ME354: Experimental Methods in Fluids Mechanics

Final Project: Bringing Life To Images
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David Manosalvas
Mehul Oswal

Contents

Chapter 1

Introduction

Removing noise from an original signal is a challenging problem receiving widespread attention from researchers. Digital images play an important role in experimental research and acquired images are often blurry and noisy and valuable information is concealed. Thus denoising and image sharpening becomes a necessary preprocessing feature to retrieve an estimate of the underlying data in analyzing images. This project aims to explore some of the widely used image enhancement algorithms to sharpen images and implement a robust metric to quantify the performance of filters under different blur sources in the image test cases where there is no reference clean image to compare with.

Experimental & Analysis setup:
The experimental and analysis setup for this project is as depicted in the following figure.

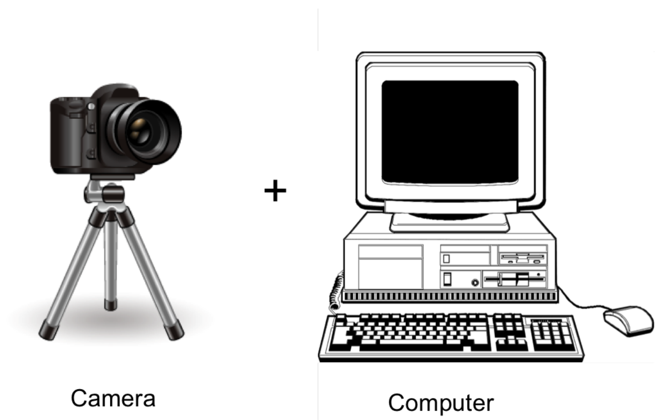


Figure 1.1: Experimental setup consists of a good camera and a computer system. The camera captures images under pre-defined settings like focal length, shutter speed, aperture size and luminance while computer is used to perform image enhancement & filter analysis.

Our analysis architecture is designed to meet the following objectives,

1. Retrieve sharper image using different filter kernels. Training images are blurred using simulated standard point spread functions (PSF) and gaussian white noise of specified variance. Filter kernel characteristics are then compared against the true training image kernel to benchmark filter performance for the chosen degradation PSF and noise variance.

2. Generally, the sharpness of an image is determined by human visual systems. This process can be automated and made simpler if there was a robust metric to evaluate the sharpness of a restored image and thus decide the optimum filter to restore a particular set of images. Three different sharpness metrics using different criteria have been implemented to automate the process of deblurring a no reference test image.

Chapter 2

Filter Performance

Image processing and degradation model:
Blurred images are modeled as the true image convolved with a point spread function and additive noise. The point spread function (PSF) that convolves the true image is generally a property associated with the optics that have contributed to the blur while noise can be due to poor illuminance, quantization errors and other sources. Mathematically, a blurry image can be represented as follows

$$v(m,n) = h(m,n) \star u(m,n) + \eta(m,n) \tag{2.1}$$

where, $u(m,n)$ is the true image, $h(m,n)$ is the PSF, $\eta(m,n)$ is the additive noise and $v(m,n)$ is the blurry image. Image sharpening involves calculating an estimate of the true image $\hat{u}(m,n)$ using filters.

$$\hat{u}(m,n) = g(m,n) \star v(m,n) \tag{2.2}$$

Filters calculate function $g(m,n)$ using some knowledge of the PSF that caused the blur and an estimate of the signal to noise ratio.

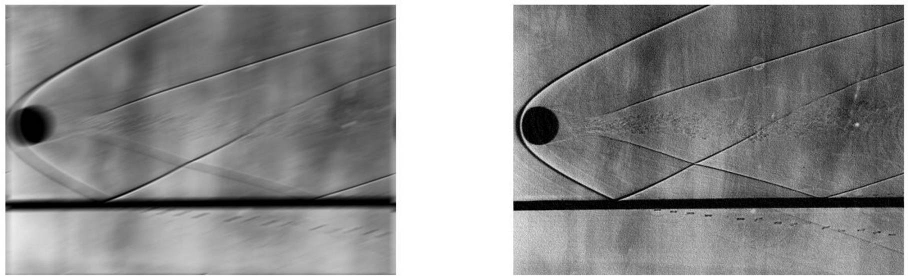
Filter kernels:
Choice of filter is very important in image restoration and retrieved image characteristics. This part of the project aims to study and compare different filters based on enhancement effectiveness and deblur characteristics under various blur sources. Before we present a comparison, let us briefly discuss the different filters studied for the purposes of this project. Various filters compared are,

1. Inverse and Pseudo filter
2. Wiener filter
3. Geometric mean filter
4. Constrained least squares filter

Mathematical formulation of these filters has been presented in the Appendix and will not be discussed here.

2.1 Train Image: Supersonic flow around a sphere

In this simulated motion blur, train image was procured from Van Dyke's Album of Fluid Motion and depicts the formation of shock around a sphere at flow Mach no. 3. This image was blurred using a motion PSF and had Gaussian white additive noise. The blurred image and recovered image are presented below. Filter deblur characteristics follow below.



(a) Blurry image (b) Wiener filter sharpened image

Figure 2.1: Image enhancement on the blurred image was performed using all the filters. For representative purposes only the sharpened image using Wiener filter has been shown here. Blur PSF used for this simulation represented blur effect due to motion. Variance of the additive noise is of $O(10^{-5}$.

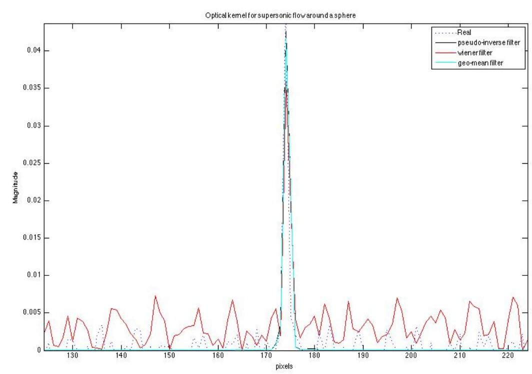
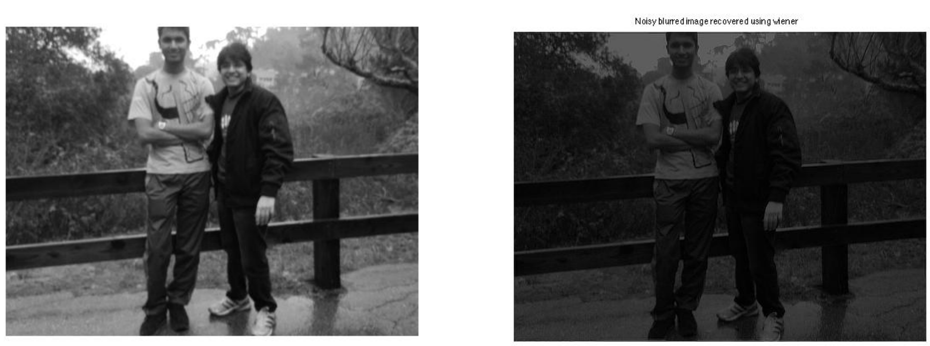


Figure 2.2: Kernel comparison for blur due to motion



(a) No reference blurry image (b) Wiener filter sharpened image

Figure 2.3: No reference image enhancement

Chapter 3

Sharpness Metric

Chapter 4

Project Summary

Chapter 5

Appendix

5.1 Additional Results

5.2 Matlab Codes

5.2.1 Master script

5.3 References

1.

2.