EE5176: Computational Photography
Programming Assignment 2

Divya Madhuri, ee24d004@smail.iitm.ac.in
Advaith H Raj, ee21b007@smail.iitm.ac.in

Note

1. Please use Moodle discussion threads for posting your doubts and also check it before sending emails to TAs, as the same question might have been asked earlier.
2. Submit a single zip file named as `PA2_Rollno.zip` containing a report and folders containing corresponding codes[1].
3. Read the problem fully to understand the whole procedure.
4. Late submissions will be evaluated for reduced marks and for each day after the deadline we will reduce the weightage by 10%.

1 Motion deblurring with conventional camera

You are given a clean image of a scene having M rows and N columns (`fish.png`). We capture the scene using a static conventional camera with the aperture kept open for the full exposure time. The exposure time is 52 seconds. For simplicity, consider that the camera captures the scene at times $t = 0, \dots, 51$ (i.e. at 52 instants). At time $t = 0$, the image has zero translation. Then, the whole image as seen by the camera moves at 1 pixel per second to the right (horizontal translation).

(a) Generate the blurred image having M rows and $N + 51$ columns captured by the camera. Generate translated versions of the image for $t = 0, \dots, 51$, and average them. Add Gaussian noise of mean 0 and standard deviation 1 (with respect to the maximum intensity of 255) from `gaussNoise.mat`. Display the blurred image. [5 marks]

[1] Kindly refrain from using formats like .rar, .7z, etc.

(b) Form the blur matrix A of size $(N + 51) \times N$ corresponding to the horizontal translation described above. Note that this matrix will be a Toeplitz matrix. Display A using `imshow` command. [5 marks]

(c) Use A to deblur the blurred image using least squares. The size of the deblurred image should be $M \times N$ for each colour channel. (Note: Since the blurring is horizontal, you have to operate A on each row of the blurred image.) Display the deblurred image. Determine the RMSEs between the given clean image and the deblurred image. Use the formula

$$\text{RMSE} = \sqrt{\frac{1}{N} \sum (I - \hat{I})^2}.$$

[5 marks]

(d) What do you observe about the deblurred image? Explain the reason. [2 marks]

2 Motion deblurring with flutter shutter

With the same setup as in the previous section, we use a flutter shutter camera with these 2 codes:

(i) 1010000111000001010000110011110111010111001001100111

(ii) 1010101010101010101010101010101010101010101010101010

where each bit represents one second of the exposure time.

(a) Generate the blurred images with noise (same as in Problem-1) for the exposure codes given above. [4 marks]

(b) Form the blur matrix A of size $(N + 51) \times N$ for each case. [3 marks]

(c) Plot and compare the DFTs of the conventional and flutter shutter codes. Use the first column of the respective A matrices. Plot the magnitude in decibels. Comment. [3 marks]

(d) Use A to deblur the blurred image using least squares. Display the deblurred images.

(e) Using the formula given in part (c) of Question 1, find the RMSE for the deblurred image compared to the original for both the flutter shutter codes. Comment on your result and explain why there is a difference. [2 marks]

(f) Let the noise be absent in both problems (1) and (2). Compare and comment on the deblurred outputs. [4 marks]

3 Deblurring with motion-invariant photography

You are given images of the top view of a road scene (`background.png`) and a foreground moving object (`redcar.png`).

(a) Assuming static camera and the velocity of the car as 1 pixel per second to the right (horizontal translation) relative to a static camera, generate the blurred image captured for an exposure time of 52 seconds.

Hint: First create individual frames for each second, i.e. 52 frames. To create each frame, apply translation corresponding to that frame on the foreground object and merge it with background. Merging: For all pixels with a non-zero value in the foreground image, assign foreground pixel values; else use background pixel values. [3 marks]

(b) Consider the same scenario captured using motion invariant photography (i.e. the camera also moves during the exposure). The translational values of the static background due to camera motion at each second are given in `CameraT.mat`. Generate the blurred image captured in this case with both camera and object motions for an exposure time of 52 seconds. [6 marks]

- Create individual frames for each second: Apply camera translations to the background image and the relative translations to the moving object separately. Then, merge them to obtain a frame.
- The relative translations of the moving object with respect to the moving camera can be obtained by:

$$\begin{aligned}\text{relative translation} = &\text{ static background translation due to camera} \\ &- \text{object translation}\end{aligned}$$

- Average all the 52 frames to obtain the blurred image.

(c) Compare and comment on the outputs of (a) and (b). [2 marks]

(d) Find and plot the PSF of the blurred image in (b). If x is the camera translation then PSF weight at x is

$$w(x) = \frac{1}{x^2}.$$

Choose $x = \{0.1, 1, 2, \ldots, 51\}$ and normalize the PSF after assigning these values. [2 marks]

(e) Use the PSF obtained in (d) to form the blur matrix A. [2 marks]

(f) Deblur the blurred image in (b) using least squares. [2 marks]