CSE585/EE555: Digital Image Processing II
Spring 2020
Project #2 — Homotopic Skeletonization and Shape Analysis

assigned: 4 February 2020
due: Friday 21 February 2020 in CANVAS project drop box
reading assignment: Sections 6.7-6.12 of P&V (PitasCh6.pdf), Maragos and Schafer paper (Maragos-Schafer.pdf), Gonzalez and Woods Ch.9 excerpt on CANVAS.

1. *Homotopic Skeletonization* — Consider $X \bigcirc B_i$, the thinning of X by B_i, defined by P&V eq. (6.10.1) as

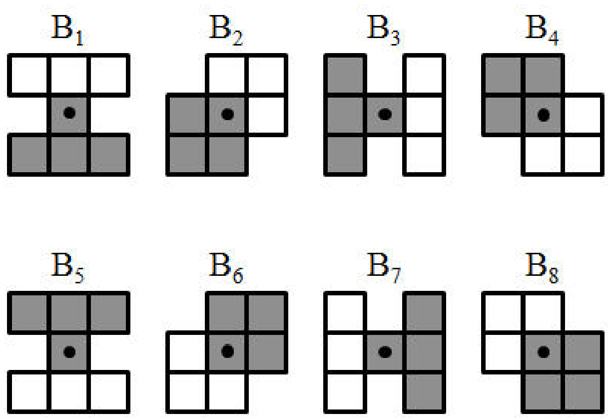
$$X \bigcirc B_i \; = X - X \circledast B_i \;, \tag{1}$$

where $B_i \; = \; \left\{ B_i^f \;,\; B_i^b \right\}$ is a set of two structuring elements and $X \circledast B_i$ is the hit-or-miss transform given by

$$X \circledast B_i = (X \ominus B_i^f) \cap (X^c \ominus B_i^b) \tag{2}$$

B_i^f probes for foreground, while B_i^b probes the background (complement). Note that (2), as defined by Gonzalez and Woods in Ch. 9 of their book (see CANVAS excerpt), is exactly the same as the hit-or-miss transform we considered earlier.

You will use the following set of B_i:



For each B_i,

- The "•' pixel corresponds to the origin
- The 4 shaded pixels correspond to the "1' values for B_i^f
- The 3 white pixels correspond to the "1" values for B_i^b
- The 2 remaining pixels in the 3×3 neighborhood are not considered!

You are to implement an algorithm for homotopic skeletonization, given by the following:

$i = 0$;
$X_i = X$;

do

$i = i + 1$;
$X_i = X_{i-1}$;
for $j = 1, 2, \ldots, 8$
$X_i = X_i \bigcirc B_j$;

while{ $X_i \neq X_{i-1}$ }

Note that each structuring element pair B_j strips/thins off a layer of pixels in a particular direction; i.e., B_1 strips off top (north) pixels, B_2 strips off top-right (northeast) pixels, B_3 strips off right (east) pixels, etc. Thus, each thinning iteration through the complete set of 8 B_j isotropically "burns off" a layer around X. Thus, the algorithm effectively implements the "grass fire" transform, while preserving the homotopy of the original image.

Also, note that B_1 is the reflection of B_5, B_2 is the reflection of B_6, etc. Hence, the need for the symmetric/reflection " $(.)^s$ " operation is unnecessary for the structuring elements in the hit-or-miss transform.

Apply your algorithm to the "penn256" and "bear" images. Give the results of the algorithm for X_2, X_5, X_{10}, and the final skeletonized image. Show each result as a superposition of X_i on the original image.

2. *Shape Analysis* — For both parts below, let B be the 3×3 square. Also, for each considered image, you will need to isolate distinct objects and find the minimum bounding rectangle (MBR) [also referred to as the bounding box] enclosing each distinct object. Feel free to use the MatLab connected-component labeling function to help with this.

   (a) Consider the "match1" image, which contains 4 objects (clover, spade, steer, and airplane).

      i. Compute the size distribution $U(n)$, pectrum $f(n)$, and complexity $H(X|B)$ of each object. Give well-labeled plots and/or tables, as appropriate, for your results. Which object is the most complex? You must give quantitative results to back up your answer.

      ii. Now, consider image "match3," which contains rotated versions of the objects in "match1." Use pecstral analysis, as discussed in P&V Section 6.11 and the Lecture 6 notes, to determine which object in "match3" best matches each of the objects in "match1." Be sure to give all necessary pecstral and distance calculations in your report, in addition to the specific algorithm you use.

   (b) Consider the image "shadow1," which has four solid objects; the objects are characters from the "Peanuts" comic strip. Quantitatively (and automatically) match them to the proper objects depicted in the complementary image "shadow1rotated." Give sufficient results to make it perfectly clear how you arrived at your results.

3. Write a detailed report describing your results and implementations. Also, give a well-commented listing of your MATLAB code, abiding by the code specifications of the class project protocol.