

EE 569: Homework #2

Issued: 9/16/2016 Due: 11:59PM, 10/9/2016

General Instructions:

1. Read *Homework Guidelines* and *MATLAB Function Guidelines* for the information about homework programming, write-up and submission. If you make any assumptions about a problem, please clearly state them in your report.
2. You need to understand the USC policy on academic integrity and penalties for cheating and plagiarism. These rules will be strictly enforced.

Problem 1: Geometric Image Modification (40%)

In this problem, you will need to apply geometric modification and spatial warping techniques to do some interesting image processing tricks. Please note that during these operations, you may need to solve some linear equations to get the matrix parameters. **ONLY** for this part, you can use some offline tools, such as Matlab or online equation solver.

(a) Geometrical Warping (Basic: 10%)

Design and implement a spatial warping technique that transforms an input square image into an output image of a diamond shape. An example is given in Figure 1.



Figure 1: Warp the original image to a diamond-shaped image



Figure 2: Kitten_1 and Kitten_2 images

Apply the same developed spatial warping algorithm to both 300x300 color images, *Kitten_1* and *Kitten_2* in Figure 2.

(b) Puzzle Matching (Basic: 15%)

You are given two images: *Hillary* and *Trump* with size 512x512, and two puzzle pieces in one image *Pieces*, each of which is shown in Figure 3 below. Apply geometric transformations to each puzzle piece and put them back to the correct positions. The holes in *Hillary* and *Trump* images are all of size 100x100.

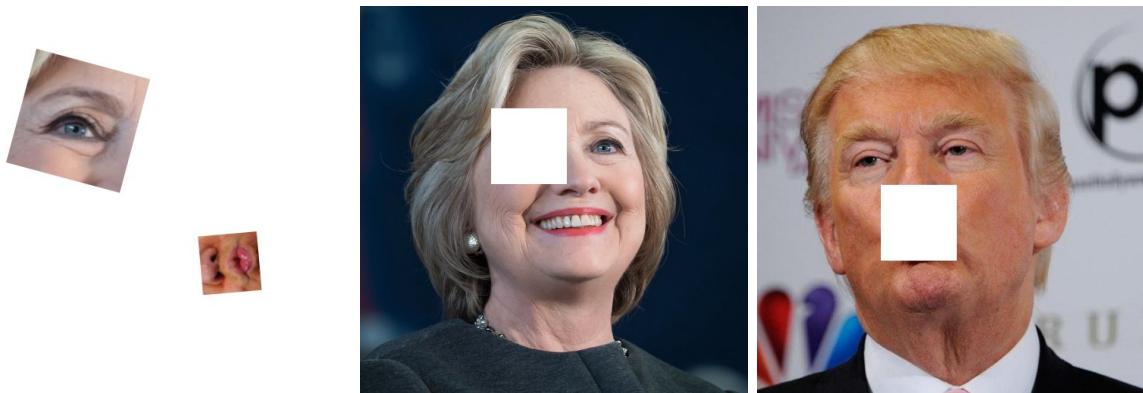


Figure 3: Component images: (a) Pieces (b) Hillary (c) Trump

Write a program to implement the hole-filling algorithm. Print out the result for both images after hole-filling.

One possible way of doing this is:

1. Find the coordinates of corners in each puzzle piece image. This must be done by your program. You are NOT allowed to do this manually.
2. Design a generic geometric transform on each puzzle piece. Here you may need to combine multiple operations (e.g. translation, rotation, scaling, etc). After the transform, each of your puzzle pieces should be a square image with its sides aligned to the horizontal and vertical axes. For up-scaling, you may need to implement an interpolation function. Drop redundant pixels when down-scaling.
3. Find the coordinates of holes in *Hillary* and *Trump* images. This must be done by your program.
4. Put the transformed puzzle piece back to the original image. You should use your program to achieve this task.

Note: Bilinear interpolation could be needed to generate pixel values at fractional positions.

(c) Homographic Transformation and Image Overlay (Advanced: 15%)

One can use the homographic transformation and the image overlap techniques to synthesize interesting images. One example is shown in Figure. 3, where the left two images are seed images and the right one is the desired output. The field image is the host image and the *Tartans* image is the embedded text image. Note that the black region outside the yellow contour of the embedded image is removed.

The homographic transformation procedure is stated below. Images of points in a plane, from two different camera viewpoints, under perspective projection (pin hole camera models) are related by a homography:

$$P_2 = HP_1$$

where H is a 3x3 homographic transformation matrix, P_1 and P_2 denote the corresponding image points in homogeneous coordinates before and after the transform, respectively. Specifically, we have

$$\begin{bmatrix} x'_2 \\ y'_2 \\ w'_2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} & H_{13} \\ H_{21} & H_{22} & H_{23} \\ H_{31} & H_{32} & H_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \\ 1 \end{bmatrix} \text{ and } \begin{bmatrix} x_2 \\ y_2 \\ w_2 \end{bmatrix} = \begin{bmatrix} x'_2 \\ w'_2 \\ y'_2 \\ w'_2 \end{bmatrix}$$

To estimate matrix H , you can proceed with the following steps:

- Fix $H_{33} = 1$ so that there are only 8 parameters to be determined.
- Select four point pairs in two images to build eight linear equations.
- Solve the equations to get the 8 parameters of matrix H .
- After you determine matrix H , you can project all points from one image to another by following the backward mapping procedure and applying the interpolation technique.

Implement above homographic transformation steps to generate the desired result as shown in Figure 4.

Now, let us keep the same host image and the same overlay region, apply the algorithm to the embedded text image *Trojans* in Figure 5 to generate a new image overlay. Show the result and make discussion on the performance.

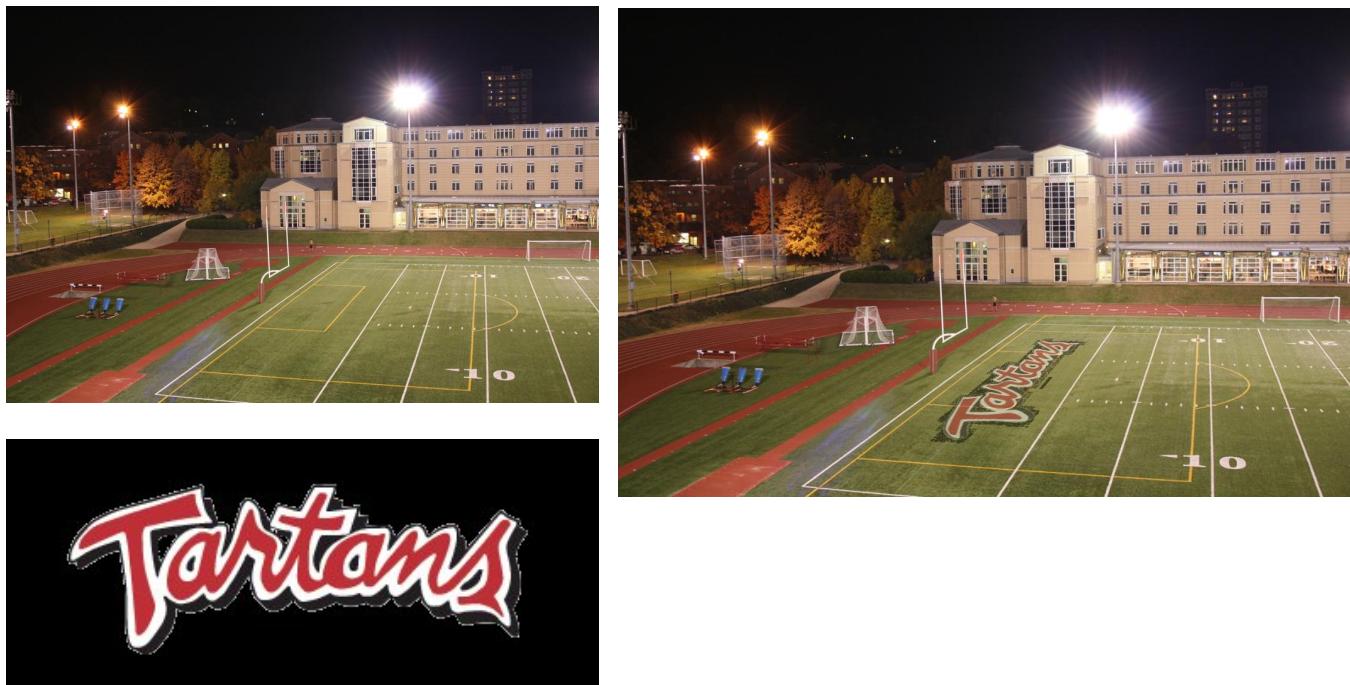


Figure 4: An example of homographic transformation and image overlay



Figure 5: The Trojans text image.

Problem 2: Digital Halftoning (30 %)

There are 256 gray levels for pixels in Figure 6. Please implement the following procedures (dithering matrices and error diffusion) to convert *House* image to a binary image. In the following discussion, $F(i,j)$ and $G(i,j)$ denote the pixel of the input and the output images at position (i, j) , respectively. **Compare the results obtained by different algorithms in your report.**

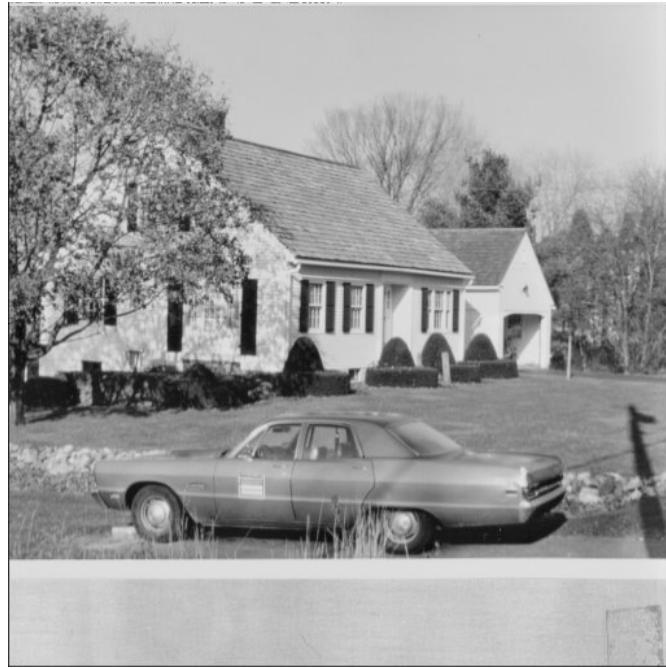


Figure 6: House image

(a) Dithering Matrix (Basic: 15%)

Convert the 8-bit *House* image in Figure 6 to a half-toned image using the dithering method. Dithering parameters are specified by an index matrix. The values in an index matrix indicate how likely a dot will be turned on. For example, an index matrix is given by

$$I_2(i,j) = \begin{bmatrix} 0 & 2 \\ 3 & 1 \end{bmatrix}$$

where 0 indicates the pixel most likely to be turned on, and 3 is the least likely one. This index matrix is a special case of a family of dithering matrices first introduced by Bayer.

The Bayer index matrices are defined recursively using the formula:

$$I_{2n}(i,j) = \begin{bmatrix} 4 * I_n(x,y) & 4 * I_n(x,y) + 2 \\ 4 * I_n(x,y) + 3 & 4 * I_n(x,y) + 1 \end{bmatrix}$$

The index matrix can then be transformed into a threshold matrix T for an input gray-level image with normalized pixel values (*i.e.* with its dynamic range between 0 and 255) by the following formula:

$$T(x, y) = \frac{I(x, y) + 0.5}{N^2} \times 255$$

where N^2 denotes the number of pixels in the matrix. Since the image is usually much larger than the threshold matrix, the matrix is repeated periodically across the full image. This is done by using the following formula:

$$G(i, j) = \begin{cases} 1 & \text{if } F(i, j) > T(i \bmod N, j \bmod N) \\ 0 & \text{otherwise} \end{cases}$$

where $F(I, j)$ and $G(I, j)$ are the normalized input and output images.

There are different ways to construct a dithering matrix. Another example for a 4x4 matrix is:

$$A_4(i, j) = \begin{bmatrix} 14 & 10 & 11 & 15 \\ 9 & 3 & 0 & 4 \\ 8 & 2 & 1 & 5 \\ 13 & 7 & 6 & 12 \end{bmatrix}$$

Answer the following questions.

1. Construct $I_2(i, j)$ and $I_8(i, j)$ Bayer index matrices and apply them to the *House* image.
2. Compare the above $A_4(i, j)$ matrix with $I_4(i, j)$ Bayer Matrix and discuss their differences. Apply both and compare the results.
3. If a screen can only display FOUR intensity levels, design a method to generate a display-ready *House* image. Show your best result in gray-scale with four gray-levels (0, 85, 170, 255) and explain your design idea and detailed algorithm.

(b) Error Diffusion (Basic: 15%)

Convert the 8-bit *House* image to a half-toned one using the error diffusion method. Show the outputs of the following three variations, and discuss these obtained results. Compare these results with dithering matrix. Which method do you prefer? Why?

1. Floyd-Steinberg's error diffusion with the serpentine scanning, where the error diffusion matrix is:

$$\frac{1}{16} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 7 \\ 3 & 5 & 1 \end{bmatrix}$$

2. Error diffusion proposed by Jarvis, Judice, and Ninke (JJN), where the error diffusion matrix is:

$$\frac{1}{48} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 7 & 5 \\ 3 & 5 & 7 & 5 & 3 \\ 1 & 3 & 5 & 3 & 1 \end{bmatrix}$$

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3. Error diffusion proposed by Stucki, where the error diffusion matrix is:

$$\frac{1}{42} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 8 & 4 \\ 2 & 4 & 8 & 4 & 2 \\ 1 & 2 & 4 & 2 & 1 \end{bmatrix}$$

Describe your own idea to get better results. There is no need to implement it if you do not have time. However, please explain why your proposed method will lead to better results.

Problem 3: Morphological Processing (30%)

Morphological processing includes three operations: shrinking, thinning, and skeletonizing. Apply these operations with attached pattern tables (patterntables.pdf) on following questions. Show outputs for all following parts in your report and discuss them thoroughly. State any assumptions you make in your solution.

(a) Rice Grain Inspection (Basic: 16%)

Rice grain inspection is a procedure to define rice quality in the marketplace. Figure 7 is an example image for rice grain type examination. Conduct the following steps to process the image and answer questions.

1. Implement image binarization

Write a program to create binary image from the incoming RGB image. You need to convert it to grayscale image first and then apply thresholding to obtain the result.

2. Count the number of rice grains

Use shrinking technique to count the number of rice grains in *Rice.raw* image. Develop post-processing algorithms to remove unwanted dots and holes caused by binarization.

3. Compare the size of rice grains

Utilize thinning and shrinking technique to rank the grain's size from small to large in terms of type. This problem has multiple solutions, discuss your ideas and show their corresponding results. You may pick one from each type for comparison.

4. Categorize rice grains

From the information you have obtained so far, can you come up a way to categorize those grains using results from all morphological operations? If so, please explain it in detail in your report.



Figure 7: Rice image.

(b) MPEG-7 Dataset (Advanced: 14%)

Morphological processing is also important to 2D shape classification, like MPEG-7 Shape Dataset [1] for instance. Assuming we now possess two different images *Butterfly* and *Fly* as shown in Figure 8 below, apply the hole-filling filter and the boundary smoothing filter as the pre-processing operations to remove interior holes. Next, perform thinning and skeletonizing filters to both images. Compare both results after thinning and skeletonizing respectively, and see if you can list all differences between these two images.



Figure 8: Butterfly and Fly images

Now we have a new *Probe* image from the dataset as shown in Figure 9. Assuming you have no clue about what shape it belongs to, please design a program that can classify the incoming shape image into above two categories based on its thinning and skeletonizing results. Preprocessing is also required.

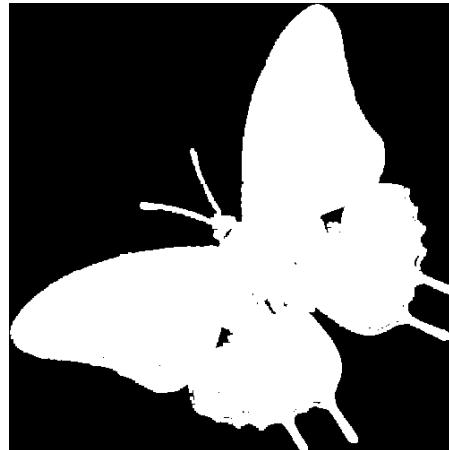


Figure 9: Probe image

Appendix:**Problem 1: Geometric image modification and image warping**

Field.raw	972x648	24-bit	color(RGB)
Tartans.raw	350x146	24-bit	color(RGB)
Trojans.raw	350x146	24-bit	color(RGB)
Hillary.raw	512x512	24-bit	color(RGB)
Trump.raw	512x512	24-bit	color(RGB)
Piece.raw	500x500	24-bit	color(RGB)
Kitten_1.raw	300x300	24-bit	color(RGB)
Kitten_2.raw	300x300	24-bit	color(RGB)

Problem 2: Digital halftoning

House.raw	512x512	8-bit	gray
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Problem 3: Morphological Processing

Rice.raw	690x500	24-bit	color(RGB)
Butterfly.raw	335x320	8-bit	gray
Fly.raw	222x223	8-bit	gray
Probe.raw	496x502	8-bit	gray

Reference Images

All images in this homework are from Google images [2] or the USC-SIPI [3] image database.

Reference

- [1] <http://www.dabi.temple.edu/~shape/MPEG7/dataset.html>
- [2] <http://images.google.com/>
- [3] <http://sipi.usc.edu/database/>