Journal of Information Technology Management

Print ISSN: 2008-5893
Online ISSN: 2423-5059

Technical Assessment of Various Image Enhancement Techniques using Finger Vein for personal Authentication

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Abstract

The most important aspects of image processing are image enhancement. The visual form of an image can be enhanced by using image enhancement techniques for better human interpretation. In this research paper we discuss an outline and analysis of commonly used image enhancement techniques using finger vein image or personal authentication. Also, experiments are carried out to compare performance of various types of filters for removal of noise from the noisy images through evaluation performance parameter such as mean square error (MSE), peak signal to noise ratio (PSNR) values and structural similarity (SSIM). It was found that application of max filter technique ensures an improved quality of the finger vein image. The mean filter is most advanced in de-noising the images. Mean filter is most efficient in eliminating the salt and pepper noise. From the experiments performed on finger vein image using SDUMLA-HMT database, it is proven that Weiner filters are outstanding for elimination of Gaussian Speckle and Poisson noises and thus, Weiner filter is found to be most appropriate and well-suited for eliminating nearly all types of noise.

Keywords: Finger Vein; Filters; Histogram Equalization; Image Enhancement; MSE; Noise; PSNR; SSIM.

DOI: https://doi.org/ 10.22059/jitm.2022.86666 Manuscript Type: Research Paper University of Tehran, Faculty of Management
Received: December 12, 2020 Accepted: March 10, 2021

Introduction

In the era of Internet of things (IoT) with billions of devices being connected together, the conventional approach of personal authentication is proving to be an inadequate and ineffective. Personal identification/authentication in cyber security is a major issue of concern. Even the advanced authentication technologies proposed to overcome these issues like biometric, finger print, iris, palm, face recognition and voice matching are susceptible to forgery as they are exposed to too many things outside human body. Thus, many researchers have focused on the finger vein technology as it obeys biometric characteristics such as uniqueness, universality, acceptability, permanence, small image capturing device, easy to use, faster computational speed (Lu, Y., et al., 2017). Finger vein pattern is difficult to spoof because it lies inside the skin and can only authenticate the finger of a living person. However, it is easily affected by quality of image capturing sensors, environmental condition such as humidity, uneven illumination, temperature, finger pressure and variation in finger pose. These may lead to inaccurate enrollment of region of interest (ROI) which causes degradation in the performance of identification system. All these issues can be easily handled by extracting the features of finger vein using image enhancement techniques.

Digital image processing is a processing of images which are digital in nature. An image enhancement technique improves the eminence of an image so that result becomes more appropriate than the actual image for certain precise application. The main aim of image enhancement is to highlight details which are hiding in an image or to focus definite specific features of attention in image through increasing contrast intensity in image. There are collections of different techniques for the improvement of better visual presence of an image: image enhancement, image de-blurring, image sharpening, image smoothing, image filtering and image de-noising (Janani et al. ,2015).

Enrichment of a noisy image is very stimulating and challenging task. The processing techniques are problem oriented because different kind of difficulties emphasizes enhancement of different kind of features in an image. Enhancing image modifies many attributes of an image for a better visual appearance/analyzing. Now a day's image enhancement is used in various fields where images are needed to understand and examine, such as image analysis for medical MRI scan, satellites image analysis, remote sensing, biometric, forensic lab, crime exploration etc. (Schulte, et al. 2007).

The most prominent technique of image enhancement is categorized into two broad categories: (1) Spatial domain operation and (2) Frequency domain operations. In spatial domain operation the enhancement techniques work directly on the image pixels or intensities and these spatial based domain operations can have three different forms namely (i) Point processing, (ii) Histogram based processing techniques and (iii) Mask processing techniques (Janani et al. ,2015) (Figueiredo & Bioucas-Dias ,2010).

In Frequency domain operation the image enhancement techniques mechanism on the mathematical functions or signals which is related to the number of times of signal is occurred, it can work straight over image - transform coefficients (as Fourier Transformation (FT), Discrete Fourier Transformation (DFT), Discrete Cosine Transform (DCT), and Discrete Wavelet Transform (DWT). Frequency domain operations can be again categorized as three different classes namely (i) Image smoothing (ii) Image sharpening (iii) Image filtering. The different operations which can be done in frequency domains are low pass, band pass, and high pass filtering. Figure1 depicts classification of image enhancement techniques.

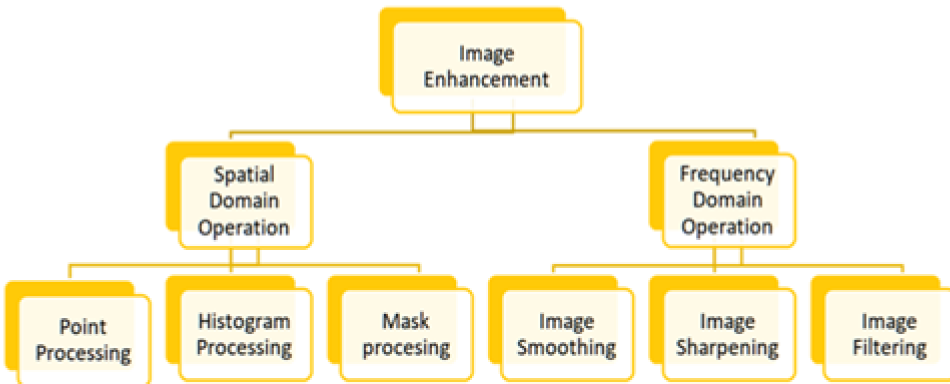

Figure 1. Image enhancement techniques

The outline of this paper is organized as follows: Section 2 gives brief overview of literature review. Section 3 briefly describes various image enhancement techniques. Section 4 describes frequency domain method. In Section 5 we address the problem of various types of noises present in the image and in order to solve it we need to deals with filters which are tested with different kind of noises. Section 6 comprised of results and discussions, the comparison is carried out with respect to the performance by calculating mean square error (MSE) and peak signal to noise ratio (PSNR) values, structural similarity (SSIM). The values are compared and results are tabulated. Section 7 gives conclusions and future scope of paper.

Literature Review

Image enhancement process is precise stimulating issue in numerous research areas. It is useful in improving photographic aspect of an image by modifying the firm types such as illumination of an image, range of optical density or the reallocation of grey level or colors intensities for specific application related. Many researchers have worked in the area of image enhancement techniques. (Singh & Mittal,2014) had studied various image enhancement techniques which were based on representative processing methods. The authors concluded that negative images are suitable to enhance white details enclosed firmly in a dark region that are very useful in MRI scanning. The authors also concluded that histogram is a qualitative change that extends the contrast by distributing a similar and new set of values uniformly. (Khidse & Nagori, 2013)compared various techniques such as histogram processing, enhancement of negative image, contrast stretching, filtering, hybrid filter delivers better results by evaluating comparison parameters like RMSE (Root Mean Square Error), PSNR (Peak Signal to Noise Ratio) and SSIM (Structural Similarity) .(Shukla et al.2017) has done the comparative analysis of various image enhancement techniques and concluded that the fuzzy rule-based approach is a powerful method for formulation of expert system. It represents the good mathematical frame works to deal with uncertainty of information. According to them artificial neural networks is used for identification of noise using the statistical parameters whereas fuzzy logic is used for enhancement purpose. The system behaves like fuzzy at the time of execution whereas it behaves like a neural network when learning of parameters occurs.

According to (Hoshyar et al. ,2014) presentation of adaptive wiener filter is most beneficial in diverse amounts of Gaussian, Poisson and speckle noise having lower intensities. Performance of mean filter is best in case of 40% increase in noise in speckle. Adaptive median is the best filter for all densities of salt & pepper noise. (Duan & Zhang, 2010) mainly focused over instinct noise detection methods and they recommended an impulse noise identification algorithm as a detection strategy using one dimensional Laplacian operator. (Abdalla, Dr. Zhijun P. and Faustini L. 2015) demonstrated the various types of noise and filters in which several linear and nonlinear filtering for noise reduction have been applied. In conclusion nonlinear filters are more effective in dealing with impulse noise as compared to linear filters as the linear filter tends to blur the edges of an image. (Janaki & Madheswaran,2016) demonstrated that adaptive median filter surpasses as an efficient noise removing scheme in preliminary processing of gray scale images using different types of filters in the comparison of PSNR, MSE, and SSIM. (Bansal et al.,2007) has simulated various image processing techniques using MATLAB and found that the spatial domain analysis is easier to implement as compared to frequency domain and it is concluded that it can be easily visualize the effects of various techniques and analyze the effects on the images by changing various parameters. The experimental results show that mean filter is more efficient than the median filter of same size of mask. For edge detection the best results can be achieved using the Sobel contour operator.

(Maini, R., & Aggarwal, H. 2010) have stated that image enhancement algorithms offer a wide variety of approaches for modifying images to achieve visually acceptable images. The choice of such techniques is a function of the specific task, image content, observer characteristics, and viewing conditions. (Panthi, et al.,2016) have introduced a new composite histogram equalization method followed by contrast stretch enhancement process for gray scale images. Composite method not only provides the way to integrate and complement data to enhance information apparent in the image but also to increase the reliability of the interpretation and their relevance to extract the structural information. (Khidse & Nagori, 2013) have done analysis of image enhancement without knowing about the source of degradation. The comparison is carried out by taking different evaluation parameters root mean square error (RMSE), peak signal to noise ratio (PSNR), structural similarity (SSIM) and correlation coefficient (CC). They concluded that edge adaptive hybrid filter gives some better results as compared to histogram processing, negative enhancement, contrast stretching, filtering, adaptive weighted mean filter (AWMF) and edge adaptive sigma filter (EASF). (Kaur, H., & Kaur, L., 2014). have done the comparative study among the different edge detection methods for natural and medical images. According to them for natural images, where the objects are considered to be a big challenge to segment, Gabor filter is proven better than canny. But in case of medical images the canny operator yields better results as it provides fine details which are essential in medical field. (Rivera et al.,2012) presented an algorithm which enhances dark images, sharpens edges and maintains the smoothness of flat regions. This algorithm takes into consideration an ad- hoc transformation for each image thereby mapping functions to each image's characteristics to give maximum enhancement.

(Jung et.al. ,2011) proposed an effective solution for eliminating the over enhancement of stereo images. The solution was evaluated using an optimization framework with extra restraint to prevent rise in luminance values. (Zhang et.al.,2011) takes into account the characteristics of the human visual system (HVS) to propose a new multi-scale enhancement algorithm and presented the logarithmic image processing (LIP) model. (Ghimire, D., & Lee, J. 2011) used a method in which the image enhancement techniques were imposed only on the V (luminance value) component of the HSV (Hue -Saturation-Value) color image and H and S component were kept unvaried to prevent the change of state of color balance among HSV components. (Yasmin et.al.,2012) describes enhancement operation which is applied to analyze the brain images precisely in order to diagnose the modality effectively and efficiently. They provide an overview of various methods with respect to brain image enhancement.

Materials and Methods

1. Spatial Domain Operations (SDO)

SDO is used for the purpose of filtering in which the neighborhood operations are done with given pixels. In this the output image is obtained using neighborhood operation by applying various algorithms. The spatial based domain operations can be classified in three different forms namely (i) Point processing, (ii) Histogram based processing techniques and (iii) Mask processing techniques as shown in figure1.An overview of these methods is discussed here.

1.1 Enhancement through Point Processing

These methods are mainly depending on intensity of each pixel. The spatial processing also embraces basic intensity transformation function. The pixel assessment of processed image has reliant on pixel assessment of unique image shown in equation (1).

$$g(x, y) = T[f(x, y)] \quad (1)$$

In this f (x, y) is given as an input image, g (x, y) is managed image and T is an operator on f, well-defined above certain area of input image g (x, y) images f and g consist numerous pixels r and s. The values of these pixels can be obtained using the equation (2).

$$S = T(r) \quad (2)$$

Pixel values (r) and (s) are mapped using the transformation T. Image enhancements through point processing techniques are graphically shown in Figure2. Point processing approach can be classified as: (i) Linear- negative and identity transformation. (ii) Threshold transformation. (iii) Logarithmic- log and inverse log transformation. (iv) Power law- Intensity transformations which are the most simple and practical to implement.

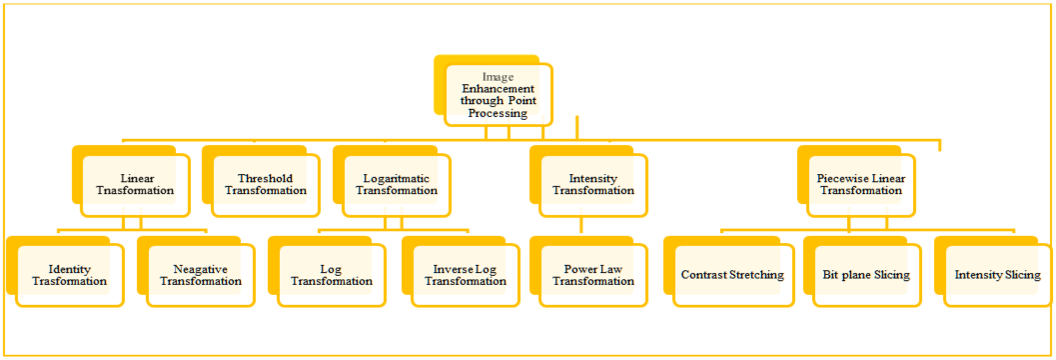

Figure 2 Image enhancements through point processing techniques.

A linear transformation contains simple identity and negative transformation.

1.1.1 Identity Transformation

In identity transformation each value of the input image is directly mapped to each other value of output image. With this process, input image and output image remain same as visible in Figure 3(a) and 3(b).

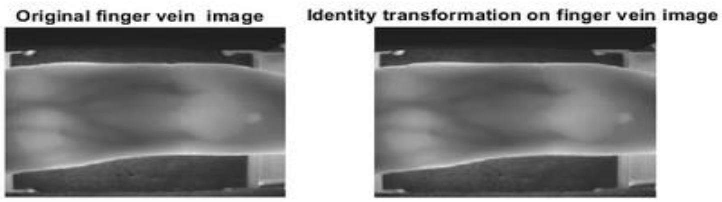

Figure 1(a) Original finger vein image (b) Identity transformation of finger vein

1.1.2 Negative transformation

Negatives of digital pictures are beneficial in presenting medicinal images and snapping a display with monochrome positive film which uses resulting negatives as normal slides. Using reversing or overturning the intensity level of an image, photographic negative of it can be obtained. Consider a 8 bit digital image size R x C, in which R is no. of rows and C is no. of columns; Later the pixel value r is subtracted by 255 as, g (x, y) = 255- f (x, y) for $0 \leq x < R$ and $0 \leq x < C$. The intensity level of a normalized gray scale can be represented in the range of [0, L-1] as shown in Equation (3) and image negatives are suitable for improving white or gray details surrounded in dark areas of an image presented in Figure 4(a)and 4(b)

$$S = L - 1 - r \quad (3)$$

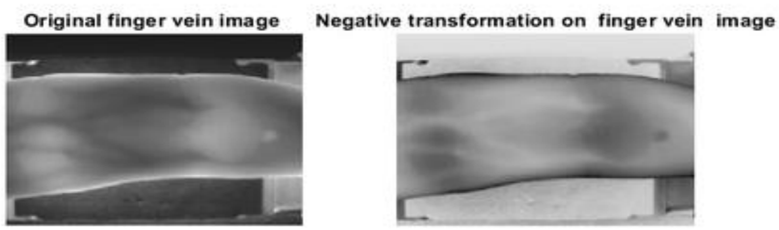

Figure 2(a) Original finger vein image (b) Negative transformation of finger vein image.

1.1.3 Transformation threshold

A transformation threshold is a simple and effective way of partitioning an image into foreground and background. By applying thresholding transformation, we can convert color or gray scale image into binary image. Black pixels correspond to background and white pixels correspond to foreground or vice versa. In this, we select some threshold value T, and then we compare each pixel in the image with this selected threshold. If the pixels intensity is higher than the threshold, then the pixel is set to1 or white else it is set to zero or black. Thresholding transformation is represented by equation (4). It can be classified as local thresholding and global thresholding. This plays an important role when image segmentation is done on finer vein image as shown in Figure 5(a), 5(b) 5(c) and 5(d).

$$T = \begin{cases} 1, & s > threshold \\ 0, & s \leq threshold \end{cases} \quad (4)$$

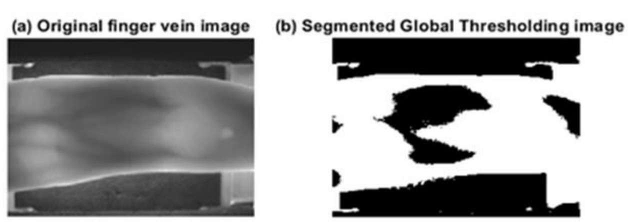

Figure 3(a) Original finger vein image (b) Segmented global thresholding transformation.

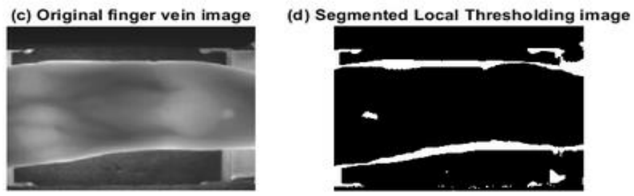

Figure 5(c) Original finger vein image (d) Segmented global threshloding transformation.

1.1.4 Logarithmic Transformation: Log and Inverse Log Transformation

The log transformation is useful in mapping the values of a slight collection of small input into a broader collection of gray level. This expands the dark pixels and compresses the brighter pixel. Log transformations are mathematically expressed as shown below:

$$s = c * log\,(1 + r) \tag{5}$$

Where s is an output image pixel value and r denote an input image and c is a constant. If pixel intensity is 0 then the value of log 0 also will be infinity. Thus, to make this value at least equal to a minimum value of 1, the value 1 is summed up for each pixel value of an image. The logarithm function performs the desired compression. Figure 6(a) and 6(b) represents the usefulness of logarithmic transformation.

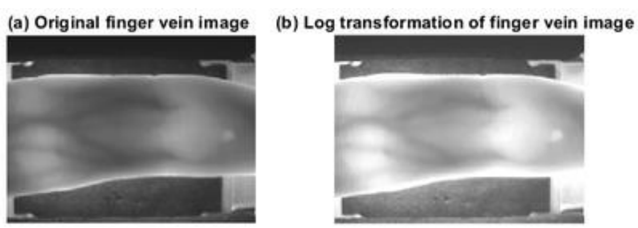

Figure 6(a) Original finger vein image and (b) Logarithmic transformations of finger vein image

1.1.5 Intensity Transformations- Power Law Transformations (PLT)

Power law transformation represents the relation between pixel values of f (x, y) and g (x, y). It is represented by equation (6)

$$s = cr\hat{}\gamma \tag{6}$$

Here, s is an output image, r is an input image, c and γ represents positive constants which can be used for contrast manipulation. For different values of λ with power law function, a group of different probable transformation curves may find. This feature differentiates the log-transformation function to power-law functions. Figure 7 represent the result obtained from the application of this function.

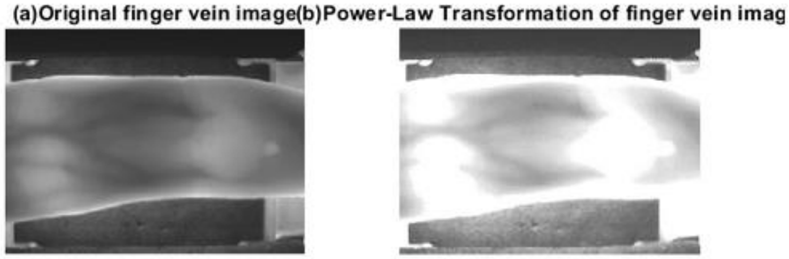

Figure 7(a) Original finger vein image and (b) Power law transformations of finger vein image

1.1.6 Piecewise Linear Transformation

In piecewise linear transformation the manipulation is done for the pixel value of the image. It is an arbitrary user defined transformation. Piecewise linear transformations are further classified as: (i) Contrast Stretching (ii) Intensity slicing (iii) Bit plane slicing. The contrast stretching process intends to regulate the native contrast in various areas of the image by highlighting particulars in its dark or bright areas to reveal to the human observers. Gray level slicing is fundamentally used to progress the eminence of an image and the function emphasizes a pool of intensities. Grey level slicing is equivalent to band-pass filtering. Bit plane slicing is alternative procedure of piecewise transformation. Its highpoints the involvement which appears in overall image with defining the competence of numerous bits used for pixel gray levels to quantize each pixel in an image compression.

Affine transformations are applied in piecewise linear transformation, discretely to areas of the image. Figure 8 reveals the effect of application of this transformation on the image of finger vein. Here the process shows top-left, top-right, and bottom-left points for the image of finger vein are retained at their original position while, the triangular region at the lower-right of the image is stretched in such a way, bottom-right corner of the image is transformed by 50% to its right and 20% lower side than the original coordinate.

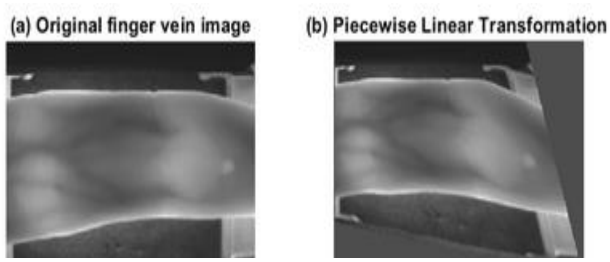

Figure 8(a) Original finger vein image (b) Piecewise linear transformation of finger vein image

1.2 Histogram Processing

It is a type of spatial domain techniques. Histogram represents the plot of frequency of intensity of pixels values. Histograms has a key role in image processing like image thresholding, analysis, monitoring brightness of image, adjusting contrast of an image to equalize an image.

The normalized histogram is obtained by dividing the histogram using numerous pixels present in image and it is an approximation to the probability mass function (PMF). A normalized histogram of an image with gray intensity in domain of [0, L-1] is a discrete function given by equation (7)

$$P(r_k) = n_k \tag{7}$$

Where r_k is the kith intensity value of an image

n_k, the number of pixels in the gray level image

n, the total number of pixels in an image

k =0,1, …, L-1.

$P(r_k)$, Estimated probability of existence of gray level rk.

The histograms are commonly normalized using numerous pixels in the image (M x N) and represented by equation (8)

$$P(r_k) = \frac{n_k}{MN} \qquad where \quad k = 0,1, \dots . L-1 \tag{8}$$

The summation of values contemporary in the histogram is normalized to one. Shape of the histogram of an image provides useful information about the likelihood for contrast enrichment. There are two categories of Contrast enhancement techniques: Histogram Equalization (HE) and Tone Mapping.

1.2.1 Histogram Equalization (HE)

The goal of histogram equalization is to approximate the gray scale value distribution of an image to the uniform distribution as shown in Figure (9). The histogram of a predominantly dark image is skewed near the lower end of the gray scale with total image particulars compacted into its dark end.

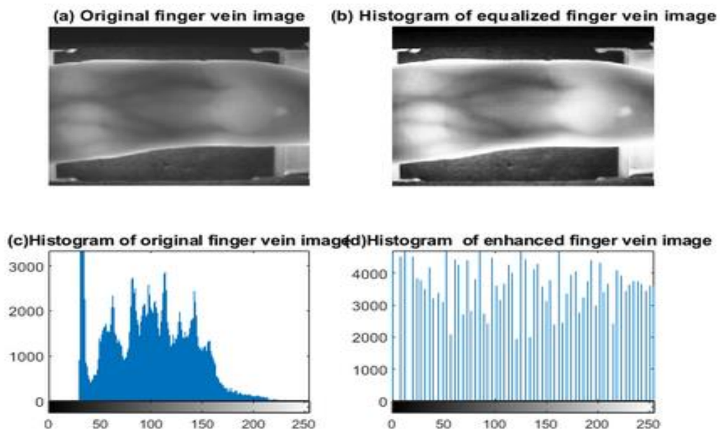

Figure 9(a) Original finger vein image (b) Histogram of equalized finger vein image (c) Histogram of original finger vein image and (d) Histogram of enhanced finger vein image.

1.2.1.1 Histogram Matching

Histogram matching algorithm generates an output image based upon a specified histogram. It is also called Histogram Specification. It matches with uniform distribution function by altering the spatial histogram (Janani et al ,2015). Steps involved in generating an image of specified histogram using histogram matching method are as mentioned below shown by equation (9), (10) and (11):

Step1. Find the histogram P_r(r)

$$s = T(r) = (L-1)\int_0^r P_r\,(w)dw \tag{9}$$

Step2. Transformed function is to be obtained by using the specified Probability Density Function P_z(r) of the output image by using equation (10)

$$G(z) = (L-1)\int_0^z p_z\,(t)dt = s \tag{10}$$

Step3. Apply the inverse transformation

$$z = G^{-1}[t(r)] = G^{-1}(s) \tag{11}$$

Step4. Firstly, by means of equalization of the input image obtain the output image; later for each pixel of the equalized image, obtain the corresponding pixel of the output image by applying inverse mapping. Figure 10 depict the similarity between gray scale distribution of histogram of original and matched image.

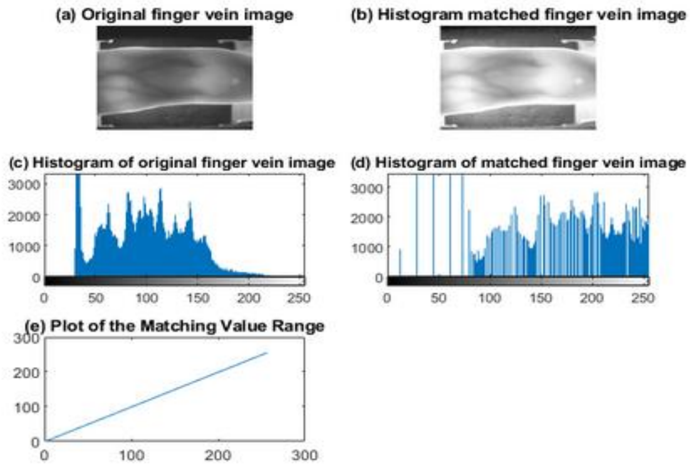

Figure 10(a) Original finger vein image (b) Histogram matched finger vein image (c) Histogram of original finger vein image and (d) Histogram of matched finger vein image (e) Plot of the matching value range.

1.2.2 Tone Mapping

Tone mapping is also one of the approaches of contrast enhancement technique. This approach is useful in image processing and computer graphics. It maps one set of colors to another to simulate the appearance of high-dynamic-range images which has limited dynamic ranged medium.

1.3 Mask Processing

Spatial filtering is better known as masking, which includes convolutions operation of a mask with an image as the name suggest in this process to blur and reduce noise in an image filter are applied on it. Filters are very useful for edge detection and sharpening of an image. Masking can be performed on a pixel along with its immediate neighbors and subsequently histogram is calculated for it. To calculate next histogram, new pixel values and previously obtained histogram can be used.

2. Frequency Domain Method

Frequency domain multiplication is equivalent to convolution operation in the spatial domain. By applying convolution theorem to an input image f (x, y) with linear time invariant operator h (x, y), an enhanced image g (x, y) can be formed which is given by equation (12).

$$g(x,y) = h(x,y) * f(x,y) \tag{12}$$

3. Noises Vs. Image Filtering Techniques

In every digital image there is an occurrence of noise and it is always difficult to remove noise in an image. For this removal of noise, different techniques available for image filtering. In this section we present various types of noise and filtering techniques of removal of noise.

3.1 Noise

Noise is degradation in the visual appearance. Noise may occur or added in digital images while capturing of an image, transmitting, coding, and processing due to various reasons such as faulty image capturing hardware, insufficient light, bad focusing, sensor temperature, motion, and environmental condition due to dust particle in scanner screen. In such type of situations, it is expected to restore a corrupted image g (x, y) by defining a degradation function and noise n (x, y) is added to an original image f (x, y) as shown in figure 11.

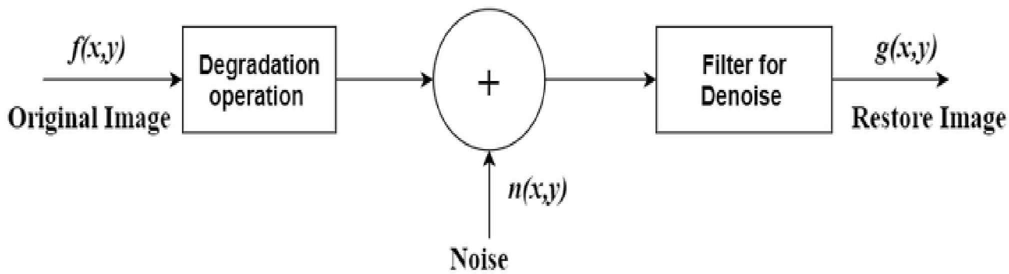

Figure11. Image restoration /degradation process

It can be represented by the equation (13)

$$g(x,y) = f(x,y)\ X\ h(x,y) + n(x,y) \tag{13}$$

Here, $f(x,y)$ is the original image, $n(x,y)$ represents the added noise, $h(x,y)$ represent the degradation functions and $g(x,y)$ is the resultant noisy image.

Removal of noise is very important and most challenging task during image enhancement. The main challenge is to remove the noise with the intention of reinstate the original one without any loss of information and preserving the significant detail. Till the date numbers of noise removal techniques have been developed which are having their own merits and demerits. Image filtering is a tool for de-noising. As the selection of appropriate de-noising algorithm depends on the specific application; it is very essential to know the type/nature of noise present in an image to choose appropriate de-noising algorithm.

Different kinds of noises which generally occur in a digital image are categorized as: Gaussian Noise, Salt and Pepper Noise, Speckle Noise, Poisson Noise, Uniform Noise, Erlang /Gamma noise and Rayleigh noise.

3.1.1 Gaussian Noise or Amplifier Noise

Amplifier noise is an additive noise which occurs when casual fluctuations in signal. It influences all the pixel values. This noise has a probability density function (PDF) of the normal distribution, is also named as the Gaussian distribution. Removal of this noise is possible by spatial filtering such as mean, averaging, median filter and gaussian smoothing, but smooth out also blurs the edges of an image and their informative specific details. The probability density function of amplifier noise is defined by equation (14).

$$P_G(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(z-\mu)^2/2\sigma^2} \quad (14)$$

Where σ is the standard deviation, μ is mean value, z represents gray level of an image.

3.1.2 Salt and Pepper Noise

Salt & Pepper noise is also known as impulse noise or spike noise. It contains black and white spots in an image. This noise causes due to errors in data transmission and malfunctioning of image sensor or camera, due to failure of memory cells, synchronization errors at the time of transmitting image over media. Median filter can be used to suppress pepper and salt noise. The probability density functions of salt and pepper noise as denoted by equation (15).

$$P(Z) = \begin{cases} P_a & if\ z = a \\ P_b & if\ z = b \\ 0 & otherwise \end{cases} \quad (15)$$

3.1.3 Poisson noise

Poisson noise is also known as shot noise or photon noise (Hoshyar et al.,2014). It occurs in a specific condition when the sensor which identifies statistical information not have sufficient number of photons. Root mean square value of Poisson noise is proportionate to square root intensity of an image. Poisson noise, PDF (probability density function) is defined by the equation (16)

$$P(x) = \frac{e^{-\lambda}\lambda^x}{x!} \qquad for\ \lambda > 0\ and\ x = 0,1,2,\ldots \quad (16)$$

3.1.4 Speckle Noise

It is also known as granular noise and act as multiplicative noise (Hoshyar et al.,2014). This kind of noises results in degradation of quality of the aperture synthetic radar images. The enhancement is done averaging of grey level of a local area which poses lots of problem during the interpretation of an image. It follows a gamma distribution as shown in equation (17).

$$P(z) = \frac{z^{\alpha-1} e^{-z/a}}{\alpha-1!a^{\alpha}} \quad (17)$$

3.1.5 Uniform Noise

Quantization noise (Janani, 2015) (Singh& Neeru,2014) occurs when the pixels of image are quantizes to a number of distinct levels. It has nearly even distribution. The gray intensities of the noise are evenly spread over a specific range. It can be used to create any type of noise distribution. It is useful for the assessment performance of image restoration algorithm. The probability density function, mean and variance of uniform noise can be shown using following equation (18).

$$P(z) = \begin{cases} \frac{1}{b-a}, & if\ a \leq z \leq b \\ 0\ , & otherwise \end{cases} \tag{18}$$

Where $\mu = \frac{a+b}{2}$ and $\sigma^2 = (b-a)^2/12$

3.1.6 Rayleigh Noise

Rayleigh distribution models the typical noises present in radar range and velocity images (Singh, & Neeru, 2014). The mean, variance and probability density function of Rayleigh noise is as shown in equation (19).

$$P(z) = \begin{cases} \frac{2}{b}(z-a)e^{\frac{-(z-a)^2}{b}} & ,for\ z \geq a \\ o & ,for\ z < a \end{cases} \tag{19}$$

Where $\mu = a + \sqrt{\pi b/4}$, $\sigma^2 = \frac{b(4-\mu)}{4}$

3.1.7 Gamma Noise

It is also known as erlang noise (Abdalla,2015) (Singh & Neeru, 2014). It is usually visible in the laser-based images. It obeys the gamma distribution. The mean, variance and probability density function of gamma noise is as shown in equation (20).

$$P(z) = \begin{cases} a^b\ z^{b-1}\ e^{-az}/(b-1)! & ,\ for\ z < 0 \\ o, & for\ z \geq 0 \end{cases} \tag{20}$$

Where $\mu = b/a$, $\sigma^2 = b/a^2$

3.2 Filters

Filtering is a technique for modifying an image by emphasizing/highlighting certain features or removal of other features. It includes smoothing, sharpening, and edge enhancement. Filters can be classified as: (1) Nonlinear filter and (2) linear filter. Linear filters are fast to compute, but they are incapable of smoothing without simultaneously blurring edges, because both edges and noise are high-frequency components of images. Linear filters can be studied in the frequency domain, as well as in the spatial domain whereas nonlinear filters are potentially more powerful than linear filters, because they are able to simultaneously reduce noise and preserve edges. Nonlinear filters are slow to compute and difficult to design. They have less secure theoretical foundations and selection of appropriate filter depends upon the application.

3.2.1 Gaussian Filter

Gaussian filter is a linear and a non-uniform low pass filter. Gaussian is used as smooth out filter in the 2-D convolution operator that is useful for deduction of noise but distorting/blurring the images. It cannot remove salt & pepper noise effectively. The gaussian function is given by equation (21) and (22).

$$g(x,y) = \frac{1}{M}\sum f(x,y)exp\left[-((x-i)^2+(y-j)^2)/2\sigma^2\right] \quad (i, j) \in S \qquad (21)$$

Where S signifies each pixel set in the neighborhood

$$M = \sum exp\left[-((x-i)^2+(y-j)^2)/2\sigma^2\right] \qquad (22)$$

The equation explains the set of pixels and associated corresponding weights S.

3.2.2 Average/Mean Filter

Mean (Average) filter is a simplest and easiest linear type of filter. It replaces every pixel value with the mean /average value of neighboring pixels as shown in Figure 12. It is easily implementable and used to eliminate gaussian noise. Most of the time it is useful in removing irrelevant details from an image but having the constraint that it hazes the edges of an image. The mean filter can be represented as in equation (23).

$$g(i,j) = \frac{1}{M \, x \, N}\sum f(m,n) \qquad (23)$$

Where m = 1, 2, M n = 1, 2……. N.

S represents the neighborhood filtering mask of image pixel f (m, n) centering at point g (i, j).

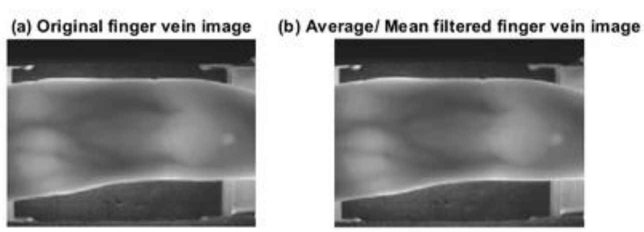

Figure 12(a) Original finger vein image and (b) Average /Mean filtered finger vein image.

3.2.3 Median filter

In this, we first arrange all the pixel values of an image in ascending order for finding the middle value and then substitute each pixel value of image with the median value. It has a limitation associated with it of blurring the image during the phase of processing. However, it has an advantage of suppressing the noise while preserving the edges and expressed by the equation (24) as shown:

$$f^{\wedge}(x,y) = \quad median\,\{g(s\,,t)\} \qquad where\ (x,t) \in S_{xy} \tag{24}$$

3.2.4 Min Filter and Max Filter

It identifies the darkest points and brightest points in an image. Also, due to its high intensity value and very low intensity value, it easily removes salt noise from an image which is expressed as shown below as equation (25) and (26).

$$f^{\wedge}(x,y) = \quad min\,\{g(s\,,t)\} \qquad where\ (x,t) \in S_{xy} \tag{25}$$

$$f^{\wedge}(x,y) = \quad max\,\{g(s\,,t)\} \qquad where\ (x,t) \in S_{xy} \tag{26}$$

Figure 13 shows the result after applying min and max filter on original finger vein image.

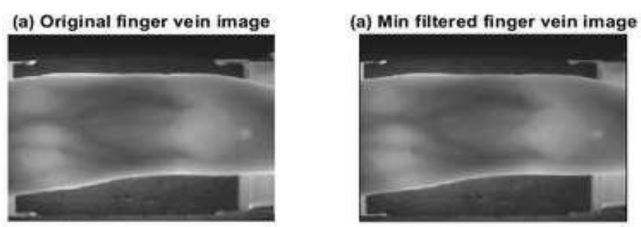

Figure 13(a) Original finger vein image and (b) Min filtered finger vein image.

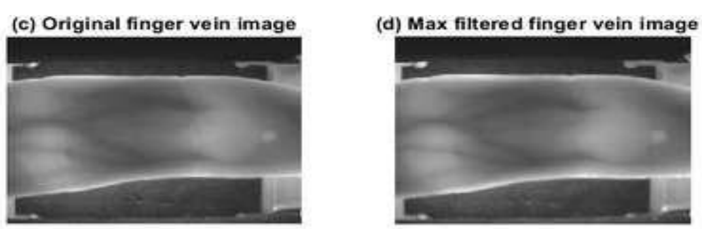

Figure 13(c) Original finger vein image and (d) Max filtered finger vein image.

3.2.5 Adaptive Median Filter (AMF)

To overcome this drawback noise levels, the adaptive median filter has been proposed. Adaptive median filter replaces noisy pixels associated with the median filter, without changing its other pixels value. Also, it remains unaffected due to presence of local features like the probable edges. Also, it outperforms well on images comprising high density of salt and pepper noise (Hoshyar,2014).

3.2.6 Weiner filter

Weiner filters are considered as statistical approach and as a kind of linear filters which generate optimum value. It filters out the noise which contributes to corruption in signal. The goal of Weiner filter is to reduce mean square error up to a great extent. Also, it reduces Poisson and speckle noise.

Result Analysis

To establish a most effective filter in controlling different kind of noises, the comparison of images has been carried out by using SNR (Signal-to-Noise Ratio), SSIM (Structural Similarity), MSE (Mean Square Error) and PSNR (Peak Signal-to-Noise Ratio). These are some of the well-known indexes which are useful in comparing the original and noise free images. The equation (27) and (28) of MSE and PSNR is given by as follows:

$$MSE = \frac{1}{MN} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i\ ,j) - k(i\ ,j\ )]^2 \tag{27}$$

$$PSNR\ = 10 \log_{10} \left(\frac{MAX^2}{MSE} \right) \tag{28}$$

The table (1) shows comparison of the values of filter parameters for different indexes like the MSE, PSNR, SNR and SSIM. The simulation is carried out in MATLAB (R019a). To carry out this experiment finger vein image has been simulated for Gaussian, salt & pepper, speckle and Poisson noises. In order to remove noise form finger vein image, we have used eight types of filters namely using min, max, average/mean, median, Gaussian, Weiner, ordered and sharpen filters. Figure14(A)-figure 14(D) reveals that each applied filter is capable of removing noise which deteriorates picture quality of an image within their best suited capacity. In image processing the lower value of MSE and higher values of PSNR results in a higher quality of image with less noise.

From simulation the results as shown in figure14(A)-figure 14(D) It is observed that most of the time the value of MSE should be low and higher PSNR conduct a higher quality and less noisy image. From the study of figures, A-D. It is also observed that Weiner filter performs better in removing almost all kinds of noises as shown in figure 15(A)- fiugre15 (B).

Table1. Comparison of various filters for various types of noises

FILTER / NOISE	METRICS	MIN	MAX	MEAN	MEDIAN	GAUSSIAN	WEINER	ORDERD	SHARPEN
GAUSSIAN	MSE	738.4683	682.9014	655.1794	607.6873	626.0082	526.8639	863.2168	555.0239
	PSNR	19.4475	19.7872	19.9672	20.2940	20.1650	20.9138	12.6124	20.6877
	SNR	11.6520	12.4357	12.3453	12.7494	12.5711	13.3463	8.3894	14.0062
	SSIM	0.1591	0.1640	0.1792	0.2756	0.1891	0.2805	0.1325	0.8263
SALT AND PEPPER	MSE	282.8637	225.1548	218.3968	180.8461	199.5797	34.9488	573.2759	36.992
	PSNR	23.6150	24.6060	24.7383	25.5577	25.1296	33.1415	20.5742	32.4497
	SNR	15.8196	17.2545	17.1134	17.9790	17.5363	25.6067	12.4174	25.0214
	SSIM	0.6809	0.6969	0.6728	0.7170	0.6922	0.9108	0.6069	0.9684
POISSON	MSE	202.8724	148.3953	144.2585	98.6689	127.1165	88.6996	839.4734	121.2173
	PSNR	25.0586	26.4166	26.5394	28.1890	27.0888	28.6516	18.8907	27.2952
	SNR	17.2631	19.0651	18.9011	20.6081	19.4820	21.0798	13.0647	19.9294
	SSIM	0.4963	0.5083	0.4940	0.5622	0.5091	0.5415	0.4280	0.8403
SPECKLE	MSE	221.2333	165.5250	160.1397	117.8857	143.2796	93.6156	594.1187	133.3584
	PSNR	24.6823	25.9422	26.0858	27.4162	26.5690	28.4173	18.9139	26.8806
	SNR	16.8868	18.5906	18.4463	19.8328	18.9610	20.8471	13.0538	19.5260
	SSIM	0.5093	0.5207	0.5086	0.5811	0.5227	0.5702	0.4580	0.8460

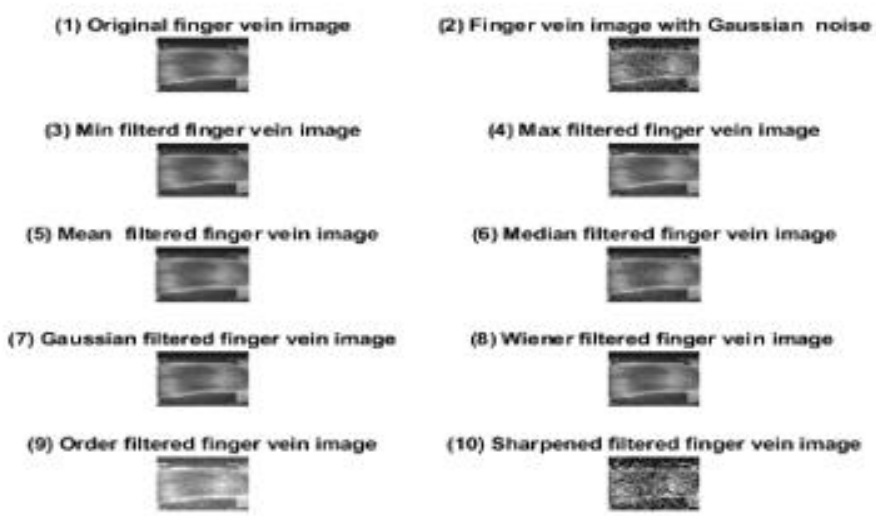

Figure14 A (1) Original finger vein image (2) Finger vein image with **Gaussian noise** and de-noising by (3) Min filtered finger vein image (4) Max filtered finger vein image (5) Average/ Mean filtered finger vein image (6) Median filtered finger vein image (7) Gaussian filtered finger vein image (8) Wiener filtered finger vein image (9) Ordered filtered finger vein image (10) Sharpened filtered finger vein image.

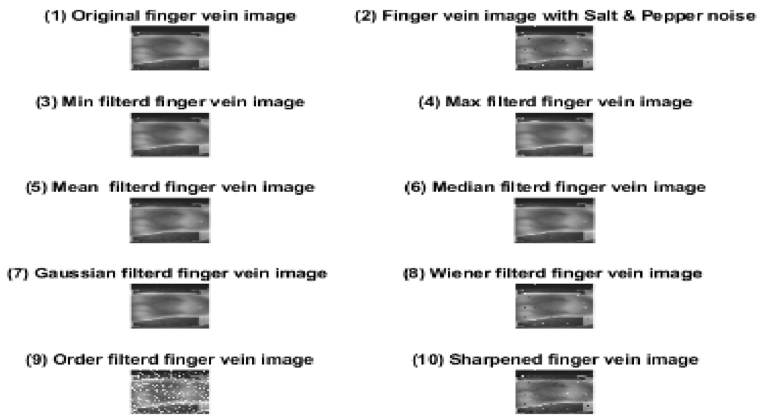

Figure14 B (1) Original finger vein image (2) Finger vein image with **Salt & Pepper noise** and de-noising by (3) Min filtered finger vein image (4) Max filtered finger vein image (5) Average/ Mean filtered finger vein image (6) Median filtered finger vein image (7) Gaussian filtered finger vein image (8) Wiener filtered finger vein image (9) Ordered filtered finger vein image (10) Sharpened filtered finger vein image

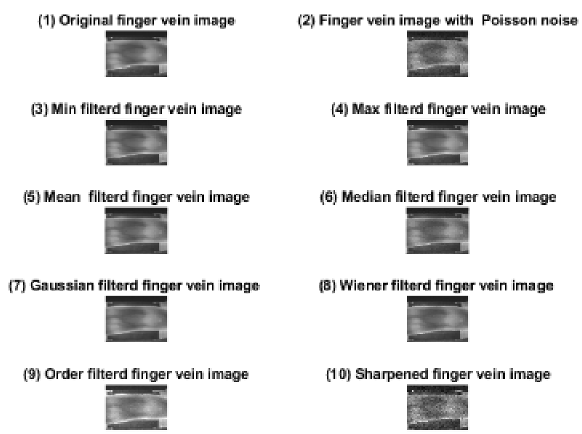

Figure14 C (1) Original finger vein image (2) Finger vein image with **Poisson noise** and de-noising by (3) Min filtered finger vein image (4) Max filtered finger vein image (5) Average/ Mean filtered finger vein image (6) Median filtered finger vein image (7) Gaussian filtered finger vein image (8) Wiener filtered finger vein image (9) Ordered filtered finger vein image (10) Sharpened filtered finger vein image

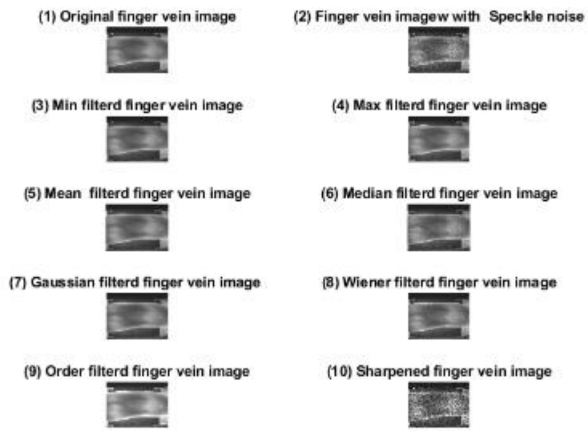

Figure14 D (1) Original finger vein image (2) Finger vein image with **Speckle noise** and de-noising by (3) Min filtered finger vein image (4) Max filtered finger vein image (5) Average/ Mean filtered finger vein image (6) Median filtered finger vein image (7) Gaussian filtered finger vein image (8) Wiener filtered finger vein image (9) Ordered filtered finger vein image (10) Sharpened filtered finger vein image

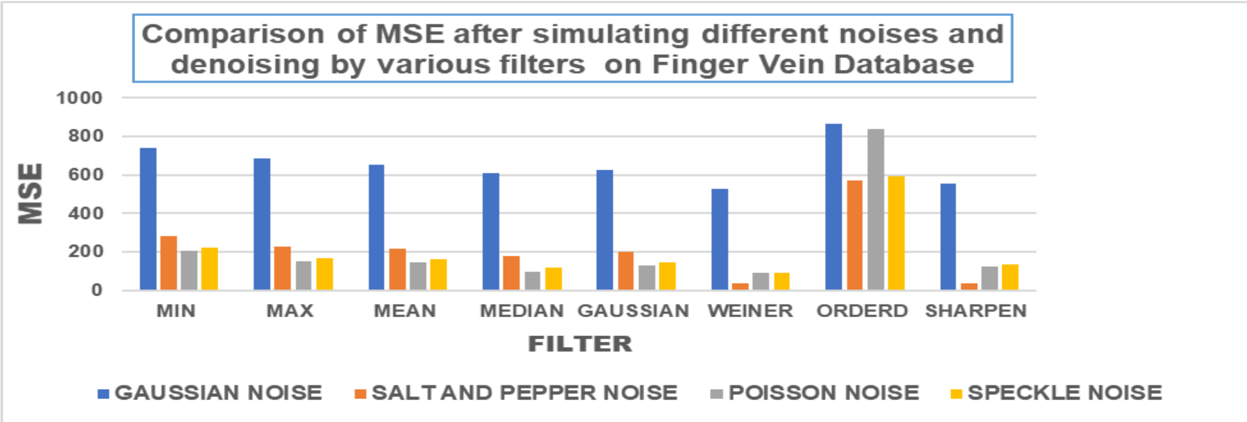

Figure15A Comparison of MSE after simulating different noises and denoising by various filters on Finger Vein Database

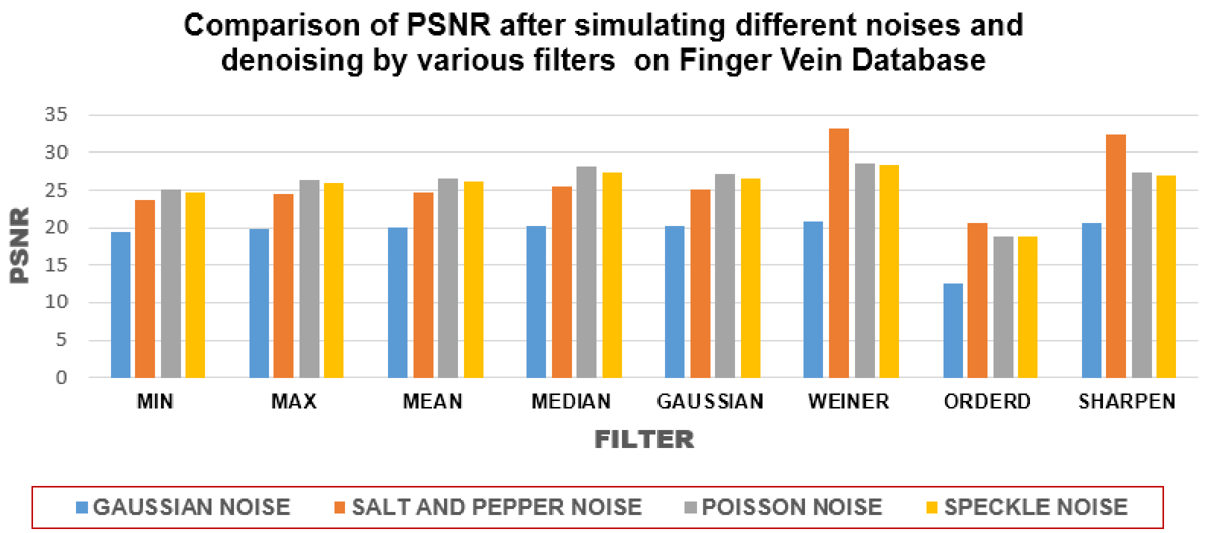

Figure15 B Comparison of PSNR after simulating different noises and denoising by various filters on Finger Vein Database

Conclusion and Future Scope

Image enhancement is the process of improving the quality of an image. In this paper various spatial domain image processing techniques were analyzed on vascular pattern-based finger vein image for personal authentication. For the purpose of research, four varied noises (such as Gaussian, Salt & pepper, Poisson and Speckle) were introduced to the original finger vein image and then to improvise the quality of this degraded image, all desired filters min, max, average/mean, median, Gaussian, Weiner, ordered and sharpen were applied for the removal of these noises. In this research, original finger vein image and improved quality image were compared and evaluated to identify the most effective filter on varied noises by using well known indexes like MSE, SNR, PSNR and SSIM. The observation was made that high PSNR and low MSE values represent the highest quality and lowest level of noise in the image. The experiment was performed on the vein images of left- and right-hand index, middle and ring finger; the image was collected from the SDUMLA-HMT database. This research concluded that Weiner filter is the most effective filter for eliminating varies noises as compared to all the other filters that have tested in this research. We also observed that sharpen is the least effective filter among all that we have tested. These results cannot be standardized and are specific only for this research as the effectiveness of any particular filter may vary depending on the existing quality of the image and the type of the noise that was introduced while capturing the image. Although, the computational cost of enhancement techniques is not focused in this study, it seems that it may play a critical role choosing a technique for real time applications. The present research can be further extended to construct/define other filtering methods to suppress other types of noises in frequency domain of color images.

Acknowledgements

We would like to thank Dr. Karan Singh who provided significant guidance, suggestions to complete the experiment and for providing access to JNU computer lab.

Conflict of interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

Funding

This research did not receive any specific grant from agencies in the public, commercial or not for profit sectors.

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Bibliographic information of this paper for citing:

Sharma, Sapna; Agrawal, Shilpy & Munjal, Manisha (2022). Technical Assessment of Various Image Enhancement Techniques using Finger Vein for personal Authentication. *Journal of Information Technology Management*, Special Issue. 200-224.