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Efficient Performance Analysis of Image Enhancement Filtering Methods Using MATLAB

K Nagaiah

Abstract*: *Image enhancement is both an art and a science, playing a pivotal role in enhancing the quality of high-resolution images like those captured by digital cameras. Its primary goal is to unveil hidden details within an image and augment the contrast in images with low contrast. This method offers a plethora of options for elevating the visual appeal of images, making it an indispensable tool in numerous applications that face challenges such as noise reduction, degradation, and blurring. In this paper, we implemented frequency domain low pass filters like ideal low pass filter, Butterworth low pass filter and Gaussian low pass filters with execution time using MATLAB. The Butterworth low pass filter given better results than other two with less execution time.

Keywords*: *MSE, PSNR, Image Enhancement, Frequency Domain, Low Pass Filters, Image Processing, Execution Time.

I. INTRODUCTION

Image processing in medical domain has a critical role in diagnosis and decision making. For automation of medical diagnosis, images captured processed through various computations to give an earlier and faster diagnosis of medical issues. With the development of new technologies, the process of computing and analysis has widened from a constraint remote processing to worldwide monitoring. In the area of medical diagnosis, this is rapidly developing in many a fold due to the criticality in data processing and the demand of faster and accurate decision [1] [2] [3] [4] [22] [23] [26]. Image processing is a rapidly evolving field at the intersection of computer science, mathematics, and engineering. It involves the manipulation, analysis, and interpretation of digital images to extract meaningful information or enhance their visual quality. In today's digital age, image processing plays a crucial role in a wide range of applications, from medical imaging and remote sensing to entertainment and artificial intelligence [5]-[8]-[10]. image processing deals with the transformation of images through algorithms and mathematical operations. These images can be photographs, medical scans, satellite images, or even digital art. The primary goal is to improve the quality of an image, extract useful information, or make it more suitable for a specific application [9]-[7]. Basic Image Processing Operations: Image processing encompasses a broad spectrum of operations, including: Image Enhancement**:** This involves improving the visual quality of an image by adjusting parameters such as brightness, contrast, and sharpness. Techniques like histogram equalization and contrast stretching fall into this category.

Image Restoration: When images are degraded by factors like noise, blur, or compression, image restoration techniques are used to recover the original information. Deconvolution is an example of a restoration technique. Image Segmentation**:** Image segmentation divides an image into regions or objects of interest. It's crucial for object recognition, medical image analysis, and scene understanding.

Image Compression: Image files can be quite large, especially high-resolution images. Compression techniques like JPEG and PNG reduce the file size while maintaining acceptable image quality. Feature Extraction: This involves identifying and extracting meaningful features from an image, such as edges, corners, textures, or shapes. Feature extraction is fundamental for pattern recognition and machine learning applications[12].

Image Registration: Image registration aligns multiple images, often from different sources or times, to enable comparative analysis. It's used in medical image fusion, remote sensing, and creating panoramic images. Color Image Processing: Many images are in color, and processing techniques are adapted to work with color channels. Color correction, colorization, and color-based object detection are some applications [11].

Applications of Image Processing: Image processing is ubiquitous in various fields: Medical Imaging: In radiology, image processing helps in diagnosis through techniques like CT scans and MRI. It's also used in image-guided surgeries and pathology [13] [24].

Satellite and Remote Sensing**:** Analyzing satellite imagery aids in weather forecasting, land use planning, disaster management, and environmental monitoring [14] [15] [16]. Entertainment: Special effects in movies, video games, and virtual reality rely heavily on image processing techniques for realistic visuals. Security: Facial recognition, fingerprint analysis, and surveillance systems all use image processing for identification and tracking. Automotive Industry: Image processing is integral to autonomous vehicles for object detection, lane keeping, and traffic sign recognition. Artificial Intelligence: Convolutional Neural Networks (CNNs) have revolutionized image analysis, enabling machines to recognize objects, people, and even emotions in images. Astronomy: Image processing helps astronomers in analyzing astronomical images, detecting celestial objects, and studying the universe [17] [18] [25].

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***Correspondence Author(s)**

Dr. K Nagaiah*, FST, ECE, THE ICFAI University Raipur, Raipur, CG-India. E-mail: nagaiah.k@iuraipur.edu.in, ORCID ID: 0009-0003-9436-5886

II. IMAGE ENANCEMENT METHODS

To filter an image in the frequency domain: Compute *F(u,v)* the DFT of the image Multiply *F(u,v)* by a filter function *H(u,v)* Compute the inverse DFT of the result

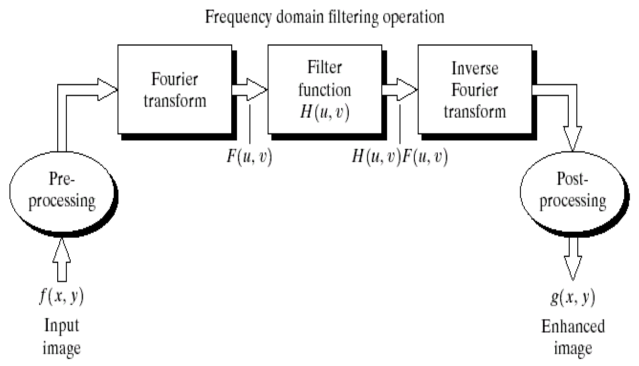

Fig. 1: Frequency Domain Block Diagram

A. Ideal Low Pass Filter

Smoothing Frequency Domain Filters Smoothing is achieved in the frequency domain by dropping out the high frequency components The basic model for filtering is:

G(u,v) = H(u,v)F(u,v)

where F(u,v) is the Fourier transform of the image being filtered and H(u,v) is the filter transform function Low pass filters – only pass the low frequencies, drop the high ones Simply cut off all high frequency components that are a specified distance D0 from the origin of the transform changing the distance changes the behaviour of the filter The transfer function for the ideal low pass filter can be given as

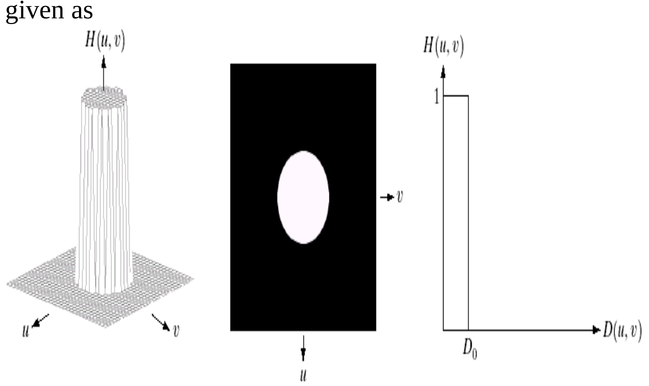

Fig. 2: Ideal low pass filter

$$H(u,v) = \begin{cases} 1 & \text{if } D(u,v) \le D_0 \\ 0 & \text{if } D(u,v) > D_0 \end{cases}$$

Where *D(u,v)* is given as:

$$D(u,v) = [(u - M/2)^2 + (v - N/2)^2]^{1/2}$$

B. Butterworth Low Pass Filter

The transfer function of a Butterworth low pass filter of order *n* with cutoff frequency at distance D_0 from the origin is defined as

$$H(u,v) = \frac{1}{1 + [D(u,v)/D_0]^{2n}}$$

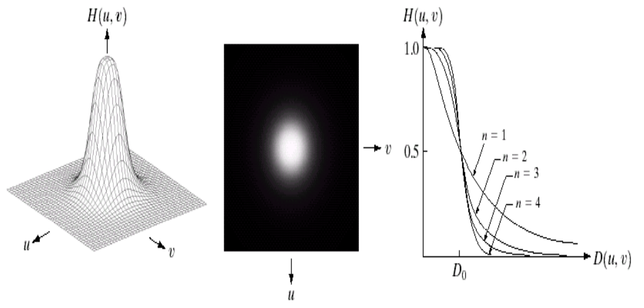

Fig. 3: Butterworth Low Pass Filter

C. Gaussian Low pass Filters

The transfer function of a Gaussian low pass filter is defined as:

$$H(u,v) = e^{-D^2(u,v)/2D_0^2}$$

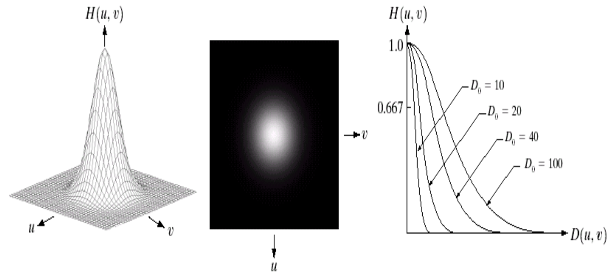

Fig. 4: Gaussian Low Pass Filter

III. PERFORMANCE ANALYSIS

Find out the efficient low pass filter in frequency domain three filters. Namely ideal low pass filter, butter worth low pass filter and Gaussian low pass filter. The metrics we are used to identify the image quality by PSNR and MSE peak signal to noise ration and mean square error [19] [20] [21].

A. Implementation

In this model of implementation.

Step 1:- We have used 6 images for testing namely 1 flower, 2 Gaurav, 3 Cameraman, 4 Banana, 5 Tamoto, 6 Nagaiah.

Step 2:- Converted colour image into grey image.

Step 3:- Applied to all three filters on that image.

Step 4:- Calculated PSNR value of both original image and the output image.

Step 5:- Calculated MSE value of both original image and the output image.

Step 6:- Compared all the images with the PSNR and MSE values.

Step 7:- the Better results given by Butterworth filter based on the PSNR and MSE values.

The following images we have tested and other 25 different images also tested. Sample here we have shown these 6 images. PSNR defines a ratio of signal strength over noise distortion strength. This is given as

$$PSNR(dB) = 10log_{10}\left(\frac{I_{peak}^2}{MSE}\right)$$

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Where I_{peak} is the peak value of the original sample. MSE reflect the average error in the filtered result as compared to the original image. This is defined by,

$$MSE = \frac{1}{MXN} \sum (f - \hat{f})^2$$

Here, f is the actual test sample, and $\hat{f}$ is the filtered output.

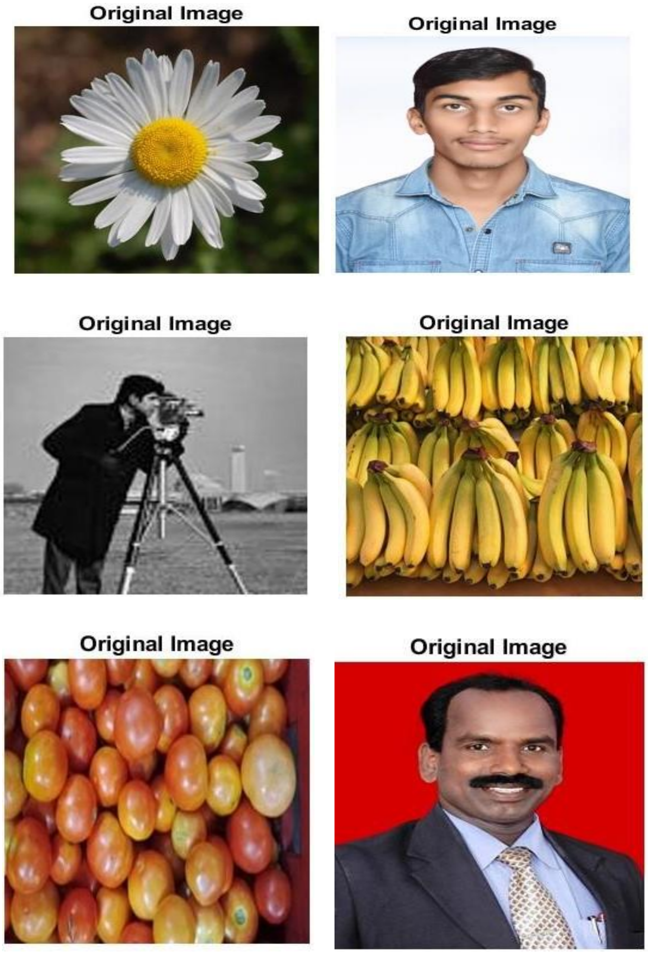

Fig. 5: Original Image and Filtered Images

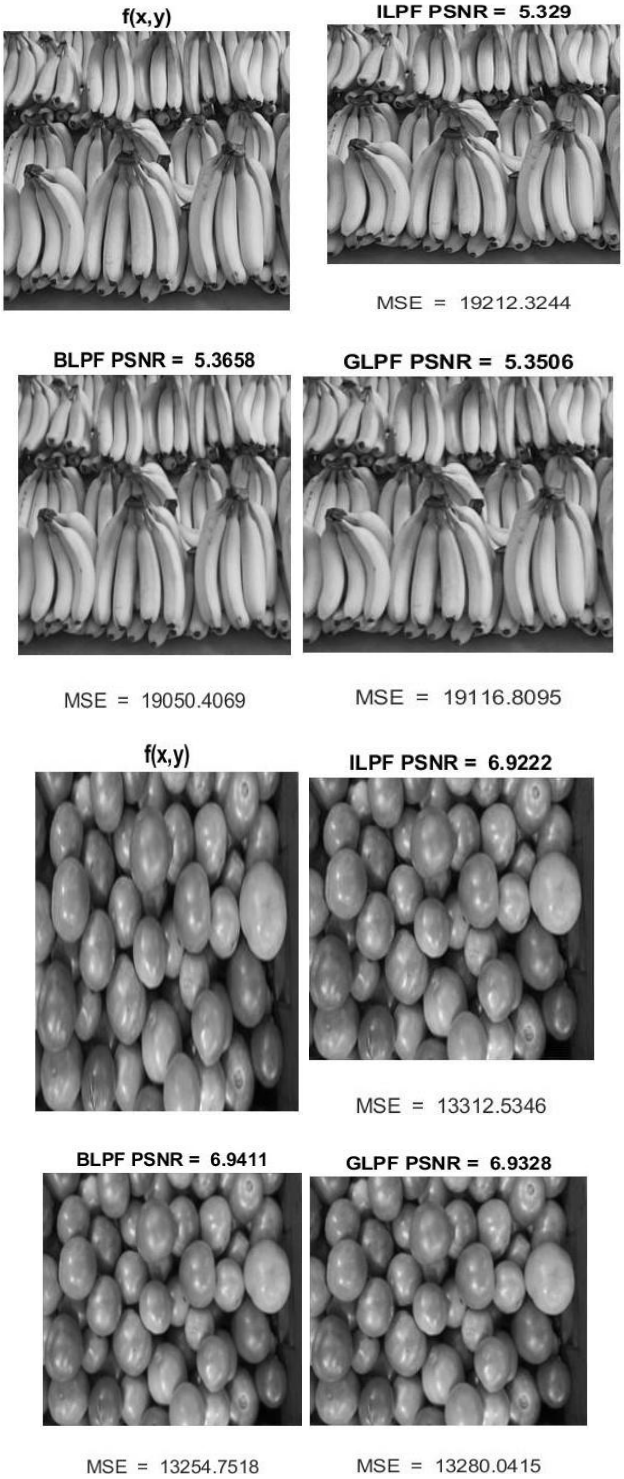

Fig. 6: All Output Images with PSNR and MSE

Table 1: Output Filtered Images with all Three Filter Outputs with PSNR Values

S NO	IMAGES	GLPF PSNR	BLPF PSNR	ILPF PSNR
1	flower	7.0522	7.0633	7.0368
2	Gaurav	2.0676	2.0706	2.0635
3	Cameraman	5.7388	5.7475	5.7273
4	Banana	5.3506	5.3658	5.329
5	Tamoto	6.9328	6.9411	6.9222
6	Nagaiah	8.3228	8.3347	8.3045

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Table 2: Output Filtered Images with all Three Filter Outputs with MSE Values

		GLPF	BLPF	ILPF
S NO	IMAGES	MSE	MSE	MSE
1	flower	12919.777	**12886.95**	12965.79
2	Gaurav	40712.008	**40684.05**	40750.065
3	Cameraman	17482.248	**17447.29**	17528.582
4	Banana	19116.81	**19050.47**	19212.324
5	Tamoto	13280.041	**13254.75**	13312.535
6	Nagaiah	9642.8007	**9616.378**	9683.356

Table 3: Comparision of Filters Three Filter with Execution Time

		GLPF	BLPF	ILPF
S No	Images	Execution time seconds	Execution time seconds	Execution time seconds
1	flower	0.0015	0.0032	0.0009
2	Gaurav	0.0008	0.0009	0.0010
3	Cameraman	0.0012	0.0013	0.0017
4	Banana	0.0008	0.0007	0.0008
5	Tamoto	0.0008	0.0008	0.0008
6	Nagaiah	0.0006	0.0007	0.0007

Importance of filters in Image analysis and medical application is very important. Frequency domain filters low pass filters are effective in high frequency noise and interference. If images are noise free then segmentation feature extraction feature selection and classification process is very effective. Ideal low pass filters used in simulation and modeling in research work. Butterworth low pass filters used audio equalizers. Gaussian low pass filters used in image smoothing, noise reduction in computer vision models. We can use in signal de-noising audio and sensor data.

IV. RESULTS AND DISCUSSION

We tested all three different filters with matrix PSR and MSE. Filtering process we got Butterworth low pass filter Given better results compared to other filter. We have tested with execution time for all three filters also.

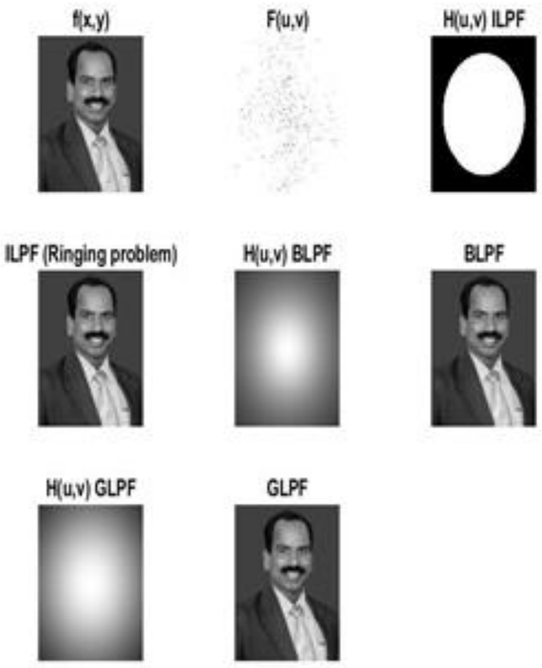

Fig. 7: All Fitered Outputs in Nagaiah image

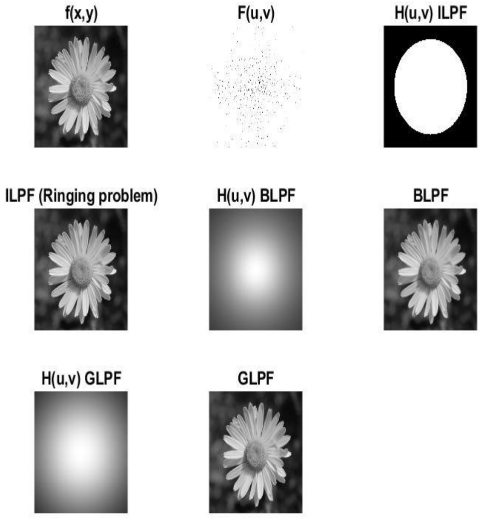

Fig. 8: All Fitered Outputs of Flower Image

V. CONCLUSSION

The above work we found that the butter worth filter is giving better results compared to ideal low pass and Gaussian low pass filters. The PSNR value is more image quality is good and MSE value low means also quality of the image is nice. These two parameters are inversely proportional. This will be very useful in image analysis. Especially in medical imaging. Execution time is also very important parameter in developing system. Image quality is good means it has the impact on further processing like next image segmentation, feature extraction, classification and final detection etc. Future scope further better filter design to be done to increase PSNR values for the better quality image processing.

DECALARION STATEMENT

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Authors Contributions	I am the sole author only.

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AUTHOR PROFILE

Dr. K Nagaiah, completed B. Tech in ECE, M. Tech in Systems and Signal Processing and Ph.D in Image Processing from JNTUH Kukatpally Hyderabad. He is having total 22 years of Experience 17 years in teaching 5 years in process industry. Present he is working as an Assistant professor in FST department ICFAI University Raipur CG INDIA..His research interest in Artificial Intelligence Machine Learning Deep Learning Medical Imaging and IoT.