Digital Video Processing (EE392J)
Department of Electrical Engineering
Stanford University

Problem Set No. 3

Issued: January 30, 2002
Due: February 6, 2002 (in class)
Reading: Finish reading chapter 6. Read 5.5.1, skim 5.5.2-5.5.3, read 5.5.4. Read chapter 13 of Tekalp (handed out in class).

Problem 1. Problem 6.6. (Note that the *final* answer is given in the back of the book - but you have to derive it here.)

Problem 2. Problem 6.16.

Problem 3. Assume you are given a continuous image with spatial bandwidths of B_x and B_y along the horizontal and vertical dimensions, respectively. The image moves with a global motion and constant velocity v_y in the vertical direction. The resulting video signal is then sampled with interlaced sampling (as shown in Figure 3.6 in the text) where $\Delta x = \frac{1}{2B_x}$, $\Delta y = \frac{1}{B_y}$, and Δt.
(a) Determine the spectrum of the sampled video signal and draw a figure to illustrate the spectrum in the $F_y - F_t$ plane. How does the spectrum vary with v_y?
(b) Determine if any critical velocities exist for this sampling lattice and signal bandwidth. If critical velocities exist, describe them in both the spatio-temporal (pixel) domain and in the frequency domain.

Problem 4. Affine Motion Models

As discussed in class, parametric motion models describe the relationship between image A pixels (x, y) and image B pixels (X, Y). The parametric motion model for affine motion is given by:

$$X = ax + by + c \tag{1}$$

$$Y = dx + ey + f \tag{2}$$

These equations map pixels in location (x, y) to location (X, Y), i.e. $(x, y) \rightarrow (X, Y)$.

A. **Written assignment**

1. Derive the equations that map pixels $(X, Y) \rightarrow (x, y)$. Is this also an affine mapping?
2. Given 3 pairs of point correspondences $(x_0, y_0) \longleftrightarrow (X_0, Y_0)$, $(x_1, y_1) \longleftrightarrow (X_1, Y_1)$, and $(x_2, y_2) \longleftrightarrow (X_2, Y_2)$, how do we calculate the affine parameters a, b, c, d, e, f ?
3. The second equation on slide 30 of the lecture notes from Lecture 4 is incorrect (and the same equation on slide 7 of Lecture 5). Replace the incorrect equations in your notes with the correct equation you calculated in A.2.

B. **Matlab script**

Write a matlab script that performs the following tasks:

i. Load two images and get point correspondence pairs between the two images by clicking on three common image features in each picture. Print the point correspondence pairs. (Hint: The ginput() command returns the coordinates of the point that you click the mouse on in the current Figure. Use the ginput(3) command to get the coordinates of three feature points in each loaded image. You can also use subplot to plot both images within the same Figure window, and then by using ginput(6) you can identify the three pairs of feature points by first clicking on the location of the feature point in the first image and then on its location in the second image, etc.)

ii. Calculate the affine parameters between $A \to B$ using the point correspondence pairs in (i). Calculate the affine parameters between $B \to A$ using the point correspondence pairs in (i). Print both sets of affine parameters.

iii. Create Bpred, the MC-prediction of image B, from image A and the affine motion model. (Which set of affine parameters in (ii) should you use for this MC-prediction?) Calculate Berr, the error signal between Bpred and B. Calculate Bpsnr, the PSNR between Bpred and B. Print and turn in your images Bpred and Berr, and the number Bpsnr. (Note: If the mapped pixel is located outside the image boundary, simply use a reasonable pixel value from inside the image boundary. However, do not use these *outside* pixels in your PSNR calculation. If the mapped pixel is located in a subpixel location, use the nearest pixel or perform a simple bilinear spatial interpolation of the surrounding pixels.)

C. **Matlab processing**

Five 640×480 gray-scale images (A.tif, B.tif, C.tif, and D.tif) are located at the Problem Set webpage off of the course webpage www.stanford.edu/class/ee392j.

1. Use your script to process images A.tif and B.tif.
2. Use your script to process images C.tif and D.tif.
3. Try generating your point correspondence pairs with different features in the images (e.g. features in the bookshelves, features in the ceiling, or features in both). Briefly comment on the quality of the predictions when using different image features, e.g. How does the quality depend on the feature points- what effects do the intensity and location of the pixels have on the quality? Where does the motion model work or fail?

D. **Bonus:** *Pseudo-Generalized Block Motion Compensation* Have your script divide the predicted image into 4, 9, or 16 blocks and for each block choose 3 point correspondence pairs and calculate the affine motion model parameters. Reconstruct a prediction of the frame by using the appropriate affine mapping for each block. Briefly comment on the performance of this scheme. (Note: It may be good to renormalize the offset of x, y, X, Y for each block.)