Fingerprint Image De-noising by Various Filters for Different Noise using Wavelet Transform
Liton Devnath¹, Md. Rafiquil Islam²
¹²Mathematics Discipline, Khulna University, Khulna-9208, Bangladesh

Abstract: Now a day’s fingerprint image identification is one of the most popular biometric technologies. The performance of a fingerprint image-matching algorithm depends on the quality of the input fingerprint images. But the images are often corrupted by various types of noises during acquisition and transmission. Such images have to be cleaned before using in any applications. Image de-noising is basic work for image processing and analysis. Wavelet transforms have become a very powerful tool for de-noising an image. In this paper four types of noise (Gaussian noise, Salt & Pepper noise, Poisson noise and Speckle noise) is used and fingerprint image de-noising performed for different noise by four types of filter (Mean filter, Median filter, Laplacian filter and Wiener filter) in MATLAB Software. Further results have been compared by PSNR (Peak Signal to Noise Ratio) values for all noises.

Keywords: Mean filter, Median filter, Laplacian filter and Wiener filter, Wavelet transform

I. Introduction
Image filtering improves the quality of images. The good quality of input fingerprint is important for Automated Fingerprint Identification System (AFIS). Most AFISs are based on minutiae matching [1]. Although the automatic fingerprint recognition and identification have wide and long practical application for image processing and pattern recognition. Several methods have been used to solve the de-noising problems in image analysis. Generally, the de-noising techniques have been categorized into spatial and frequency domain techniques [2, 3, 8]. In spatial domain, adaptive spatial filter is one of the best filtering techniques to restore the heterogeneous pixel characteristics perfectly. Image denoising algorithm consists of few steps; consider two dimensional matrix of an input signal x(t) and noisy signal n(t). Add these components to get noisy data y(t) i.e,

\[ y(t) = x(t) + n(t) \]

Here the noise can be Gaussian, Salt and pepper, Poisson’s and speckle, then apply wavelet transform to get w(t), i.e,

\[ y(t) \xrightarrow{\text{Wavelet Transform}} w(t) \]

Apply filter for different noise by four types of filter (Mean, Median, Laplacian and Wiener), then by inverse wavelet transform to get de-noising image \( \hat{x}(t) \).

II. Related work
Alle Meije Wink et al. (2004) analyses the performance of general wavelet-based de-noising scheme with Gaussian Smoothing. Yong-Hwan Lee et al. (2005) proposed a simple and efficient algorithm for adaptive noise reduction, which combines the linear filtering and thresholding methods in the wavelet transform domain. P. L. Shui et al. (2007) proposed Image de-noising algorithm via best wavelet packet base using Wiener cost function. A. Buades et al. (2010) focus of his work is, first, to define a general mathematical and experimental methodology to compare and classify classical image de-noising algorithms, second, to propose an algorithm addressing the preservation of structure in a digital image. Sachin D Ruikar et al. (2011) proposed Wavelet Based Image De-noising Technique. This technique is computationally faster and gives better results. Dr.E.Chandra et al (2011) given a solution for Noise Elimination in fingerprint image using median filter. T. Vidhya et al. (2012) concluded that the fingerprint images are enhanced to a higher quality by de-noising the images using Wavelet based enhancement procedure. Hari Om et al. (2012) proposed An Improved Image Denoising Method Based on Wavelet Thresholding. S. Sutha et al (2013) projected A Comprehensive Study on Wavelet Based Shrinkage Methods for Denoising Natural Images. M. Neelima et al. (2014) project was to study various techniques such as visuShrink, SureShrink, NeighShrink and determine the best one for image denoising. Hani M. Ibrahim (2014) presented an efficient switching filter based on cubic B-Spline for removal of salt and pepper noise. The author reported with the PSNR value of 50db with 0.2 noise density. S. Usha et al. (2015) proposes Performance Analysis of Fingerprint De-noising Using Stationary Wavelet Transform.
III. Wavelet Transform, Image noise and filters

A. Wavelet Transform

Wavelet transform gives a full and precise image of the quasi-harmonic components’ dynamics in signal. A wavelet allows one to do multi-resolution analysis, which helps to achieve both time and frequency localization. Wavelet algorithms process data at different scales or resolutions. As a result, the multi-resolution analysis of the wavelet has good characteristics and advantages in both the space domain and frequency domain. Nowadays, wavelet analysis has successful applications in bio-medical engineering, signal processing, image processing, video image compression, digital television, image coding, edge detection and other fields [11]. In most of the applications of image processing, it is essential to analyze a digital signal. The wavelet transform is better than Fourier transform because wavelets are localized in both time and frequency whereas the standard Fourier transform is only localized in frequency [6]. Wavelet transform of any function \( f \) at frequency \( a \) & time \( b \) is computed by correlating \( f \) with wavelet atom \( a \)

\[
wf(a, b) = \int_{-\infty}^{+\infty} f(t) \Psi \left( \frac{t-b}{a} \right) dt
\]

Wavelet transform is always defined in terms of a “mother” wavelet \( \Psi \) and a scaling function \( \varphi \), along with their dilated and translated versions [4]. The use of wavelet transform on image shows that the transform can analyze the approximation, horizontal, vertical and diagonal components in the fingerprint image [5, 7].

B. Image noise

Image noise is random variation of brightness or color information in images, and is usually an aspect of electronic noise. Usually, the noise hides some information about the images and it makes it difficult to diagnose. Image diagnosis is always done after applying image enhancement and de-noising techniques to the original images. There are many types of noises occurs in fingerprint images during acquisition and transmission. Mostly occurred noises are Gaussian noise, Salt and Pepper noise, Poison Noise, Speckle noise and so on [10].

B.1. Gaussian noise

This type of noise has a probability density function (PDF) of the normal distribution (also known as Gaussian distribution). It most commonly presents as additive noise to be called additive white Gaussian noise. The general model of amplifier noise is additive, Gaussian, independent at each pixel and independent of the signal intensity. Principal sources of Gaussian noise in digital images arise during acquisition e.g. sensor noise caused by poor brightness or high temperature or electronic circuit noise. Gaussian noise is a major part of the “read noise” of an image sensor, i.e. of the constant noise level in dark areas of the image [9].

B.2. Salt and pepper noise

Impulsive noise is sometimes called salt-and-pepper noise. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. The salt & pepper noise is generally caused by fitting of camera’s sensor cells, by memory cell failure or by combination errors in the image digitizing or transmission. It can be mostly eliminated by using dark frame subtraction, median filtering and interpolating around dark/bright pixels. For an 8 bit/pixel image, the typical intensity value for pepper noise is close to 0 and for salt noise is close to 255 [9].

B.3. Poison Noise

This noise is also known as photon shot noise. Poison Noise is typically caused by the variation in the number of photons sensed at a given exposure level. In addition to photon Poison Noise, there can be additional shot noise from the dark leakage current in the image sensor. Shot noise has a root-mean-square value proportional to the square root of the image intensity, and the noises at different pixels are independent of one another. Shot noise follows a Poisson distribution, which except at very low intensity levels approximates a Gaussian distribution. Since the mean and variance of a Poisson distribution are equal, the image dependent term has a standard deviation if it is assumed that the noise has a unity variance (R. Kaur et al., 2013).

B.4. Speckle noise

This type of noise occurs in almost all coherent systems such as SAR (Synthetic Aperture Radar) images, Ultrasound images etc. The source of this noise is random interference between the coherent returns. It increases the mean grey level of a local area. All conventional medical images B-mode ultrasonic have speckle noise and can be an unwanted property since it masks small but diagnostically significant features (Chen et al., 2003). In general, speckle noise commonly referred to data dropout noise. The speckle can also represent some useful information, particularly when it is linked to the laser speckle and to the dynamic speckle phenomenon, where the changes of the speckle pattern, in time, can be a measurement of the surface's activity. Speckle noise follows a gamma distribution function.
C. Image Filtering

Filtering is a technique for modifying or enhancing an image. Image processing operations implemented with filtering include smoothing, sharpening, and edge enhancement. Filtering is a neighborhood operation, in which the value of any given pixel in the output image is determined by applying some algorithm to the values of the pixels in the neighborhood of the corresponding input pixel. In this paper four types of noise is used and fingerprint image de-noising performed for different noise by four types of digital filter. Such as Mean filter, Median filter, Laplacian filter and Wiener filter [9, 10].

C.1. Mean filter

Mean filtering is a simple, intuitive and easy to implement method of smoothing images, i.e. reducing the amount of intensity variation between one pixel and the next. It is often used to reduce noise in images. The idea of mean filtering is simply to replace each pixel value in an image with the mean (‘average’) value of its neighbors, including itself. This has the effect of eliminating pixel values which are unrepresentative of their surroundings. Mean filtering is usually thought of as a convolution filter.

C.2. Median filter

Median filtering is similar to the mean or averaging filter since they produce pixel, this is set to an "average" of the pixel values in the surrounding region of the corresponding input pixel. In median filtering, the importance of an output pixel is determined by the median of the surrounding region of pixels rather than the mean. Instead of simply replacing the pixel value with the mean of neighboring pixel values, it replaces it with the median of those values. The median is calculated by first sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value [9]. A major advantage of the median filter over linear filters is that the median filter can eliminate the effect of input noise values with extremely large magnitudes.

C.3. Laplacian filter

The Laplacian is a 2-D isotropic measure of the 2nd spatial derivative of an image. The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection. The Laplacian is often applied to an image that has first been smoothed with something approximating a Gaussian smoothing filter in order to reduce its sensitivity to noise. The Laplacian \( L(x, y) \) of an image with pixel intensity values \( I(x, y) \) is given by: \( L(x, y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \). This can be calculated using a convolution filter.

C.4. Wiener filter

The most important technique for removal of blur in images due to linear motion or unfocussed optics is the Wiener filter. From a signal processing standpoint, blurring due to linear motion in a photograph is the result of poor sampling. Each pixel in a digital representation of the photograph should represent the intensity of a single stationary point in front of the camera. Unfortunately, if the shutter speed is too slow and the camera is in motion, a given pixel will be an amalgam of intensities from points along the line of the camera's motion. This is a two-dimensional analogy to \( \hat{G}(u, v) = F(u, v) \cdot H(u, v) \) where \( F \) is the fourier transform of an "ideal" version of a given image, and \( H \) is the blurring function. In this case \( H \) is a sinc function: if three pixels in a line contain info from the same point on an image, the digital image will seem to have been convolved with a three-point boxcar in the time domain. If \( G \) and \( H \) are known, then this technique is inverse filtering [9, 10].

D. Performance Estimation

Peak Signal to Noise Ratio (PSNR)

PSNR is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale.

\[
\text{PSNR} = 10 \cdot \log_{10} \left( \frac{255^2}{\text{MSE}} \right)
\]

Where, MSE is mean square error between the original image and the denoised image.

IV. Performance Analysis

After wavelet transform in MATLAB, we adding four types of Noise (Gaussian noise, Salt & Pepper noise, Poisson noise and Speckle noise) to synthesized image. Adding the noise with standard deviation \((0.02)\) and removed those noises using Mean filter, Median filter, Laplacian filter and Wiener filter and comparisons among them. All performance are given below:
Fig. 4.1: Original Image (left), Wavelet Decomposition at level 3 (middle), Synthesized Image (right).

Fig. 4.2: Gaussian noise (above left), Salt & Pepper noise (above right), Poisson noise (below left), Speckle noise (below right).

Fig. 4.3: Removed Gaussian noise by Mean Filter (left), Removed Gaussian noise by Median Filter (right).

Fig. 4.4: Removed Gaussian noise by Laplacian Filter (left), Removed Gaussian noise by Wiener Filter (right).
Fig. 4.5: Removed Salt and Pepper noise by Mean Filter (above left), Removed Salt and Pepper noise by Median Filter (above right), Removed Salt and Pepper noise by Laplacian Filter (below left), Removed Salt and Pepper noise by Wiener Filter (below right).

Fig. 4.6: Removed Poisson noise by Mean Filter (above left), Removed Poisson noise by Median Filter (above right), Removed Poisson noise by Laplacian Filter (below left), Removed Poisson noise by Wiener Filter (below right).

Fig. 4.7: Removed Speckle noise by Mean Filter (left), Removed Speckle noise by Median Filter (right).
Fig. 4.8: Removed Speckle noise by Laplacian Filter (left), Removed Speckle noise by Wiener Filter (right).

Table 1: PSNR Values by Four Filters

<table>
<thead>
<tr>
<th>Noise</th>
<th>Mean Filter</th>
<th>Median Filter</th>
<th>Laplacian Filter</th>
<th>Wiener Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaussian noise</td>
<td>62.9136</td>
<td>64.3691</td>
<td>49.9885</td>
<td>66.4402</td>
</tr>
<tr>
<td>Salt &amp; Pepper noise</td>
<td>62.7369</td>
<td>64.3860</td>
<td>49.4106</td>
<td>66.6671</td>
</tr>
<tr>
<td>Poisson noise</td>
<td>63.5810</td>
<td>65.8804</td>
<td>49.7048</td>
<td>67.5685</td>
</tr>
<tr>
<td>Speckle noise</td>
<td>63.2148</td>
<td>64.9956</td>
<td>50.0820</td>
<td>66.7156</td>
</tr>
</tbody>
</table>

The performances of four filters are analyzed using PSNR values of the de-noised (enhanced) image and these values are tabulated in Table 1. From the Table, it is evident that the wavelet enhancement procedure works well than that of the Wiener filter enhancement procedure and from the above Fig. (4.3 to 4.8) we conclude that the median filter gives clearer image than other filters.

V. Conclusion

We used the fingerprint image (Fig.4.1) in “jpg” format, adding four noise (Gaussian, Salt & Pepper, Poisson and Speckle) in original fingerprint image with standard deviation (0.02) (Fig.4.2), De-noised all noisy images by four filters and conclude from the results (Table 1) that, the performance of the Wiener Filter after removing noise for all Gaussian noise, Salt and Pepper noise, Poisson noise and Speckle noise is better than Mean filter, Median filter and Laplacian Filter.

References


VI. Acknowledgments

The authors gratefully acknowledge the helpful comments and suggestions of the reviewers that have improved the presentation.