1. **Binary Morphological Operators: Erosion**

   You are given a set A (shown below left) and a structuring element B (shown below right). X marks the origin of the structuring element. Sketch the erosion of the set A by the structuring element B. You can sketch it by using set A and clearly indicating which pixels are added and/or deleted to form the eroded set.

2. **Compactness**

   (a) What is the compactness of a square?

   (b) What is the compactness of a rectangle?

   (c) What, if anything, can you conclude about the relative compactness of a square and a rectangle? Justify your answer.
3. **Quadtree Segmentation:**

Segment the binary image shown below by using the quadtree segmentation procedure in which \( P(R_i) = \text{TRUE} \) if all the pixels in \( R_i \) have the same intensity. Show the quadtree corresponding to your segmentation.
4. Noise reduction:
You are given an original image (called ORIG). This image is corrupted with salt and pepper noise to form a noisy image (called NOISY). The noisy image is cleaned to form a clean image (called CLEAN).

We will use $\text{mse}(A,B)$ to denote the mean squared error between images A and B.

The cleaning operation to go from NOISY to CLEAN can be either:

- 3x3 median filtering
- spatial averaging with the filter $\frac{1}{16} [1 1 1; 1 2 1; 1 1 1]$
- spatial averaging with the filter $\frac{1}{16} [1 1 1; 1 8 1; 1 1 1]$

(a) Which of the three cleaning operations is likely to produce the lowest $\text{mse}(\text{NOISY},\text{CLEAN})$?
(b) Which of the three cleaning operations is likely to produce the lowest $\text{mse}(\text{ORIG},\text{CLEAN})$?

Explain your answers.

5. Color:
You are given the choice of two different sets of phosphors for your monitor. The color gamuts for the two sets, labeled A and B, are shown below in the xy chromaticity diagram.

![xy chromaticity diagram]

Which of the two triangles would be likely to produce a greater range of discriminable colors, or would they be likely to produce the same number of discriminable colors? Note that the areas of the two triangles are precisely equal.
6. **Contrast Manipulation:**

(a) (5 points) Shown below are an original image of an airplane, and its histogram. On the next page, there are 5 contrast manipulated versions of this image, labeled c through g. There are 7 contrast re-mapping functions, labeled h through n. Five of these functions were used to produce images c through g. For each image, c through g, indicate which re-mapping function was used to produce it.

(b) (1 point) Which of the re-mapping functions, if any, corresponds to global histogram equalization?

(c) (1 point) Which of the re-mapping functions, if any, would produce false contours?

(d) (1 point) Which of the re-mapping functions, if any, corresponds to adaptive histogram equalization with a small block size?

You are not asked to provide any explanations.