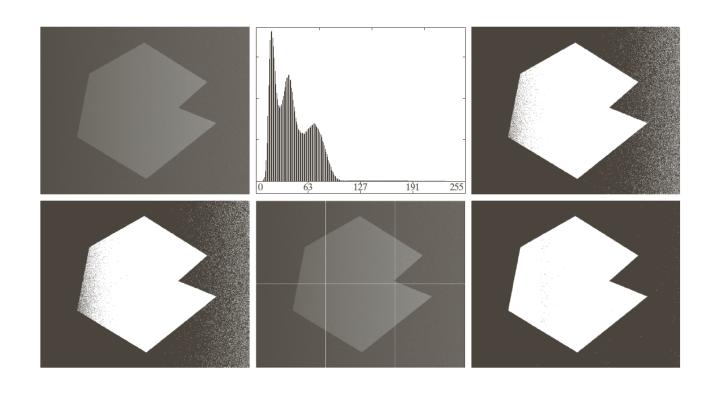
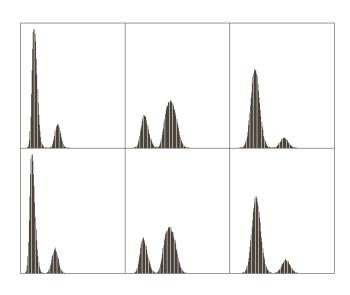




Image partitioning (图像分块)







Variable thresholding based on local image properties

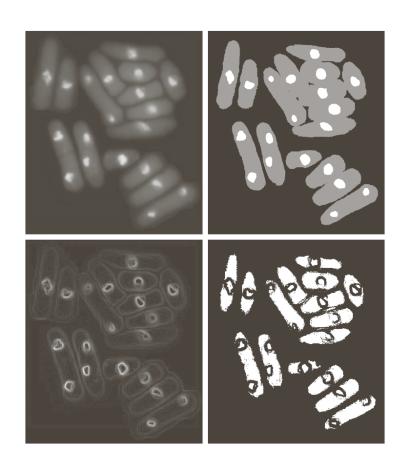
> Algorithm:

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

or

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

Matlab function:





Moving average (移动平均)

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

I sinty by between stocker of Fernesky and State of Fernesky and State of Tennesky and the have have for a sund stocker donelson for a fand paid the two thousand hand haid they presente ath and hand hat their and confirmation has keined and confirmation has keined and confirmation has keined and a sandauren on thousandaure

and stay of The and stay of The sure faction of the other point stockly donelson for the Dum of two thomsas and paid the tweet where the and he there present alien entroff and Con what he herry and with a lient of the son he herry and with a lient of the son her thous

indrintly six between stockly of Know and start of Tennersy underest Jackson of the Country and Start aford the other part 3 and stockly Donelson for a fand paid the two thousand hand paid the tweether where ath and he there presents of allien enfort and Confir Jackson his heirs and a cartain traits or parule of La sand airer (ong thousand aire

Indicate Big between Storkly of Know and State of Fernancies bulkers of the Journal of the Journal of the Storkly Soulson for a thing summer of two the warmer and faid the their presents of alien entropy and Confer and area to the confer and area to the confer and area to the confer and area to my thousand area.

of all si let in to by an expected for all for all of the all of t

ly Indrinity by between stockly it of Know and stay of Tennessy it hudrew Jackson of the bount wit tay aforesaif of the other part a 3 aid stockly Donelson for a 14 the Sum of two thousand it hand haid the twent where to hath and by their prisents for full alien enfort and longer to Jackson his heirs and a full a certain traits or parallof La re sand acres 10 mg, thousandage



Region Growing (区域生长)

> Algorithm based on 8-connectivity:

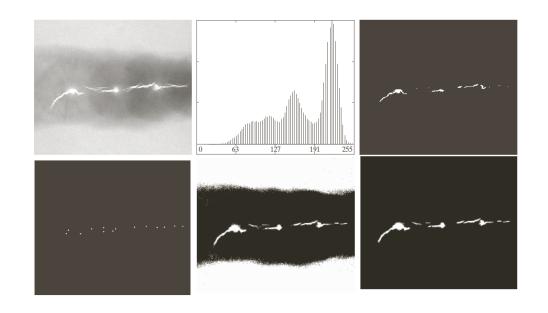
Where

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.

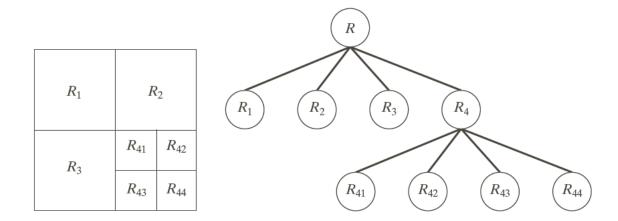




Region Splitting and Merging(区域分裂与聚合)

> 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_i and R_k for which $Q(R_i \cup R_k) = True$;
- 3. Stop when no further merging is possible.





Region Splitting and Merging(区域分裂与聚合)

