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 \( T_1 \leq f(x, y) \leq T_2 \), 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 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

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
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:

\[
\begin{align*}
\hat{s}(x,y) &= \begin{cases} 
0 & \text{if } \nabla^2 f(x,y) < 0 \\
+ & \text{if } \nabla^2 f(x,y) \geq 0 \text{ and } \nabla^2 f(x,y) \geq 0 \\
- & \text{if } \nabla^2 f(x,y) > 0 
\end{cases} 
\end{align*}
\]

- 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 +