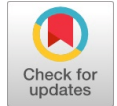# Image Quality and Performance Analysis Using Frequency Domain Techniques

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 high pass filters like ideal high pass filter, Butterworth high pass filter and Gaussian high pass filters with execution time using MATLAB. 60 cancer images also tested. The Gaussian high 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 [1]. For automation of medical diagnosis, images captured processed through various computations to give an earlier and faster diagnosis of medical issues [2]. With the development of new technologies, the process of computing and analysis has widened from a constraint remote processing to worldwide monitoring [3]. 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 [4].

Image processing is a rapidly evolving field at the intersection of computer science, mathematics, and engineering [5]. It involves the manipulation, analysis [6], and interpretation of digital images to extract meaningful information or enhance their visual quality [8]. 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 [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 [9]. The primary goal is to improve the quality of an image, extract useful information, or make it more suitable for a specific application [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].

Satellite and Remote Sensing**:** Analyzing satellite imagery aids in weather forecasting, land use planning [14], disaster management, and environmental monitoring [15]. Entertainment: Special effects in movies, video games, and virtual reality rely heavily on image processing techniques for realistic visuals [16].

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 [17].

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Astronomy: Image processing helps astronomers in analyzing astronomical images, detecting celestial objects, and studying the universe [18].
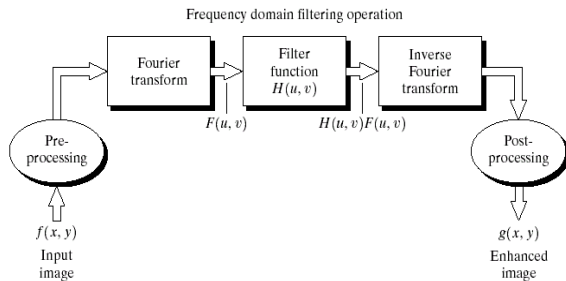
II. IMAGE ENANCEMENT METHODS

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]

Sharpening in the Frequency Domain
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
Edges and fine detail in images are associated with high frequency components
High pass filters – only pass the high frequencies, drop the low ones
High pass frequencies are precisely the reverse of low pass filters, so:
$$H_{hp}(u, v) = 1 – H_{lp}(u, v)$$

A. Approach

Step 1: Input – Read an image
Step 2: Saving the size of the input image in pixels
Step 3: Get the Fourier Transform of the input image
Step 4: Assign the order and cut-off frequency
Step 5: Designing filter: Butterworth High Pass Filter
Step 6: Convolution between the Fourier Transformed input image and the filtering mask
Step 7: Take Inverse Fourier Transform of the convoluted image
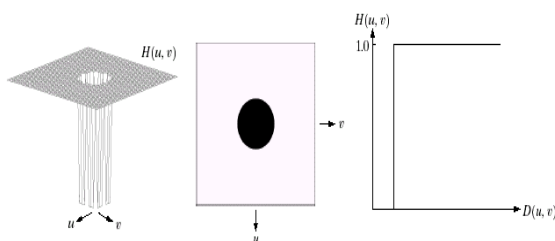Step 8: Display the resultant image as output

III. IMPLEMENTATION

A. Ideal High Pass Filters

The ideal high pass filter is given as:
$$H(u,v) = \begin{cases} 0 & \text{if } D(u,v) \leq D_0 \\ 1 & \text{if } D(u,v) > D_0 \end{cases}$$
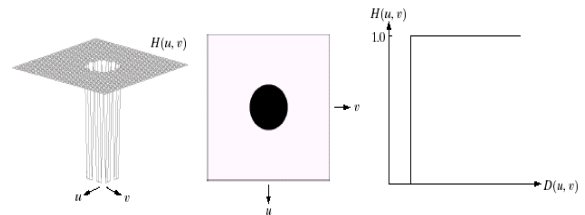where D_0 is the cut off distance as before

B. Butterworth High Pass Filters

The Butterworth high pass filter is given as:
$$H(u,v) = \frac{1}{1 + [D_0/D(u,v)]^{2n}}$$
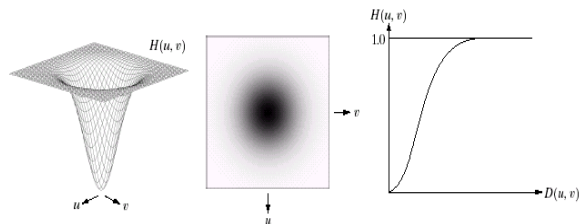where n is the order and D_0 is the cut off distance as before

C. Gaussian High Pass Filters

The Gaussian high pass filter is given as:
$$H(u,v) = 1 - e^{-D^2(u,v)/2D_0{}^2}$$
where D_0 is the cut off distance as before

Performance Analysis

Find out the efficient high pass [19] filter in frequency domain three filters [20]. Namely ideal high pass filter [21], butter worth high pass filter and Gaussian high pass filter [22]. The metrics we are used to identify the image [23] quality by execution time [24], PSNR and MSE peak signal to noise ration and mean square error [25]. Execution time is very important in design of any image analysis system the parameters like area, execution time, power consumption and efficient algorithm [26].

```
% Calculate and display the execution time
tic;
g1=(ifft2(G1));
execution_time = toc;
fprintf('IDHPF Execution time: %.4f seconds\n', execution_time);
tic;
g2=(ifft2(G2));
execution_time = toc;
fprintf('BWHPF Execution time: %.4f seconds\n', execution_time);
tic;
g3=(ifft2(G3));
execution_time = toc;
fprintf('GHPF Execution time: %.4f seconds\n', execution_time);
```

D. 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.

Step 8:- Execution time for all three filters.

The following images we have tested 60 cancer images also and other 25 different images also tested. Sample here we have shown these 6 images and one cancer 002 image outputs.

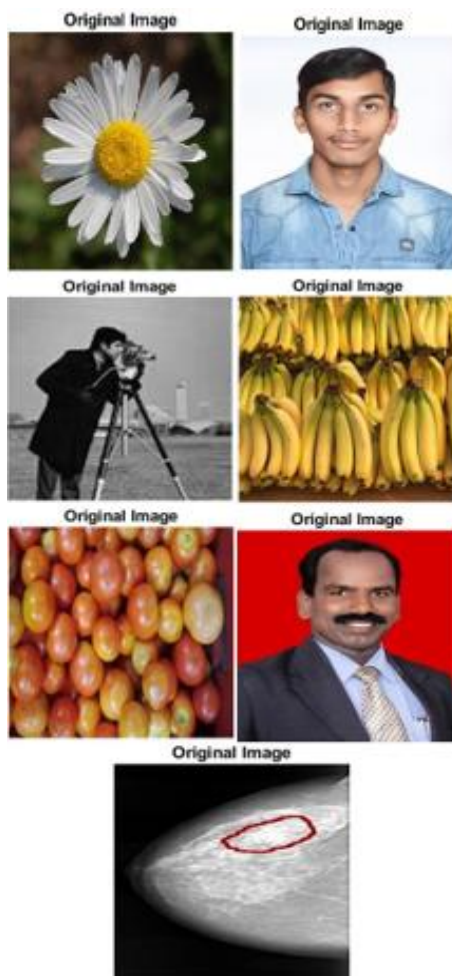PSNR defines a ratio of signal strength over noise distortion strength. This is given as

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

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,

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

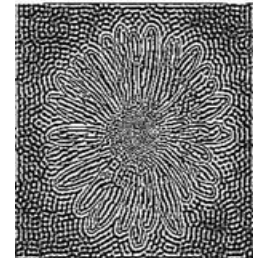Here, f is the actual test sample, and $\hat{f}$ is the filtered output.
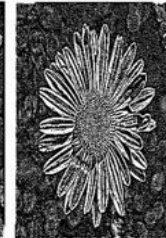

Original Images
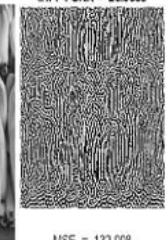Flower,banana and Tamato imagse outputs of all three filters

BHPF PSNR = 33.9548 GHPF PSNR = 35.6031

MSE = 26.3636 MSE = 18.0371
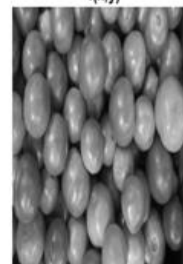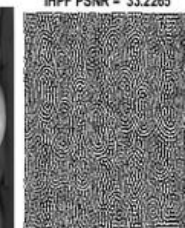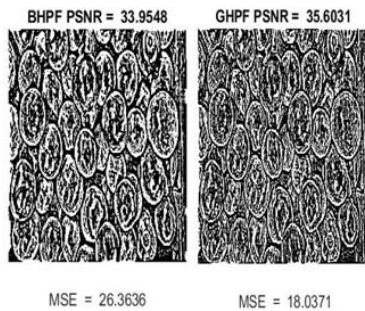
Table-I: Output Filtered Images with all Three Filter Outputs with MSE Values

		IHPF	BHPF	GHPF
		PSNR	PSNR	PSNR
S NO	IMAGES	PSNR	PSNR	PSNR
1	flower	29.199	30.7606	31.6434
2	Gaurav	30.25	31.7332	32.613
3	Cameraman	32.2157	32.3385	34.6031
4	Banana	26.9588	28.3032	29.6131
5	Tamoto	32.2265	33.9548	35.6031
6	Nagaiah	28.7872	31.0066	31.653

Table-II: Images with all Three Filter Outputs with PSNR Values

		IHPF	BHPF	GHPF
		MSE	MSE	MSE
S NO	IMAGES	MSE	MSE	MSE
1	flower	78.8098	55.0071	44.8888
2	Gaurav	61.7329	43.97	35.9069
3	Cameraman	39.3377	38.2499	22.7075
4	Banana	132.008	96.8625	71.6425
5	Tamoto	31.1764	26.3636	18.0371
6	Nagaiah	86.6499	51.7903	44.7903

Table-III: Execution Time Images with all Three Filters

|		IHPF	BHPF	GHPF
S NO	IMAGES	Execution time seconds	Execution time seconds	Execution time seconds
1	flower	0.0012	0.0026	0.0009
2	Gaurav	0.0007	0.0010	0.0016
3	Cameraman	0.0011	0.0014	0.0012
4	Banana	0.0011	0.0013	0.0019
5	Tamoto	0.0008	0.0008	0.0009
6	Nagaiah	0.0010	0.0010	0.0009

Table-IV: Advantages and Applications of Filters High Pass Filters

Name	Advantages	Applications
Ideal HPF	It removes low-frequency components from an image, preserves high-frequency components.	Image sharpening, Fine details and highlight the edges, Edge detection, segmentation.
Butterworth HPF	It removes low-frequency components from an image, preserves high-frequency components.	Image sharpening, Fine details and highlight the edges, feature extraction and classification.
Guassian HPF	It removes low-frequency components from an image, preserves high-frequency components.	Image sharpening, Fine details and highlight the edges, Medical image prediction and analysis Application

IV. RESULTS AND DISCUSSION

Three different images also implemented in one page With all filters outputs. Cancer images output.

MSE = 37.809

GHPF PSNR = 33.5861 IHPF PSNR = 31.1515

MSE = 28.6995 MSE = 50.2726
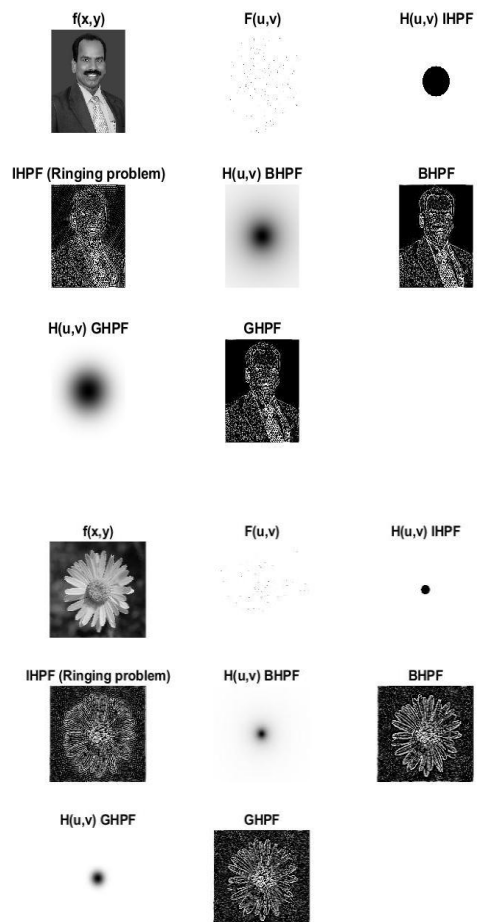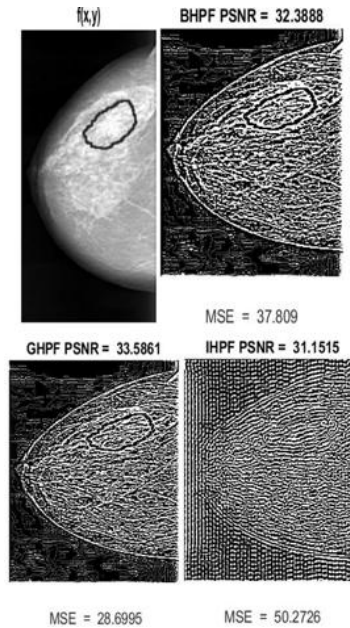
The above three images one Cancer two Nagaiah and three flower images all filtered outputs.

Cancer image output execution time.
IDHPF Execution time: 0.0013 seconds
BWHPF Execution time: 0.0015 seconds
GHPF Execution time: 0.0014 seconds.

4

V. CONCLUSSION

The above work we found that the Gaussian filter is giving better results compared to ideal high pass and Butterworth high 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. We tasted cancer images 60 also. Sample outputs shown in figure. 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 and execution time for the better quality image processing analysis

DECLARATION STATEMENT

I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been sponsored or funded by any organization or agency. The independence of this research is a crucial factor in affirming its impartiality, as it has been conducted without any external sway.
- **Ethical Approval and Consent to Participate:** The data provided in this article is exempt from the requirement for ethical approval or participant consent.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors Contributions:** The authorship of this article is contributed solely.

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