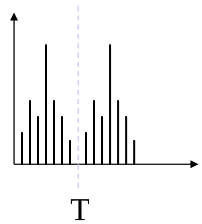
Computer Vision & Digital Image Processing

Image Segmentation: Thresholding

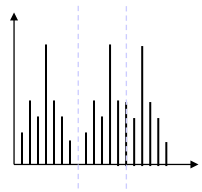
Image segmentation: thresholding

- Suppose an image *f*(*x*,*y*) is composed of several light objects on a dark background.
- The histogram for such an image may look like the following: showing two dominate modes
- An obvious way to extract object information is to select a threshold *T* that separates the two modes



Thresholding (continued)

- Suppose several objects with differing gray levels (with a dark background) comprise the image
- An object may be classified as belonging to one object class if $T_1 < f(x,y) \leq T_2$, to a second class if $f(x,y) > T_2$ or to the background if $f(x,y) \leq T_1$
- This, however, is generally less reliable than single level thresholding



Thresholding (continued)

- Thresholding may be viewed as an operation that tests against a given function of the form

$$T = T[x, y, p(x,y), f(x,y)]$$

- where $f(x,y)$ is the gray level of point (x,y) and $p(x,y)$ is some local property of the point -- the average gray level of a neighborhood around (x,y)
- The thresholded image is given by

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

- Pixels labeled 1 (or any other convenient gray level value) correspond to objects

Thresholding (continued)

- When T depends only on $f(x,y)$ the threshold is called *global*
- If T depends on $f(x,y)$ and $p(x,y)$ the threshold is *local*
- If, in addition, T depends on the spatial coordinates (x,y), the threshold is called *dynamic*
- For example, a local threshold may be used if certain information about the nature of the objects in the image is known a priori
- A dynamic threshold may be used in the case where object illumination is non-uniform

Thresholding based on boundaries

- Important aspect of threshold selection: the ability to reliably identify mode peaks in a given histogram
- The chances of selecting a "good" threshold are enhanced if mode peaks are
  - tall
  - narrow
  - symmetric
  - and separated by deep valleys
- One approach for improving the histogram shape is to consider only those pixels that lie on or near a boundary between objects and the background

Boundary characteristic thresholds (continued)

- An obvious advantage is that the histogram becomes less dependent on the size of objects in the image
- By choosing pixels on or near object boundaries (assuming an equal probability of choosing a pixel on the object or boundary) the histogram peaks tend to be made more symmetric
- Using pixels that satisfy some simple measures based on the gradient and Laplacian operators tends to deepen the valleys between histogram peaks

Boundary characteristic thresholds (continued)

- Determining if a pixel lies on a boundary: compute the gradient
- Determining what side, background (dark) or object (light), a pixel lies on: compute the Laplacian
- Using the gradient and Laplacian, a three-level image may be formed according to

$$s(x,y)=\begin{cases}0 \text{ if } \nabla f < T \\ + \text{ if } \nabla f \geq T \text{ and } \nabla^2 f \geq 0 \\ - \text{ if } \nabla f \geq T \text{ and } \nabla^2 f < 0\end{cases}$$

- where 0, + and - are three distinct gray levels

Boundary characteristic thresholds (continued)

- For a dark object on a light background, s(x,y) is produced where
  - all pixels not on an edge are labeled 0
  - all pixels on the dark side of an edge are labeled +
  - all pixels on the light side of an edge are labeled -
- For a light object on a dark background, s(x,y) is produced where
  - all pixels not on an edge are labeled 0
  - all pixels on the dark side of an edge are labeled -
  - all pixels on the light side of an edge are labeled +