NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA, SURATHKAL

Image Processing and Computer vision

Homework Assignment 2

Image Rotation using Interpolation Methods

"Implementation of Histogram Matching, Spatial Filters (Gaussian, Median, Laplacian), and Advanced Denoising (Non-Local Means) with Analysis and Comparison"

https://github.com/VedaMahi321/MTech-SPML-Homework2-ImageProcessing_HW2_Filters.git

Submitted by:

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Abstract
This report presents the implementation and comparison of various spatial domain image processing techniques including histogram matching, Gaussian and Median filtering, Laplacian filtering, and an additional spatial filter (Non-local Means). Both manual implementations and MATLAB built-in function-based implementations were carried out. The outputs were compared in terms of visual results and quantitative measures such as Mean Square Error (MSE).

1. Introduction
Image processing techniques are widely used for enhancement, restoration, and analysis of digital images. In this assignment, multiple filtering and transformation methods were implemented to study their effects. The focus is on comparing manual implementations versus MATLAB built-in functions, analyzing the impact of noise removal and sharpening, and selecting optimal parameters.

2. Background Theory
2.1 Histogram Matching:
Histogram matching modifies the intensity distribution of an image to match another reference image.

2.2 Gaussian and Median Filtering:
Gaussian filter smooths an image using a weighted average with Gaussian distribution. Median filter removes salt-and-pepper noise by replacing each pixel with the neighborhood median.

2.3 Laplacian Filtering:
Laplacian operator highlights intensity transitions, useful for edge detection and sharpening.

2.4 Additional Filter:
Non-local Means filter denoises by averaging similar patches across the image, preserving edges better than Gaussian/Median.

3. Manual Calculations
The following describes the step-by-step manual computation methods:
- Histogram Matching: compute histograms, CDFs, and map intensities.
- Gaussian Filter: perform convolution with Gaussian kernel.
- Median Filter: compute local median in neighborhood.
- Laplacian Filter: apply Laplacian kernel and add back to original.

4. Methodology and MATLAB Code

Two approaches were used for each task:

1. Manual Implementation (custom code written from scratch).
2. Function Implementation (using MATLAB built-in functions).

Code Snippets:

- Histogram Matching: histeq(), custom CDF mapping.
- Gaussian Filter: imgaussfilt().
- Median Filter: medfilt2().
- Laplacian Filter: fspecial('laplacian'), imfilter().
- Non-local Means: imnlmfilt().

5. Results and Observations

Figures are included below for input and output images.

Figure 1: Input Image 1

Figure 2: Input Image 2

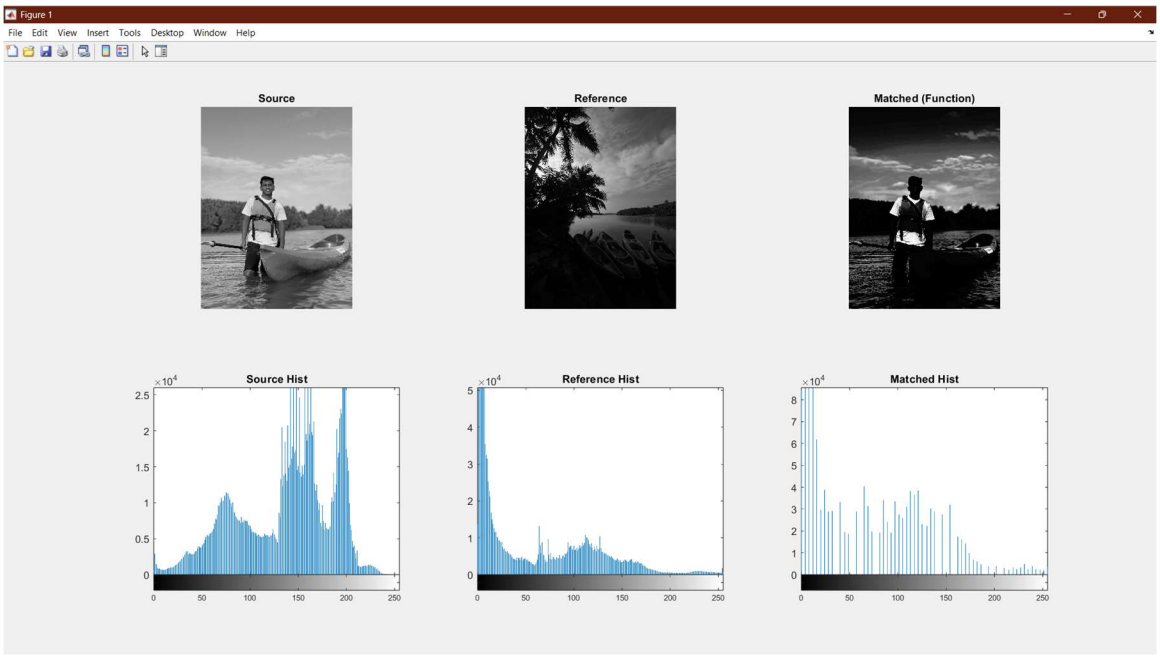

Figure 3: Histogram Matched Output (Function)

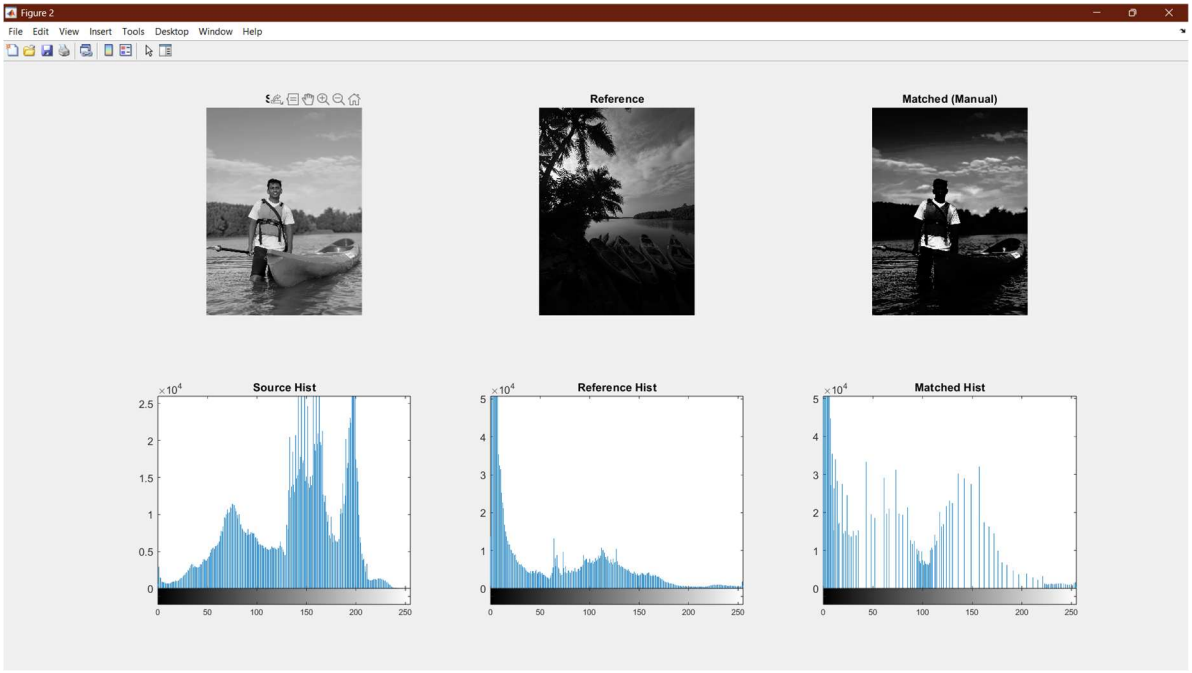

Figure 4: Histogram Comparison Graph (Manual)

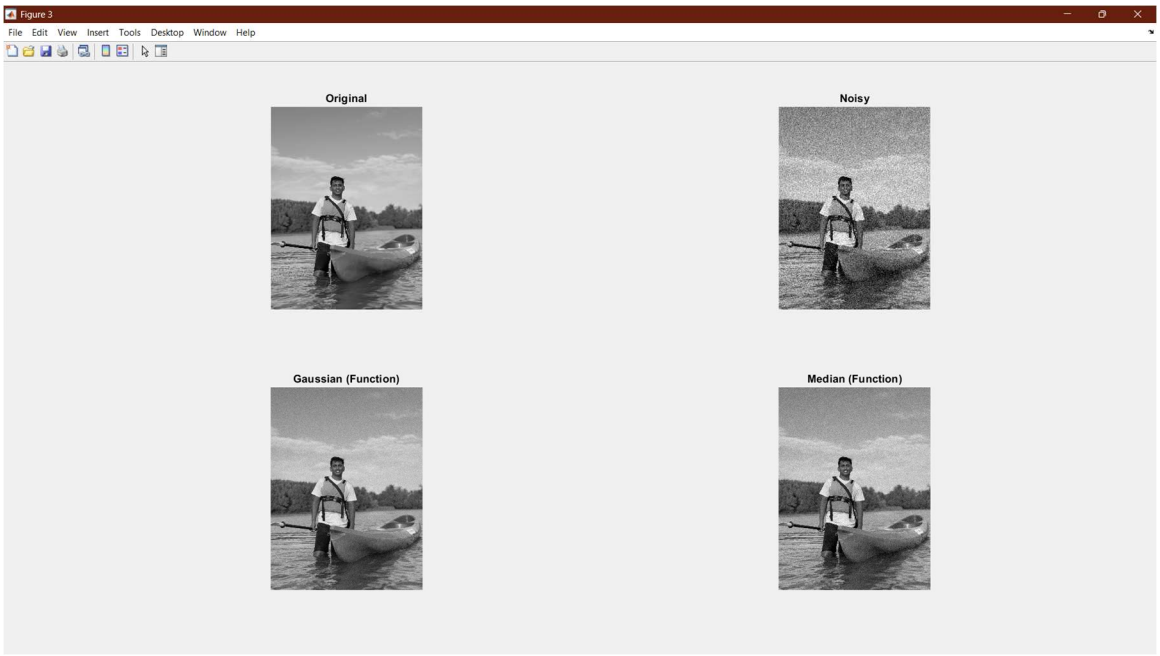

Figure 5: Gaussian And Median Filters Input Image (function)

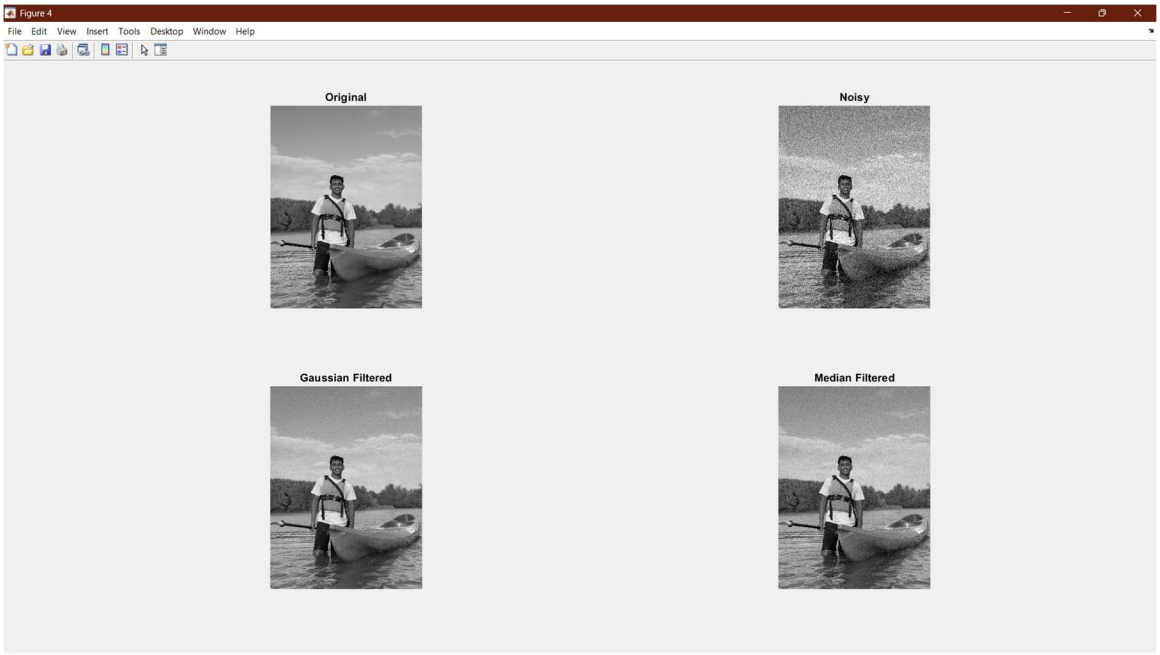

Figure 6: Gaussian And Median Filters Input Image (Manual)

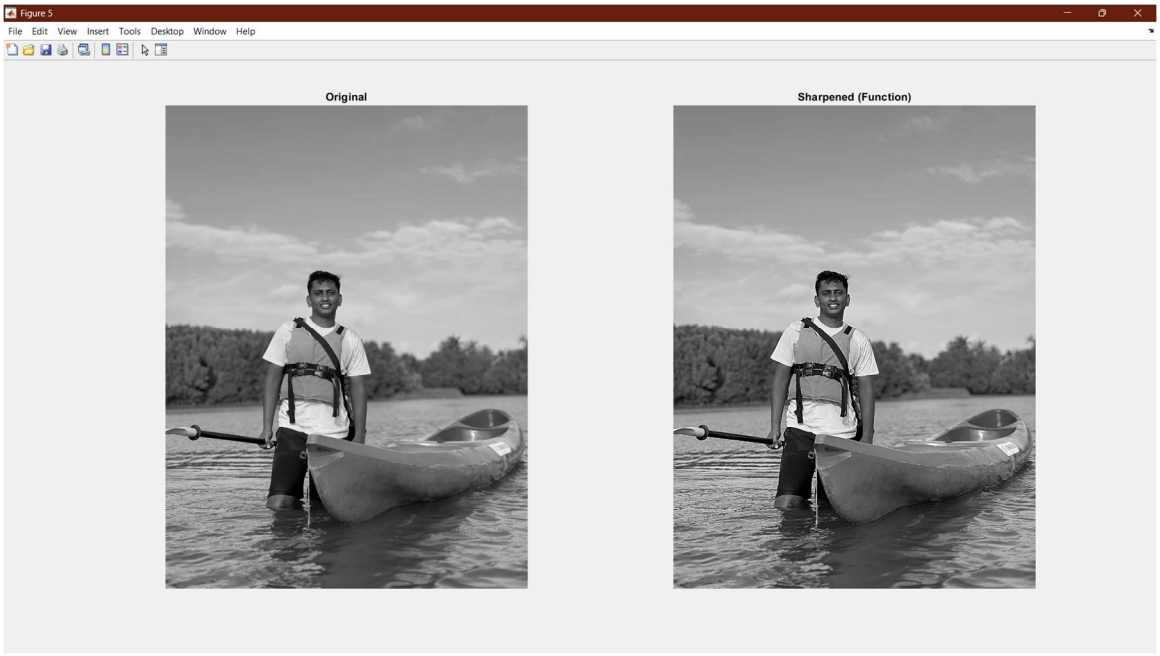

Figure 7: Laplacian filter (Function)

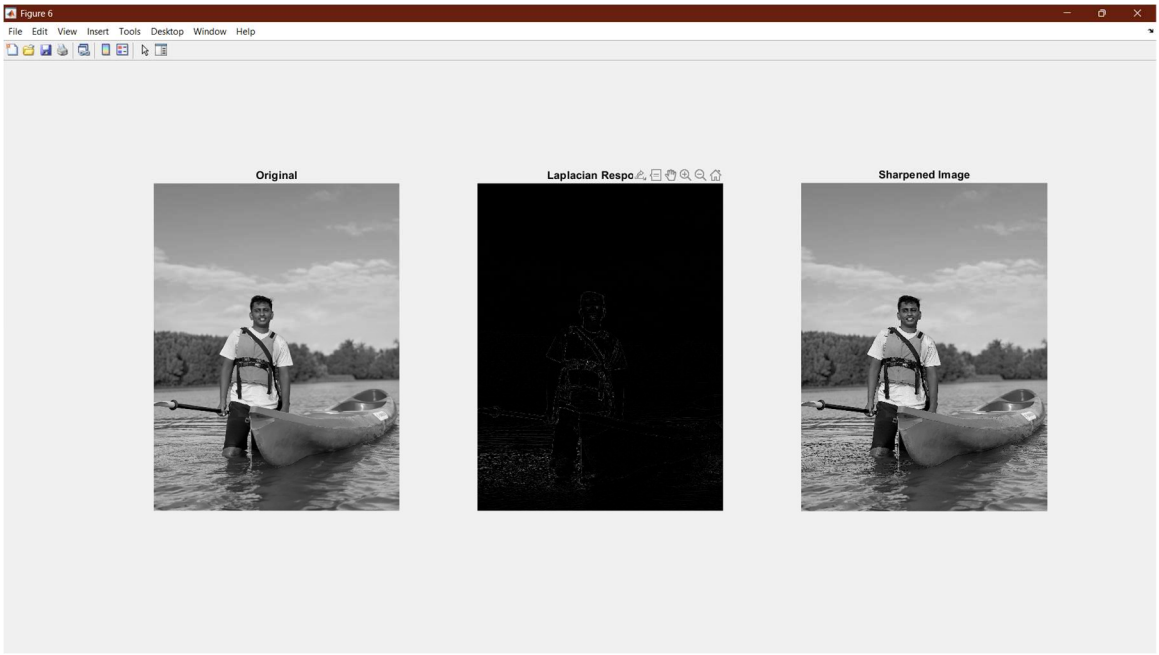

Figure 8: Laplacian filter (Manual)

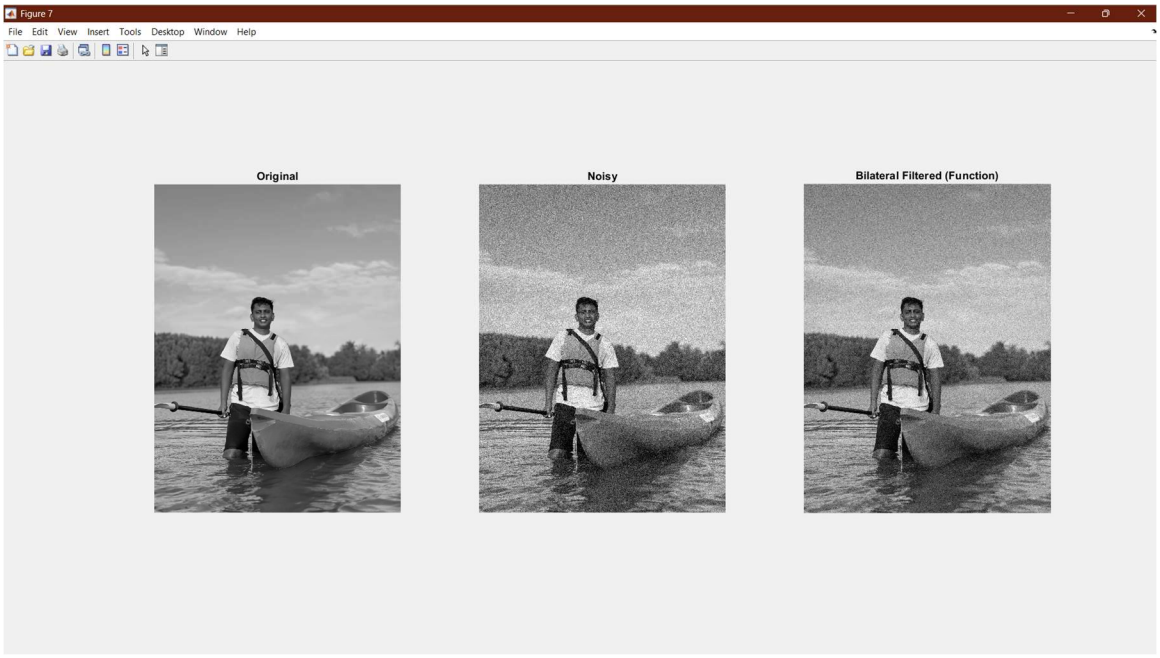

Figure 9: : Non-local Means Output (Function)

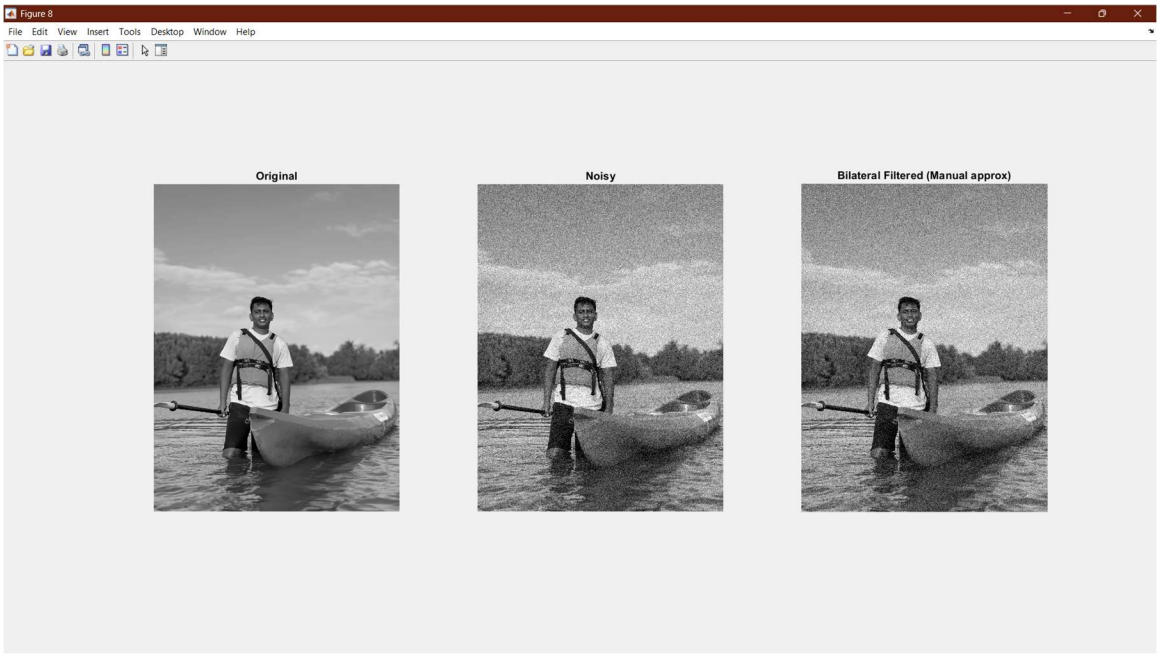

Figure 10: : Non-local Means Output (Manual)

6. Discussion

From the results:
- Histogram matching successfully adjusted brightness/contrast.
- Gaussian smoothing reduced noise but blurred edges.
- Median filtering was effective against salt & pepper noise.
- Laplacian sharpening enhanced edges but amplified noise.
- Non-local Means balanced noise reduction and edge preservation, achieving the best trade-off compared to Gaussian/Median/Laplacian.

7. Conclusion

The experiments demonstrate the strengths and weaknesses of different spatial filters. Gaussian and Median filters are effective for noise removal, Laplacian is suited for sharpening, while advanced filters like Non-local Means provide superior denoising with edge preservation. Manual implementations validated the theoretical concepts, and MATLAB built-in functions ensured efficient execution.

References

[1] Gonzalez and Woods, Digital Image Processing, 4th Edition.
[2] MATLAB Documentation.
[3] Class Notes and Slides.