Programming Assignment-2: Motion deblurring

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1 Introduction

In this assignment, we explore different techniques of deblurring, from traditional deconvolution in conventional cameras to motion invariant photography.

2 Implementation

The code has been implemented and tested to run on MATLAB R2019b. The helper functions are present in the scripts folder and image files are assumed to be present in the data folder. The scripts and data folder are assumed to be present in the same directory as PA2.m which is the main file. Results to different sections can be obtained by executing individual sections in PA2.m, which have been separated using MATLAB's operator and named appropriately.

3 Motion deblurring with conventional camera

The image obtained upon blurring and adding Gaussian noise is shown in Figure 1. The blur matrix corresponding to the horizontal translation that generated the blurred image is shown in Figure 2. The image obtained upon deblurring using least squares is shown in Figure 3. RMSE between the clean and the deblurred image comes out to be 10.7991(when maximum intensity is 255).

4 Motion deblurring with flutter shutter

The image obtained upon blurring using the flutter shutter code and adding Gaussian noise is shown in Figure 4. The blur matrix corresponding to the blurring operation is shown in Figure 5. The DFT coefficients of the PSF of the conventional camera and that of the flutter shutter camera are shown in Figure 6. The deblurred outputs of the noiseless conventional camera image

Figure 1: Q 1(a) Blurred image

Figure 2: Q 1(b) Blur matrix

and noiseless flutter shutter image are shown in Figures 7 and 8 respectively.
Comparison of the DFT coefficients of the conventional camera and flutter shutter :
The DFT coefficients of the flutter shutter have nearly equal non-zero values

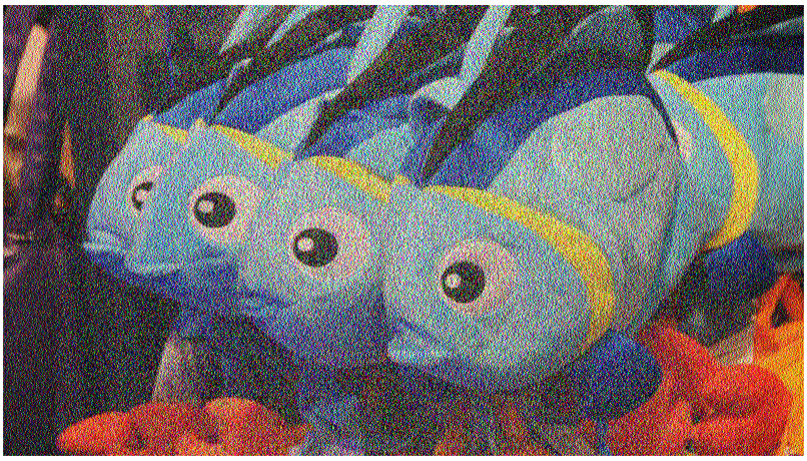

Figure 3: Q 1(c) Deblurred image

for all the frequencies and hence, a deblurring operation would not lead to amplification of noise. On the other hand, the DFT coefficients of the conventional camera has a lot of dips(very small values) and would amplify the noise in the image as shown in Figure 3.

Figure 4: Q 2(a) Blurred image

As we can see, the deblurred image for the noiseless flutter shutter case is very similar to the original image, while the deblurred image for the noiseless

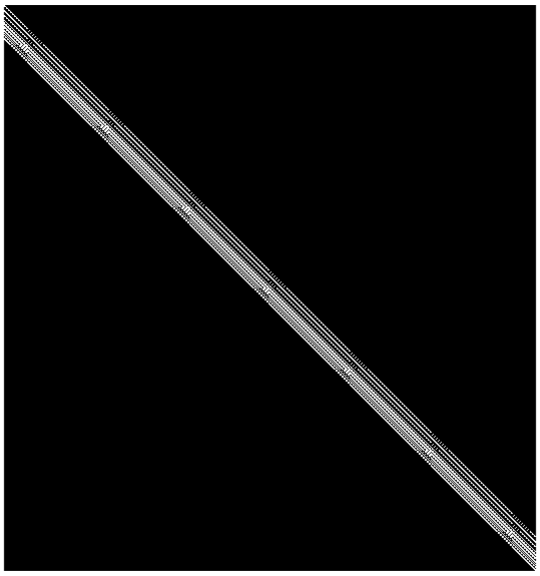

Figure 5: Q 2(b) Blur matrix

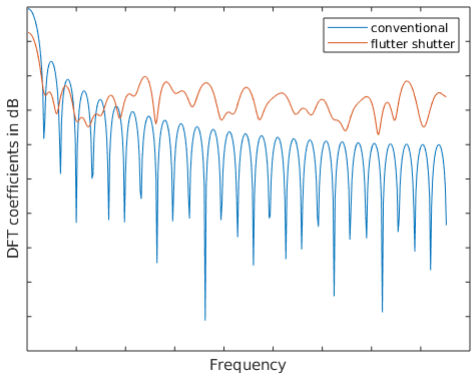

Figure 6: Q 2(c) DFTs of conventional and flutter shutter codes

conventional camera case has some speckles. This is because some of the DFT coefficients of the PSF of the conventional camera are very close to zero and hence while performing an inverse filtering operation, some noise in the image will get amplified as the inverse filter will have some very large values due to this. The deblurred image corresponding to the conventional camera is much better than the case when noise was added. This is expected as the noise is absent and no longer gets amplified and ruins the image.

Figure 7: Q 2(d) Deblurred image(conventional camera, noiseless)

Figure 8: Q 2(d) Deblurred image(flutter shutter, noiseless)

5 Deblurring with motion-invariant photography

The blurred outputs of the static camera and a moving object is shown in Figure 9. The blurred output of motion-invariant photography is shown in Figure 10, for speed of the moving object = 1 pixel/second.
Comparison of the two blurred outputs in Figures 9, 10 :
In Figure 9, the image has a statically variant blur due to the motion of the car, i.e., only the car has a blur and the rest of the image is static. In Figure

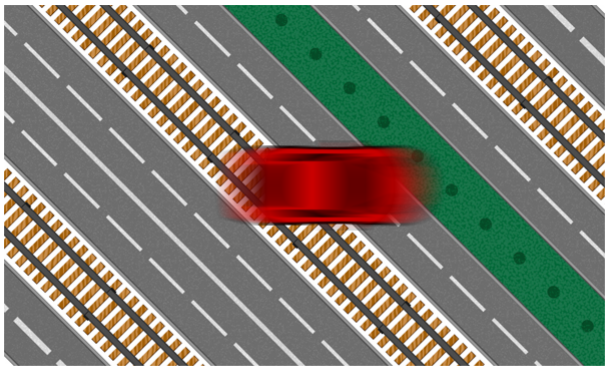

Figure 9: Q 3(c) Blurred image - static camera

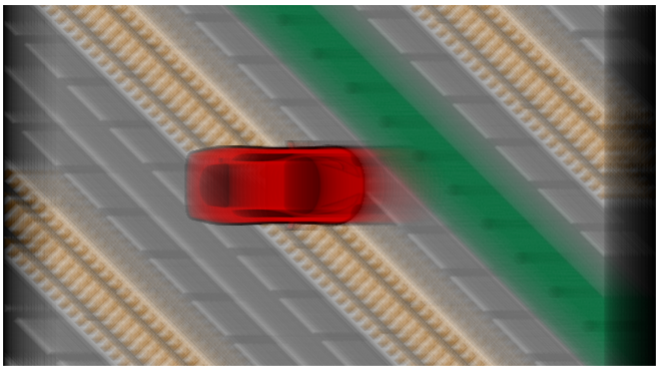

Figure 10: Q 3(c) Blurred image - moving camera, vel = 1 pixel/sec

10, due to motion invariant photography, the entire image has uniform blur. The structure of the car is difficult to make out in Figure 9 whereas it is quite evident in Figure 10.
The blurred output of motion-invariant photography is shown in Figure 11, for speed of the moving object = 2 pixels/second and in Figure 12, for speed of the moving object = 3 pixels/second.

Comparison of the two blurred outputs in Figures 11, 12 :
In Figure 11 and 12, the entire image has the same blur however, in Figure 12, the headlight of car has a higher blur due to its faster motion as compared to Figure 11.
The PSF of the blurred image in Figure 10 has been plotted in Figure 13.

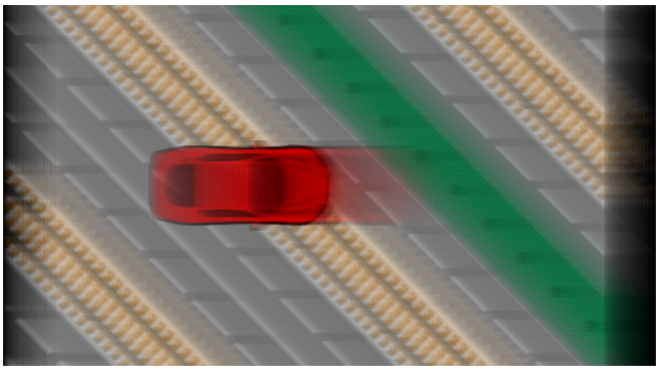

Figure 11: Q 3(d) Blurred image - moving camera, vel = 2 pixel/sec

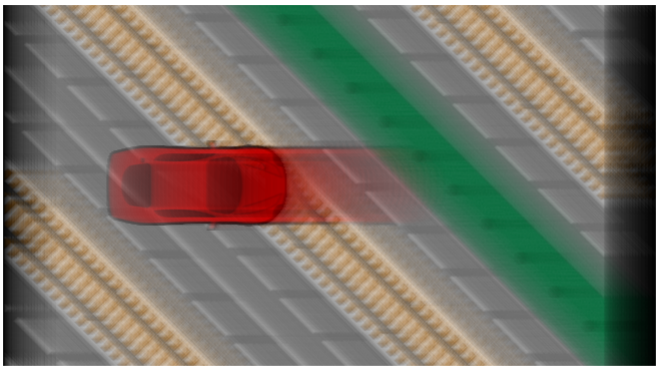

Figure 12: Q 3(d) Blurred image - moving camera, vel = 3 pixel/sec

The deblurred image of Figure 10 and the corresponding blur matrix have been plotted in Figures 14 and 15 respectively.

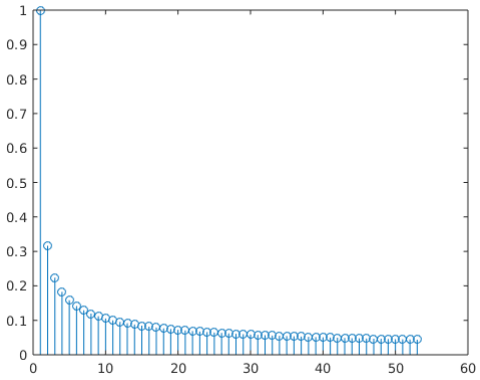

Figure 13: Q 3(e) PSF for motion invariant photography, vel = 1 pixel/sec

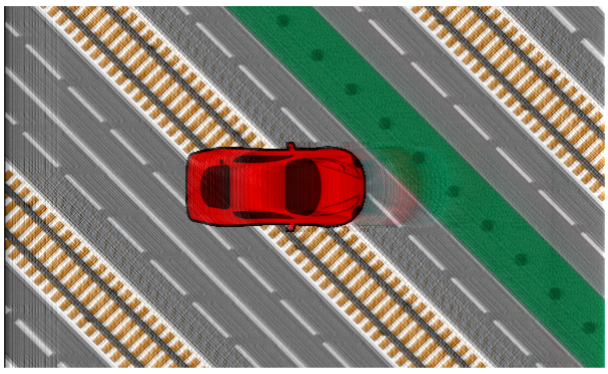

Figure 14: Q 3(f) Deblurred image - moving camera, vel = 1 pixel/sec

Figure 15: Q 3(f) Blur matrix - vel = 1 pixel/sec