计算机辅助手术讲座（2）
Image-Guided Surgery (2)

灰度直方图和二值化操作
Gray-level Histogram and Threshold

顾 力栩
上海交通大学 Med-X 研究院

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Image Processing Example

Image Processing Categories

- Low level: from image to image, often called image filtering
- Intermediate level: from image to symbolic representation, also called image segmentation
- High level: from symbolic to functional description, also called image understanding or pattern recognition

TYPICAL IMAGE PROCESSING SYSTEM FOR MEDICAL IMAGING

Image Acquisition

-Low Level-

Pre-Processing (filtering)

Enhancement (sharpen, smooth, …)

Interpolate, reduce noise, crop

-Intermediate Level-

Segmentation

Region (or Contour) Extraction, Labeling, Grouping

-High Level-

Recognition

Region feature analysis (position, orientation, size…), Object Matching

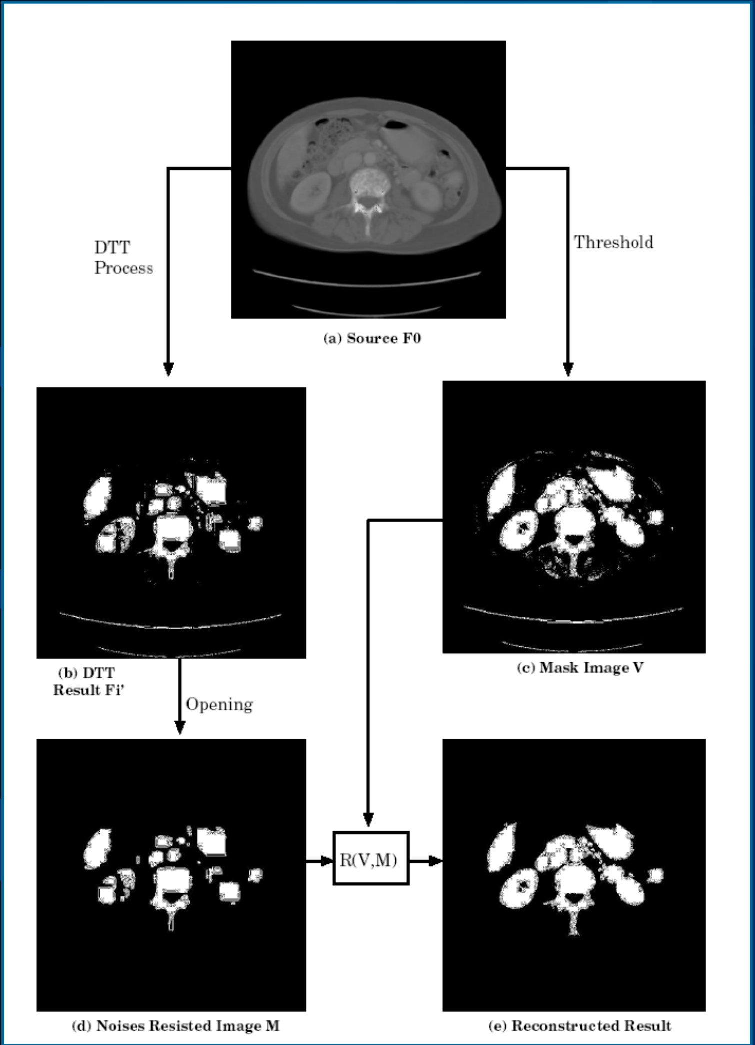
-High Level-

Modeling

Volume Rendering, Deformable Models, Mathematical Models

Output

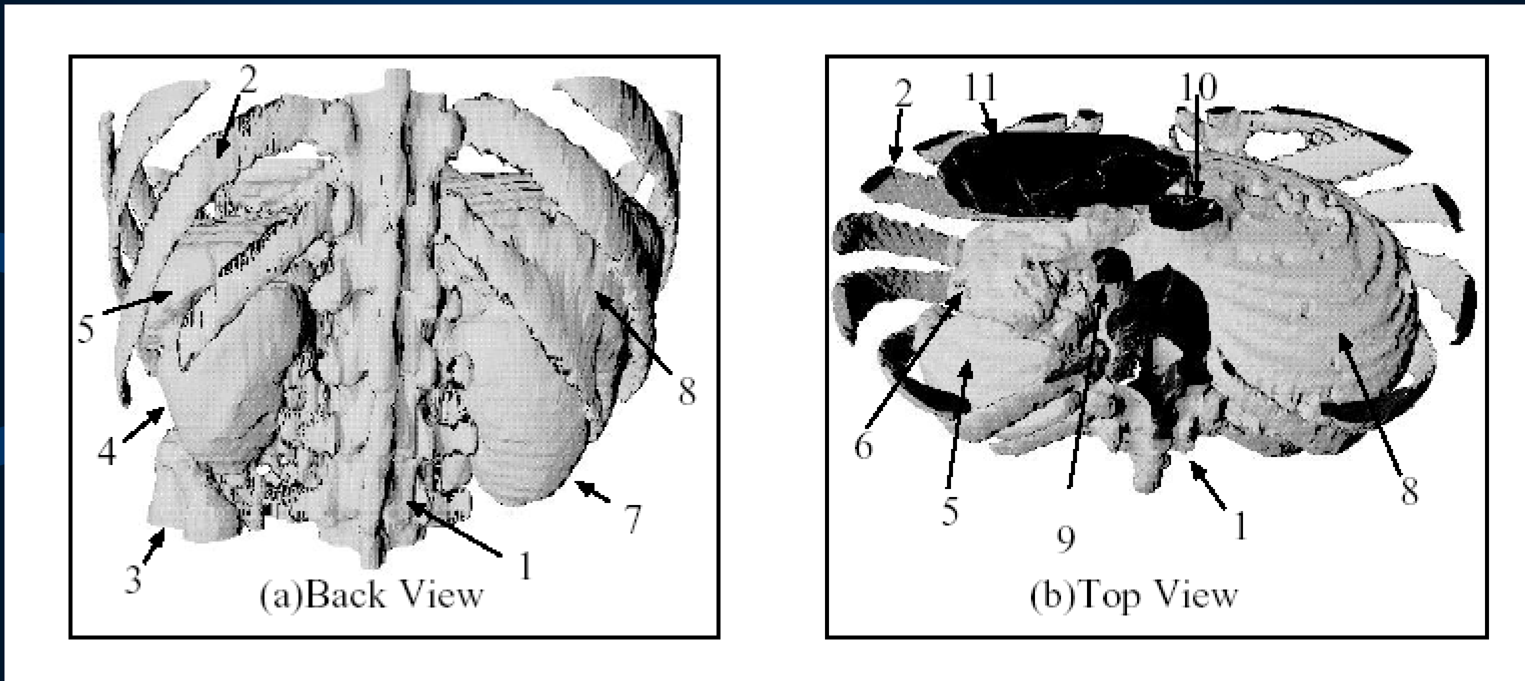
EXTRACTION OF ORGANS FROM 3D ABDOMINAL CT IMAGE - 1



- Segmentation (Extraction):
  1. Thresholding
  2. Differential Top-hat
  3. Noise Reduction
  4. Region Reconstruction

EXAMPLE

EXTRACTION OF ORGANS FROM 3D ABDOMINAL CT IMAGE - 2

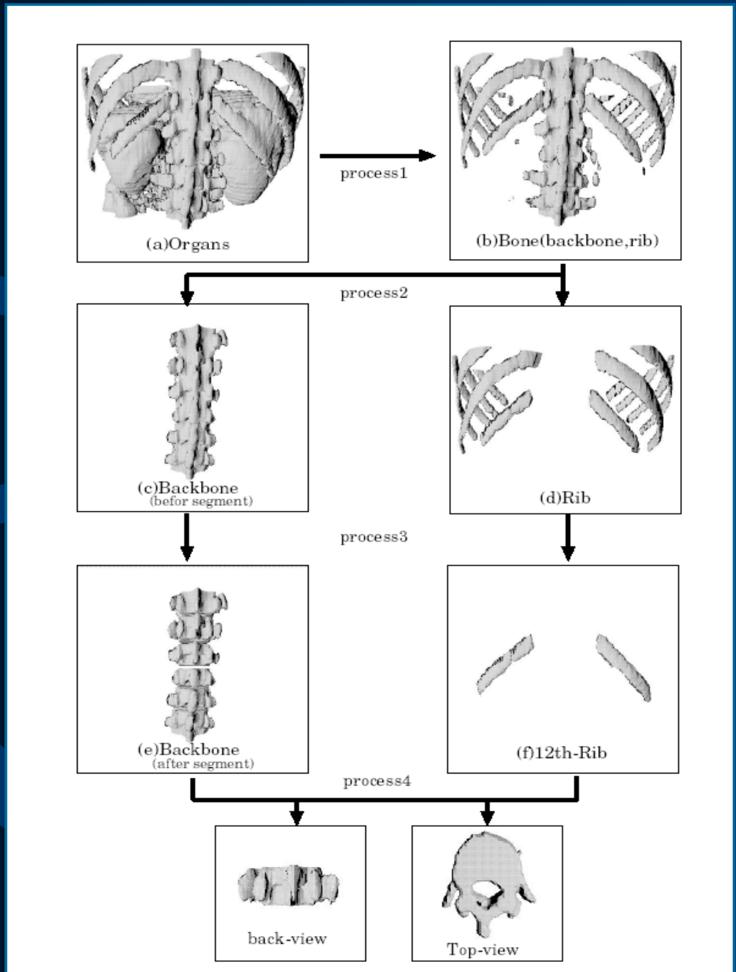


Volume View

1.vertebra, 2.rib, 3.pelvis, 4.left kidney, 5.spleen, 6.stomach,7.right kidney, 8.liver, 9.artery, 10.vein, 11.heart

EXAMPLE

EXTRACTION OF ORGANS FROM 3D ABDOMINAL CT IMAGE - 3

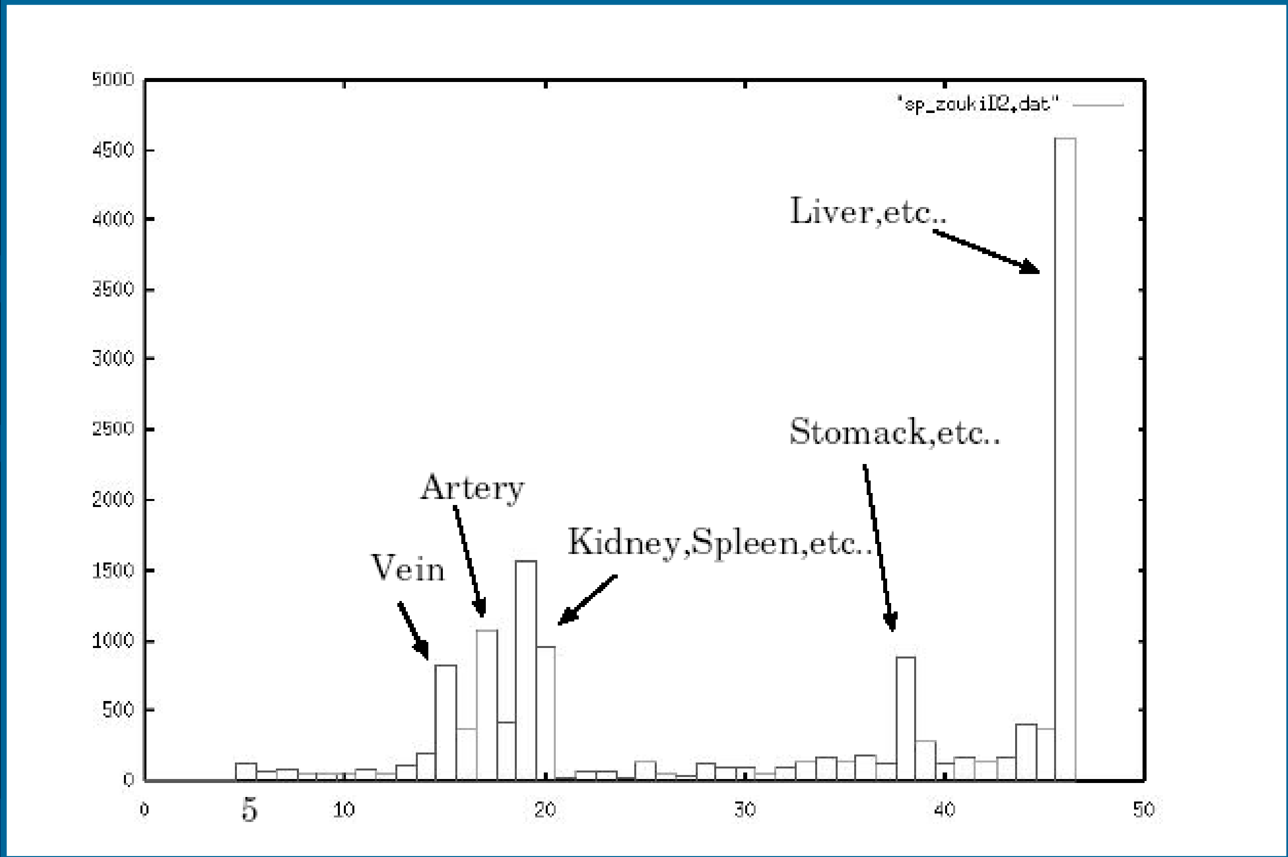


(g) Standard Cervical

- Bone segmentation and reference point:
  1. Extract bones
  2. Separate spine from ribs
  3. Find the 12th rib
  4. Find the vertebra connected with the 12th rib
  5. Set the center of gravity of the vertebra as the reference point (origin of our specified coordinate system)

EXAMPLE

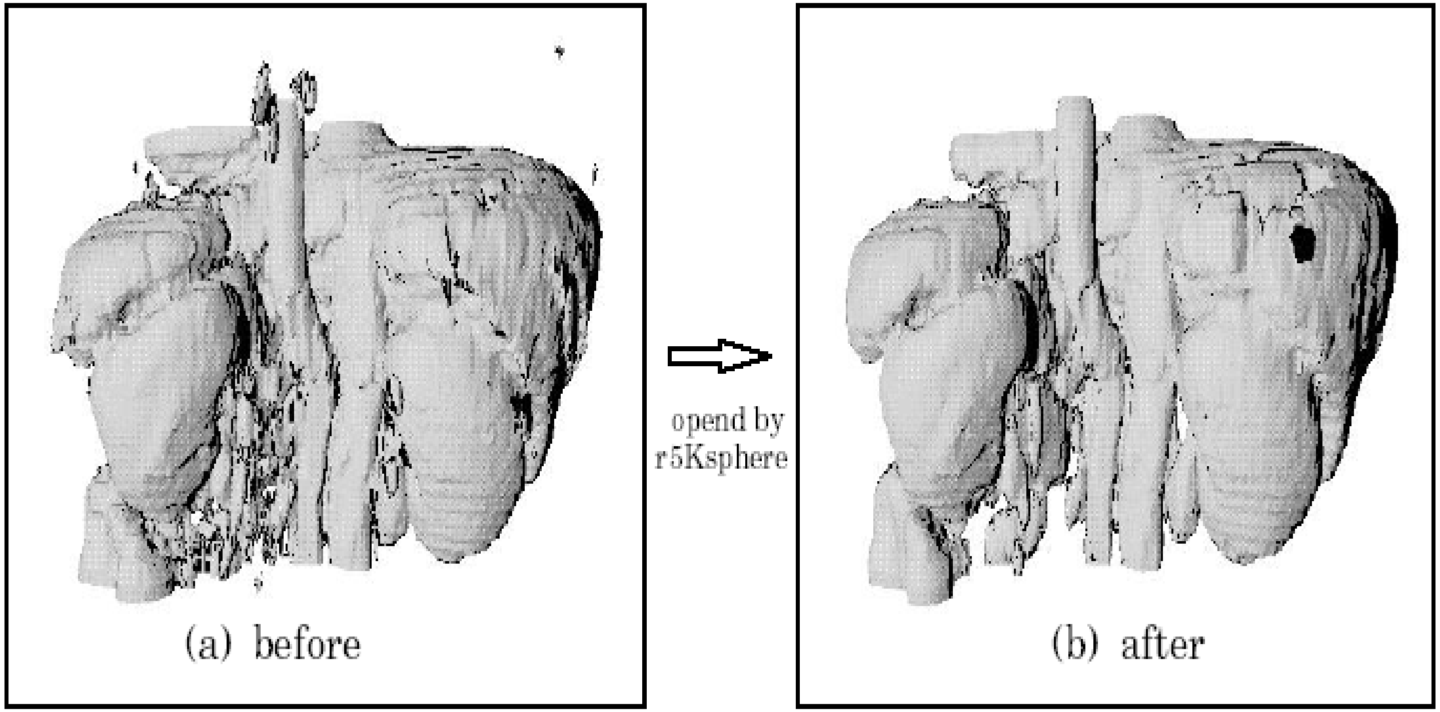
EXTRACTION OF ORGANS FROM 3D ABDOMINAL CT IMAGE - 4



Pattern Spectrum -- size analysis

EXAMPLE

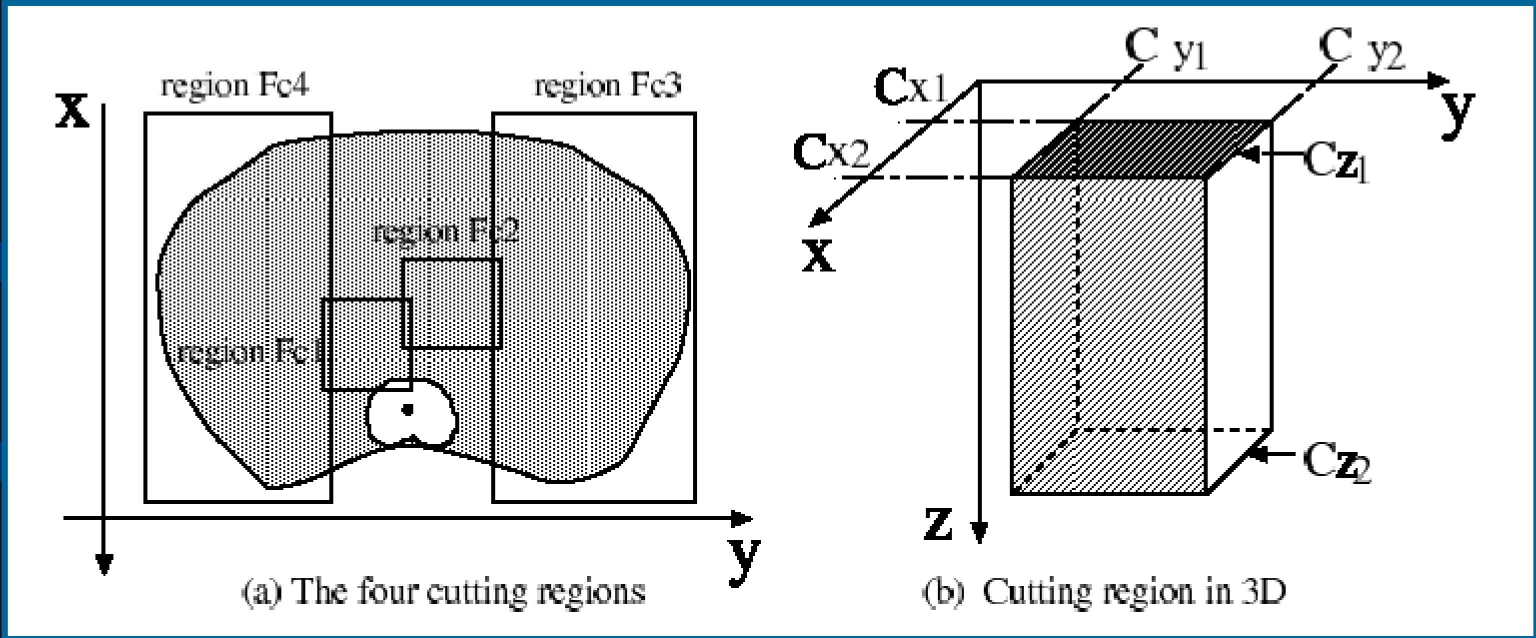
EXTRACTION OF ORGANS FROM 3D ABDOMINAL CT IMAGE - 5



Noise Reduction

EXAMPLE

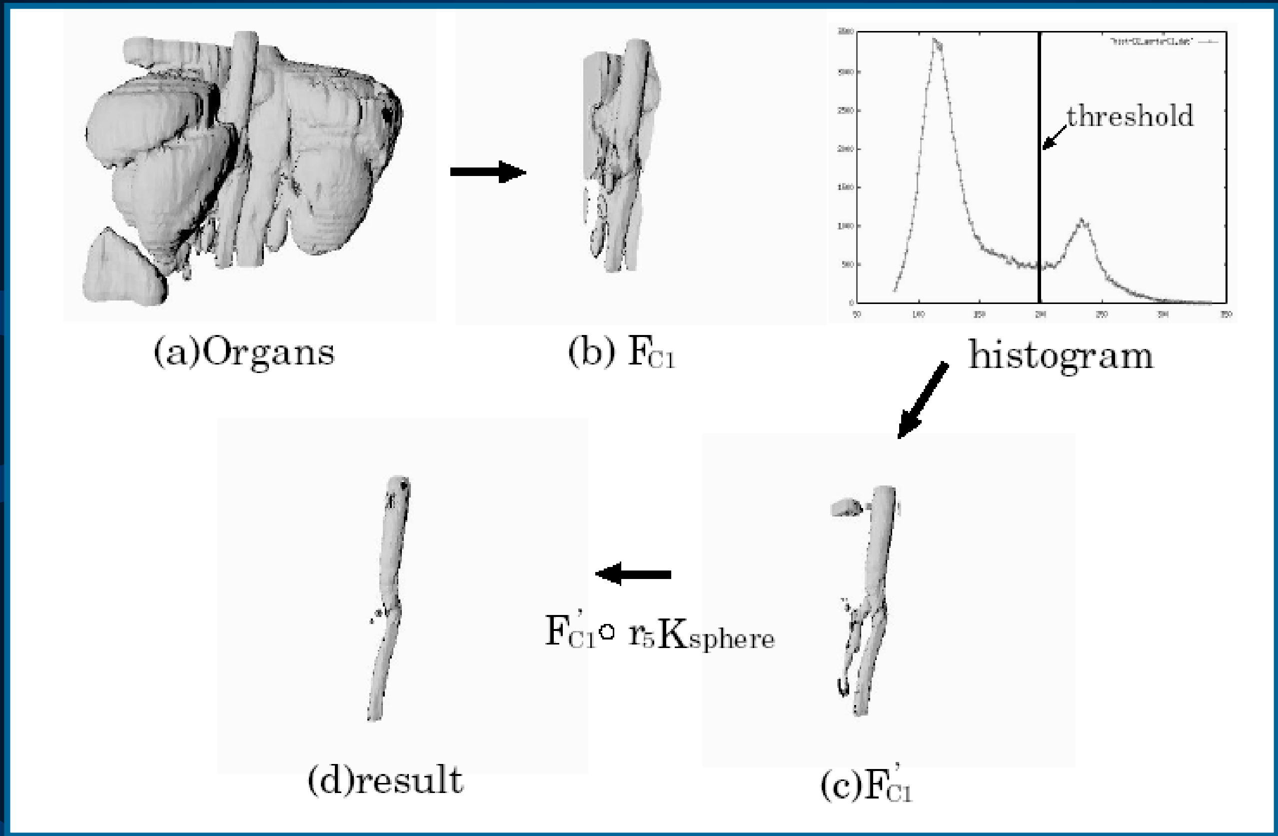
EXTRACTION OF ORGANS FROM 3D ABDOMINAL CT IMAGE - 6



Subdivision into regions

EXAMPLE

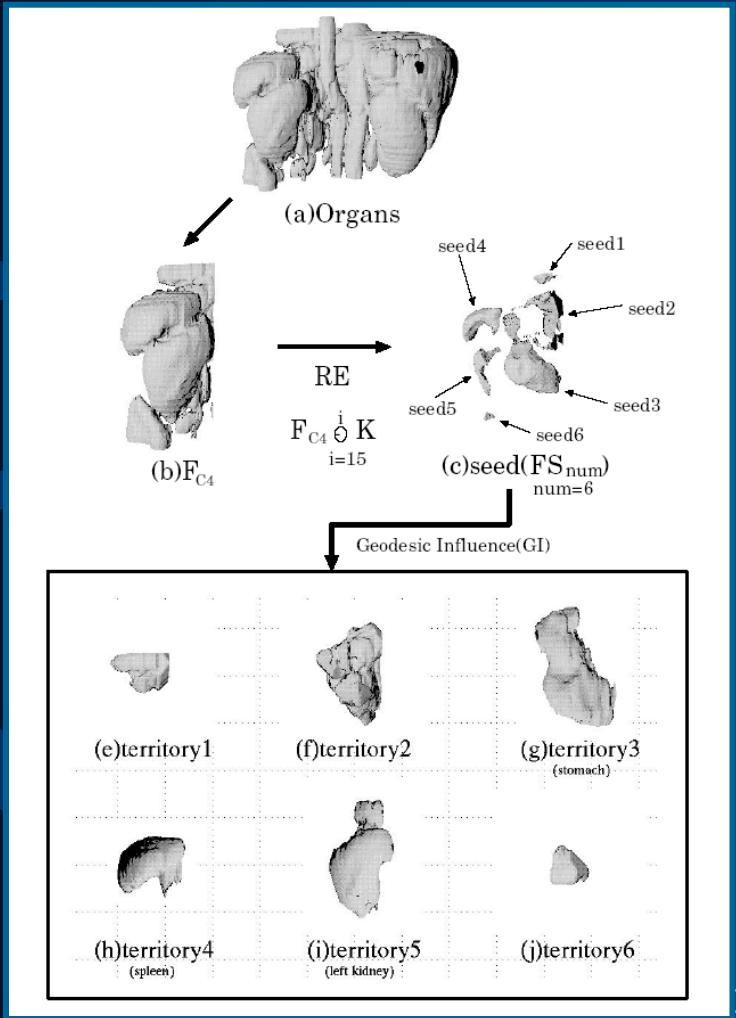
EXTRACTION OF ORGANS FROM 3D ABDOMINAL CT IMAGE - 7



Threshold segmentation

EXAMPLE

EXTRACTION OF ORGANS FROM 3D ABDOMINAL CT IMAGE - 8

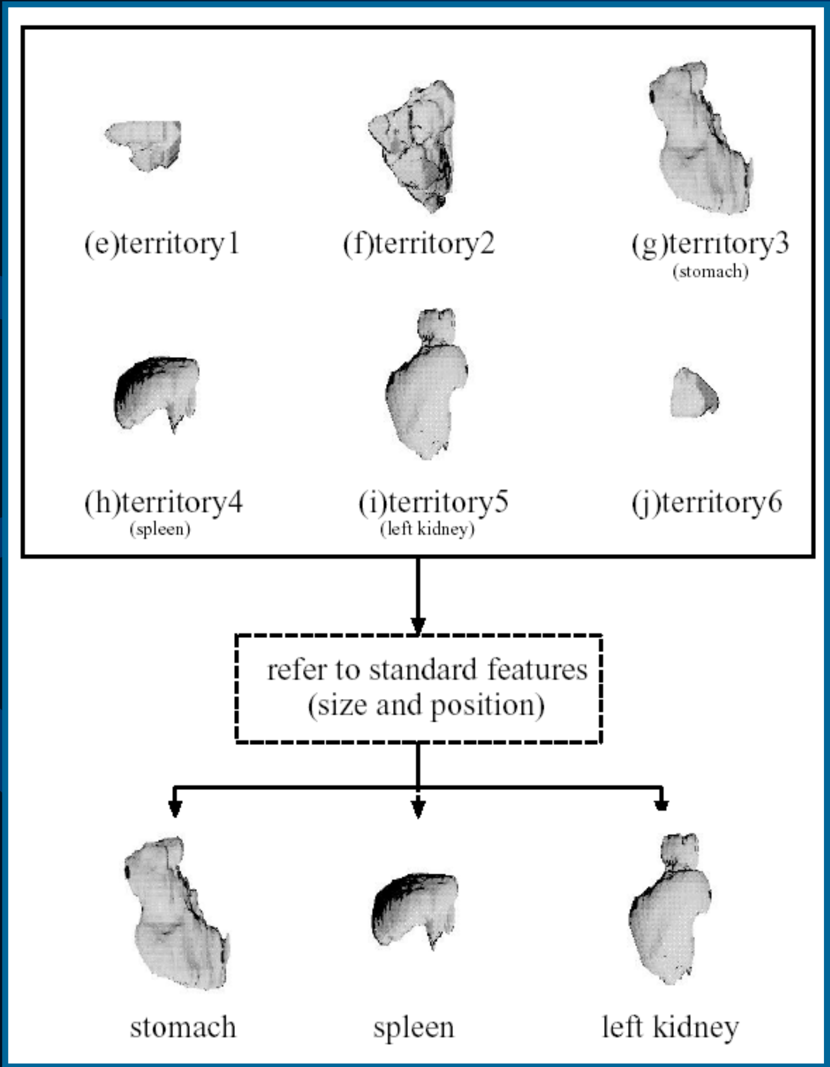


- Segmentation using Recursive Erosion (RE) and Geodesic Influence(GI):

1. RE: region shrinking to generate all the candidate seeds
2. GI: region reconstruction to recover separated organs

EXAMPLE

ORGAN RECOGNITION



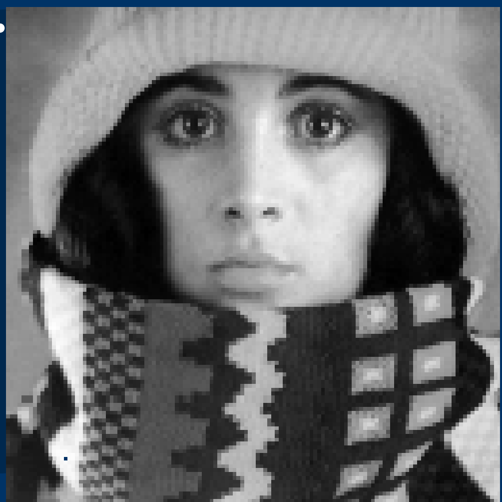
- Organ recognition:
  1. Feature analysis (size, position)
  2. Match the data base or "dictionary"
  3. Label the objects with an unique symbol (a number or an anatomic name)

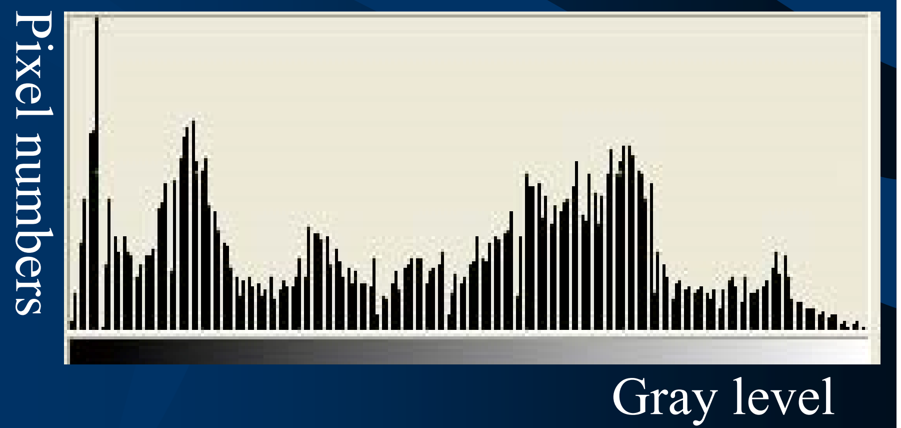
EXAMPLE

Histogram and Threshold

Histogram

- Definition: Histogram is a pixel distribution function based on each gray level.
- Its x-coordinate represents each gray level when y showing the according total pixel numbers.



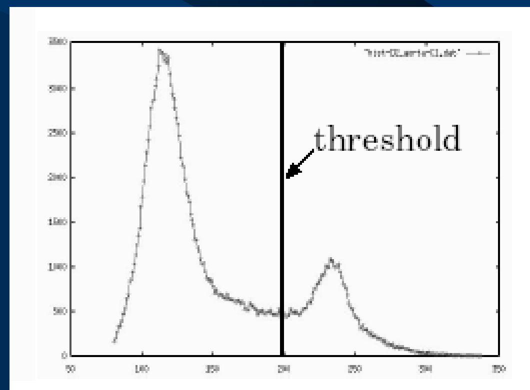


Features of Histogram

- An image condensed into a histogram, all spatial information is discarded
  – Specify the number of pixels having each gray level
  – No hint as to where those pixels are located
  – Moving a object within an image have no effect on the histogram
- Histogram VS. area of an image

Histogram Application

- Histogram can help us to set up the digitizing parameters
- Help to find a optimal threshold level
  - A bimodal histogram.
  - The gray level corresponding to the minimum of two peaks is the optimal for defining the boundary



Binary Operation

- Thresholding is a simple, non-contextual, efficient segmentation technique
    - Usually refer to Intensity Thresholding
    - Classify pixels (voxels) into two categories
    - Create a binary image (binarisation)
- Thresholding can employ either a *fixed* or an *adaptive* threshold value
- A variety of techniques have been devised to automatically choose a threshold, but no one is robust

Binary vs. Histogram

- Thresholding usually involves analyzing the histogram
  - Different image features give rise to distinct features in a histogram (Bimodel)
  - In general the histogram peaks corresponding to two features will overlap
- An example of a threshold value is the mean intensity value

Fixed Threshold

- *Fixed* or *Global* threshold: the threshold value is held constant throughout the image
- Fixed Threshold is in the form of: (T is the threshold)

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

Normal Threshold

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

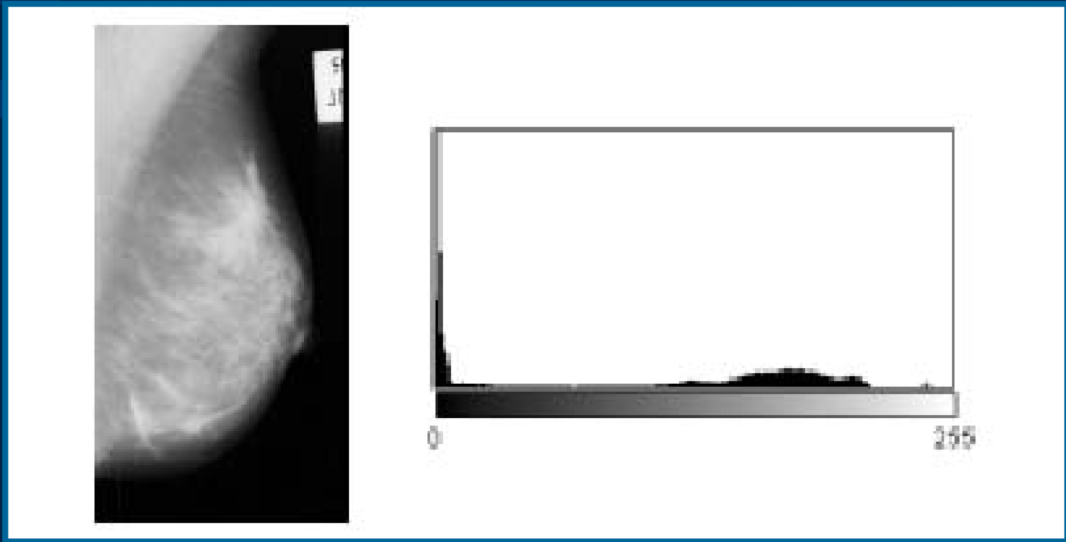
Reverse Threshold

- A variation which uses two thresholds to define a range of intensity values:

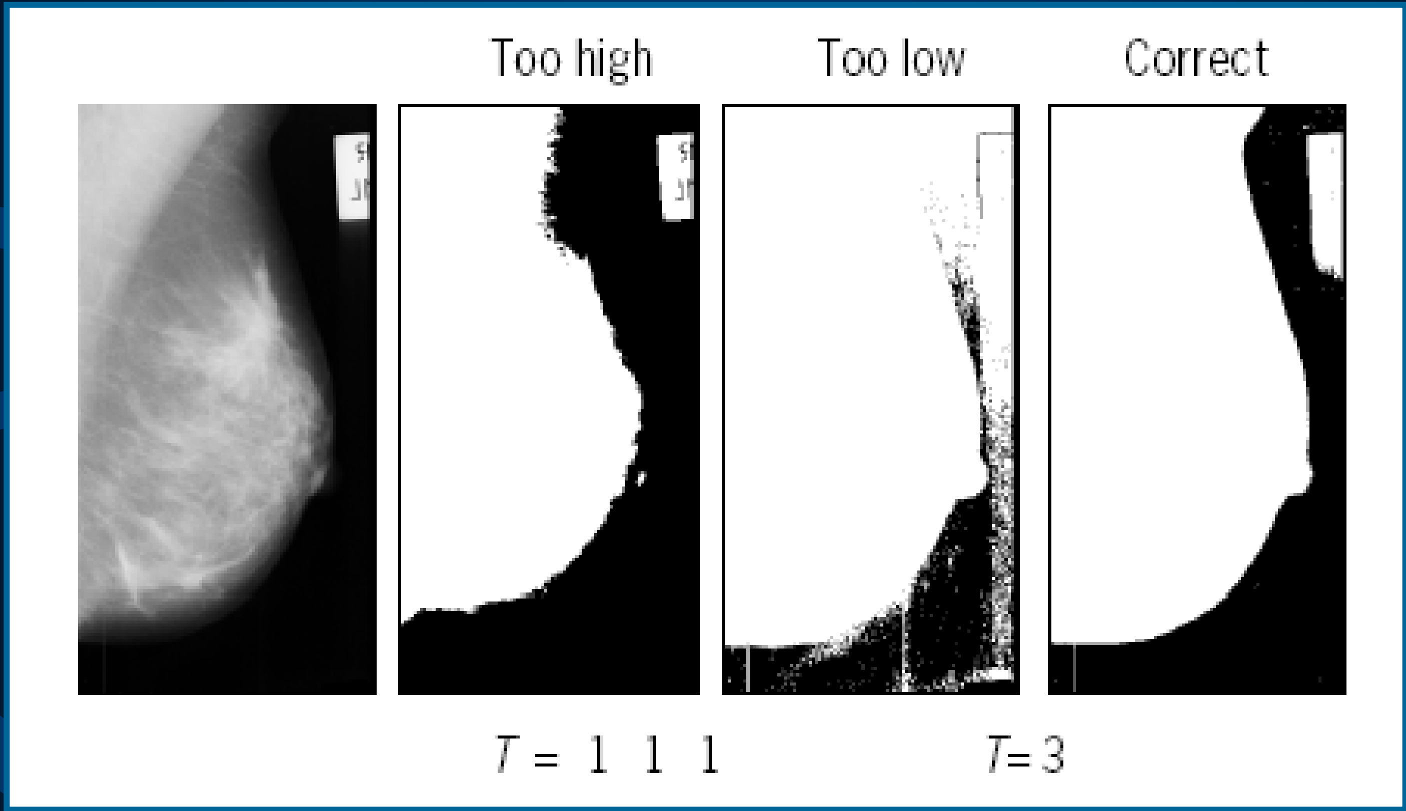
$$g(x,y) = \begin{cases} 0 & f(x,y) < T_1 \\ 1 & T_1 \leq f(x,y) \leq T_2 \\ 0 & f(x,y) > T_2 \end{cases}$$

Fixed Threshold

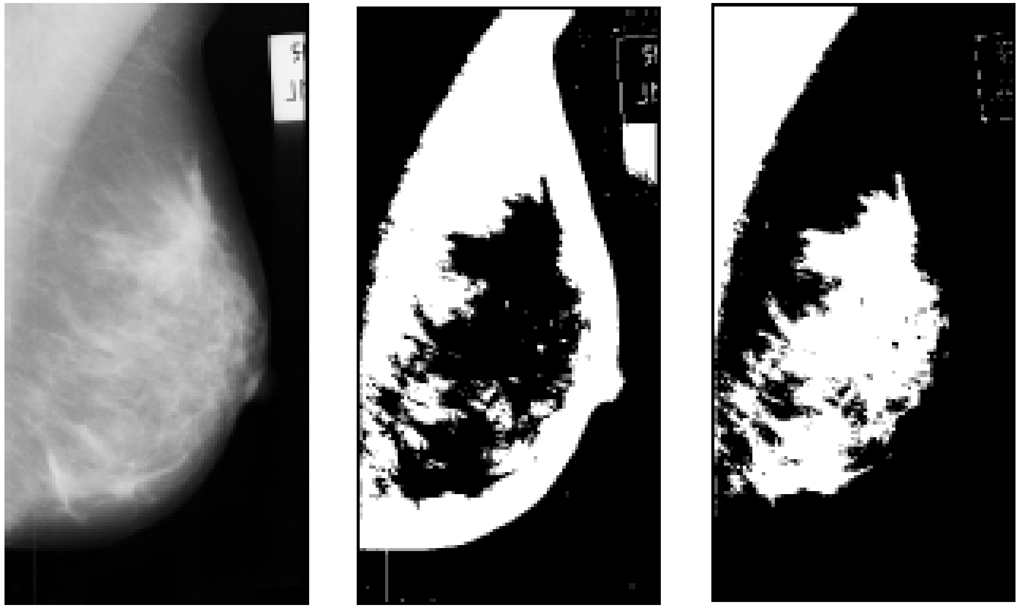
- The success of thresholding depends critically on the selection of an appropriate threshold
- An Example:



Single Threshold (Example)



Double Thresholds (Example)



T_1=8, T_2=169　　T_1=169, T_2=223

Isodata Algorithm

- This iterative threshold selection technique was developed by Ridler and Calvard
- The algorithm works as:
  1. Select an initial threshold T_0 (*e.g.* the mean intensity)
  2. Partition the image into two groups (R_1 and R_2) using the T_0
  3. Calculate the mean intensity values μ_1 and μ_2 of the partitions R_1 and R_2.
  4. Select a new threshold: $T_i = (\mu_1 + \mu_2)/2$
  5. Repeat steps 2-4 until: $T_i = T_{i-1}$

Optimal Thresldling

- Histogram shape can be useful in locating the threshold. However it is not reliable for threshold selection when peaks are not clearly resolved
- Optimal thresholding: a criterion function is devised that yields some measure of separation between regions
- A criterion function is calculated for each intensity and that which maximizes/minimizes this function is chosen as the threshold

OTSU Algorithm

- Otsu's thresholding method is based on selecting the lowest point *between* two *classes* (peaks).
- Frequency and Mean value:
  - Frequency: $\omega = \sum_{i=0}^{T} P(i) \qquad P(i) = n_i / N$ N: total pixel number
  - Mean: $\mu = \sum_{i=0}^{T} iP(i) / \omega$ **n_i:** number of pixels in level i
- Analysis of variance (variance=standard deviation^2)
  - Total variance:

$$\partial_t^2 = \sum_{i=0}^{T} (i-\mu)^2 P(i)$$

OTSU Algorithm

- *between-classes* variance (δ_b^2): The variation of the mean values for each class from the overall intensity mean of all pixels:

$$\delta_b^2 = \omega_0 (\mu_0 - \mu_t)^2 + \omega_1(\mu_1 - \mu_t)^2,$$

Substituting $\mu_t = \omega_0 \mu_0 + \omega_1\mu_1$, we get:

$$\delta_b^2 = \omega_0\omega_1(\mu_1 - \mu_0)^2$$

$\omega_0, \omega_1, \mu_0, \mu_1$ stands for the frequencies and mean values of two classes, respectively.

OTSU Algorithm

- The criterion function involves *between-classes* variance to the total variance is defined as:

$$\eta = \delta_b^2 / \delta_t^2$$

- All possible thresholds are evaluated in this way, and the one that <u>maximizes</u> η is chosen as the optimal threshold

Entropy Method

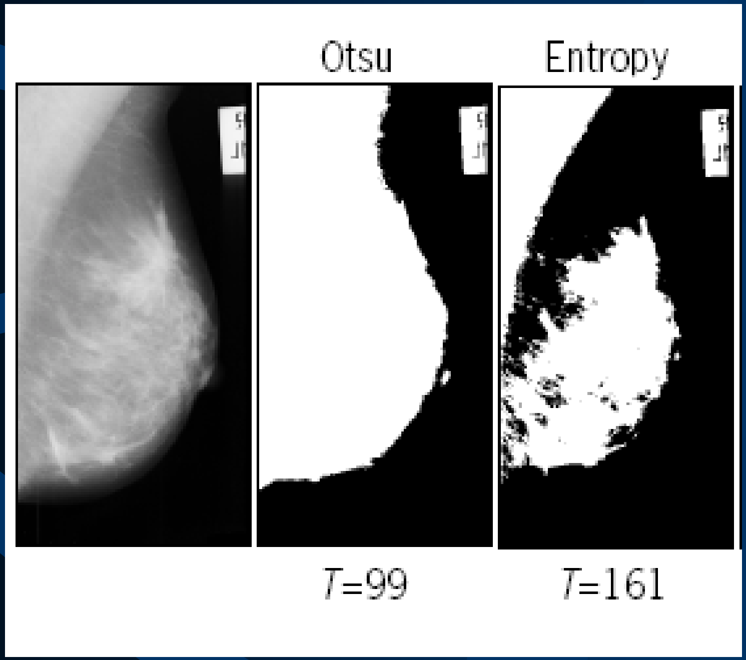
- Entropy is served as a measure of information content
- A threshold level *t* separates the whole information into two classes, and the entropy associated with them is:

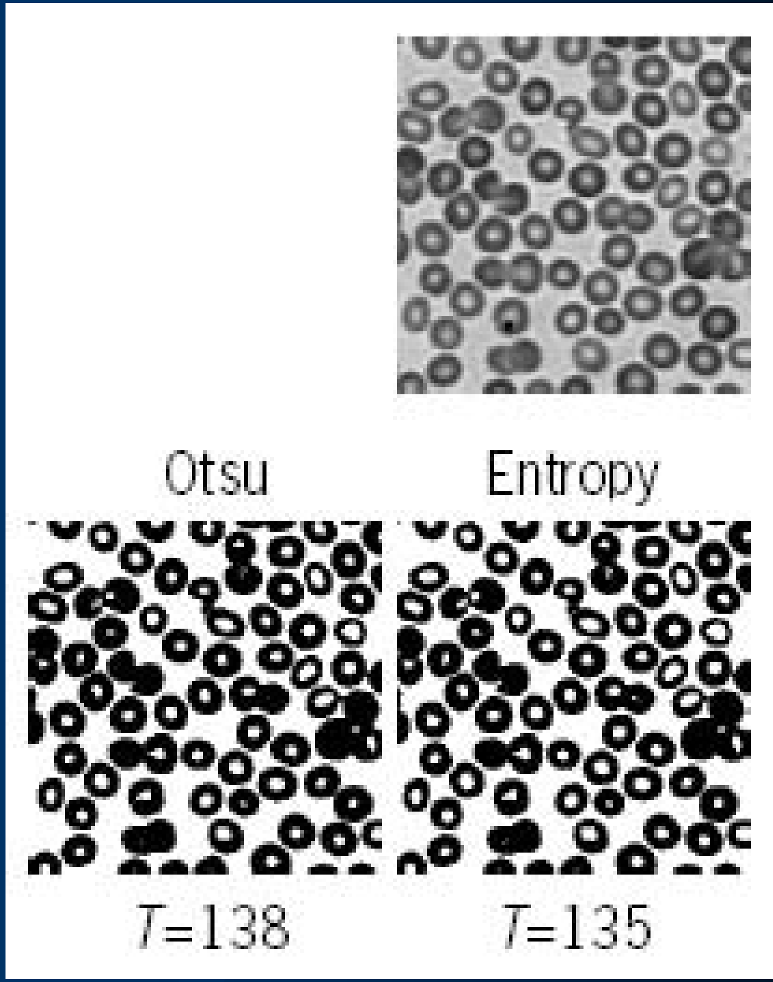
$$H_b = -\sum_{i=0}^{t} p_i \log(p_i) \qquad H_w = -\sum_{i=t+1}^{255} p_i \log(p_i)$$

- Optimal threshold is the one maximize:

$$H = H_b + H_w$$

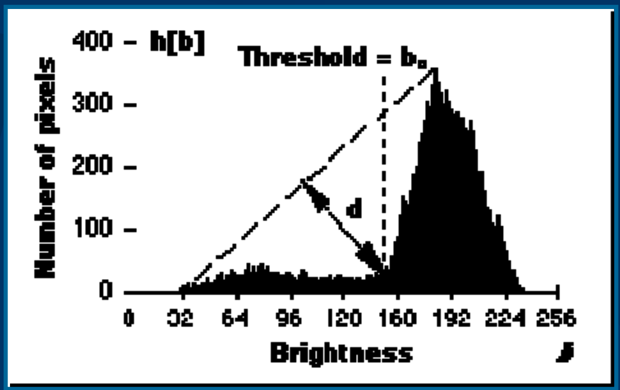
Comparing Threshold Value





Other Algorithms

- Triangle Algorithm:
  – Maximized distance ***d*** indicate the optimal threshold



Adaptive Thresholding

- Adaptive thresholding is also called *local (or regional)* thresholding
    - Employ more than one threshold value.
    - Works when the background intensity level is not constant and the object varies within the image.
    - Examines the relationships between intensities of neighboring pixels to adapt the threshod according to the intensity statistics of different regions.
- Difficulties of thresholding:
  – Poor image contrast, Spatial non-uniformities, Ambiguity…

Discussion