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Frequency Domain Enhancement Filters: A Survey

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Abstract: Fingerprints are majorly used to extract the physiological characteristics of human for identification and authentication purpose. Since the fingerprint became essential factor in day today life, features of fingerprints can be tainted which includes noises. Noise is a distortion and unwanted element of an image. It affects the accuracy of the biometric system in identifying and authenticating a person. Noises are of different types such as Gaussian, Salt and Pepper, Speckle noise etc. They are generated either due to internal or external factors. Noises are removed by applying various types of filtering techniques. Usually images are filtered based on the noises. Filters are applied in either spatial or frequency domain of the image. Frequency domain transformations are functions in Fourier transformations of image. This survey aims to identify the best suitable frequency domain filtering technique which is applied to enhance fingerprint quality.

***Keywords*:** Frequency – domain, FFT, fingerprints, quality, filters.

I. INTRODUCTION

Fingerprints are considered as major biometric metrics in differentiating the persons from one another. Arcs, whorl and loop are three major fingerprint patterns. Unlike other images fingerprints are affected by the noises often which reduces the quality of the image. Sometimes image is caused as unrecognizable due to occurrence of noise. Filters are used to remove the noises in images. Image enhancement techniques are broadly categorized into two ways like spatial domain frequency domain (see fig. 1). Spatial domain techniques are directly deal with the image pixels [10]. In frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier Transform of the image is computed first. All the enhancement operations are performed on the Fourier-transformed image and then the Inverse Fourier transformation is performed to get the resultant image [11].

Filters are created based two methods like linear or non-linear as in fig. 2. Output of the linear methods is linear combinations of the pixels in original image [12]. Nonlinear filters results are not corresponding to the linear function of the input image.

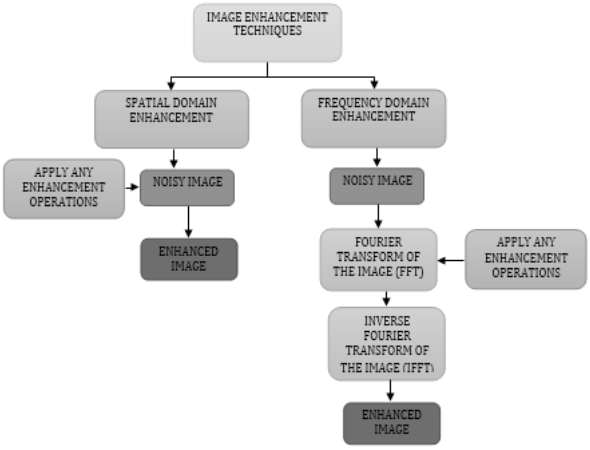

Figure 1: Image Enhancement Techniques

Filters are grouped into four types based on their performance as given in Fig. 3. They are:

a) Low-pass filters: preserve low frequencies (smoothing) in the image

b) High-pass filters: preserve the high frequencies (sharpening) in the input image

c) Band-pass filter: conserve the frequencies in certain range and rejects the frequencies from outside the range

d) Band –reject filters: remove the frequencies within the particular band.

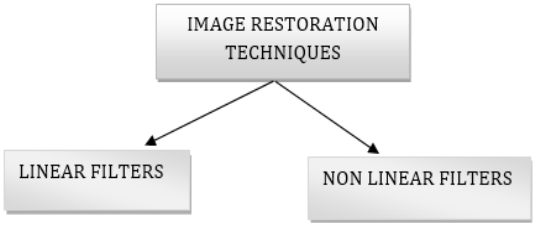

Figure 2: Image Restoration Techniques

Through the survey low-pass filters and high-pass filter are found to be frequently used filters than band-pass filters and band-reject filters in image processing. In each of this category, Ideal filter, Butterworth filter and Gaussian filters are repeatedly used filters to reduce noise in fingerprint image.

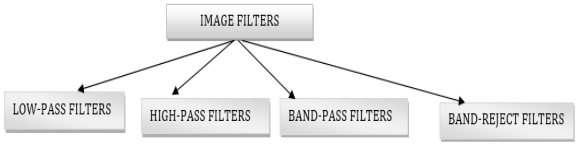

Figure.3.Major types of image filters

II. LITERATURE SURVEY

Amit Shukla et al. (2014) examined the performance of frequency domain filters. Quality of the images is assessed with quality analysis metrics like PSNR and MSE. This study considered Low pass, High pass and High boost filters of Gaussian and Butterworth filters for examination [1].

Khorsheed et al. (2014) reviewed low-pass and high-pass filters. The work is implemented based on convolution kernel. Author used frequency domain data for smoothing and sharpening images [2].

C Chang et al. (2008) focused on stripped noise on images. The noise reduction methods of this stripped image are mainly studied. It is concluded that Gray Value Substitution and Wavelet Transformation are satisfactory in stripped noise reduction [3].

Shaikh et al.(2016) implemented low-pass and high-pass filters in same cut off frequency. Through the results ideal filter gives better performance in both the smoothing and sharpening images. High-order Butterworth filter and Gaussian filters are also applied to remove the noise[4].

Susan John Jiju (2013) reviewed different frequency domain filtering and highlights the working of each digital filters image processing in remote sensing. Ideal filter, Butterworth filter and Gaussian filters are compared with the experimented results [5].

Bhopal et.al (2011) discussed about frequency domain algorithm and proposed a technique to better noise removal in finger print images. New method produces 80-90 % of quality finger prints [6].

Ezhilmaran et al.(2014) reviewed the spatial domain, frequency domain and fuzzy methods in image processing. Particularly, Gabor filter enhancement techniques are used in so many researches, because of time consuming and parameter selection such as ridge centre frequency, radial bandwidth and central orientation [7].

Sivaranjani (2015) compared three variations of gabor filter for finger print images based on frequency domain enhancement. And concluded modified gabor filter produces better results than other filters. [8]

Kanalagalakshmi et al. (2012) have proposed a frequency domain enhancement algorithm based on Log-Gabor and FFT. Through this techniques number of terminations is increased and number of bifurcations are decreased in finger print images due to filter performance [9].

III. COMPARISON OF METHODS

Filters are optimally involved in removing the unwanted noise factors in images. Choosing the right filter in removing the noise is a challenging thing frequency domain filtering techniques. Table 1.[5] shows the major kinds of filters used in frequency domain filtering. H(u,v) denotes filter function, *D(u,v)* is the distance between center of the frequency rectangle and a point *(u,v)* in the frequency domain image calculated by eqn. 1.

$$D(u,v) = \sqrt{\left(u - \frac{p}{2}\right)^2 + \left(v - \frac{Q}{2}\right)^2} \quad (1)$$

D_0 represents the cutoff frequency in image filter represented by the pixel distance from center pixel of the image [4].

Ideal filters give the ideal response to the image filtering. Butterworth filter is a popular filter due to its varying performance depends on its order. An Increased ordered Butterworth filter tends to performance towards ideal filter. Gaussian filters are the generalized filter for digital images.

Table 1. Different types of frequency domain filters

Properties	Ideal filter	Gaussian filter	Butterworth filter
Low-pass	$H(u,v)=\begin{cases}1 & \text{if } D(u,v)\le D_0\\ 0 & \text{if } D(u,v)>D_0\end{cases}$	$H(u,v)=e^{-D^2(u,v)/2D_0^2}$	$H(u,v)=\frac{1}{1+[D(u,v)/D_0]^{2n}}$
High-pass	$H(u,v)=\begin{cases}0 & \text{if } D(u,v)\le D_0\\ 1 & \text{if } D(u,v)>D_0\end{cases}$	$H(u,v)=1-e^{-D^2(u,v)/2D_0^2}$	$H(u,v)=\frac{1}{1+[D_0/D(u,v)]^{2n}}$

Frequency domain techniques work upon the cut off frequency. Choosing frequency domain is to gain accurate details of the image. Finger prints are mostly needed to be preserved the minutiae details. Unlike other types of images finger print enhancement techniques are performed based on its frequency domain (by using Fourier transformations). Table 2 [5][4] gives an idea about choosing the right filter for various types of noises in fingerprint images.

Table 2 is intended based on the survey results. Green arrow (▲) refers better performance of the filter to corresponding noise. Red arrows refer (▼) poor performance of the filters. Apart from this, ideal filter gives generalized performance in both the high pass and low pass for all types of noises.

Table 2. Comparison of filters

Filter	Speckle noise	Salt and pepper noise	Gaussian noise	Poisson noise
Butterworth low pass	▼	▲	▼	▼
Butterworth high pass	▼	▲	▲	▲
Gaussian low pass	▼	▲	▲	▲
Gaussian high pass	▲	▼	▲	▼

IV. CONCLUSION

The image enhancement in frequency domain depends on other factors like order of the filter, cut off frequency, noise type, magnitude and phase values, degree of convolution, etc. in addition to filters. Through this survey, it is observed that the Gaussian low pass filter and Butterworth high pass filter give the constants performance on removing the noise. Ideal filters can be chosen based on the image type and noise. In addition to the above, it is also surveyed that reviewed filters are also used as base to develop new filtering techniques. For example Gaussian function is used in Gabor filter to remove the noise in fingerprint images. Likewise some other filters like Isotropic filters, Anistrophic filters and Wiener filter, etc. also frequently used filters in fingerprint enhancement techniques.

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Dr. K. Kanagalakshmi is working as an Associate Professor and Head in Department of Computer Applications in Nehru Arts and Science College, Coimbatore, Tamilnadu. She is having 17 years of teaching experience. She has published more than 15 research papers in International Journals and presented more than 65 papers in International, National and State level Seminars, Conferences together. Her areas of interest include Biometric, Pattern Recognition, Digital Image Processing, Security etc. She has produced more than 5 M.Phil. Scholars and she is guiding 8 Ph.D. Scholars. She has published 4 books. She is an Associate member of CSI.

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