Digital Image Denoising In Medical Metacarpal Images

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Abstract

The medical image processing techniques are used to extract meaningful information in order to understand the disease and prescribe the appropriate treatments. With the advancement of medical science, there are number of image acquisition techniques are available to provide computer aided analysis of images for diagnose and treatment of diseases. The major sources of medical images are X-ray images, MRI images, CT-Scan images, PET scan images, Ultra sound images etc. The careful analysis of these images greatly helps to understand anatomy of different diseases, but due to unavoidable circumstances, noise may be introduced into these images which hinder the accuracy of decisions to be taken for the treatments. The noise suppression in medical images is a delicate and difficult process as there is always trade-off between noise reduction and preservation of relevant features. In this paper, we have considered X-rays medical images of metacarpal for analysis of denoising techniques. We have implemented standard denoising tools such as linear arithmetic mean, geometric mean, harmonic mean, contra harmonic mean, min-max midpoint filters. We have also studied the comparative statements of these methods in order to find out most suitable method for medical metacarpal images. The study of metacarpal images plays a significant role in study of childhood growth disorders.

Keywords: X-Ray Images, MRI Images, CT-Scan Images, Mean Filters, Median Filters, MSE, SNR, PSNR.

INTRODUCTION

The digital medical images contain vital information about diseases which need to be correctly identified and localized. The medical image acquisition techniques such as X-Rays, MRI (Magnetic resonance imaging), CT (Computed Tomography)-Scan, PET (Positron emission tomography) Scan, Ultra Sound 2D and 3D Microscopy Imaging etc. are different sources of generation of medical images which act as critical tool for understanding and treating the diseases. The image quality enhancement through noise suppression has become indispensable. The presence of noise in image degrades the performance of medical images and affects the scanning process of diagnosis. In literature, there are several methods [1] are proposed to denoise medical images. The noise suppression in medical images is a delicate and difficult process as there is always trade-off between noise reduction and preservation of relevant features. In this paper, we have considered X-rays of carpal images of hands along with wrist. We have implemented linear arithmetic mean, geometric mean, harmonic mean, contra harmonic mean, min-max midpoint filters. These are linear filters to denoise digital images by processing all the pixels in image. This procedure is time consuming and does not show good results. To overcome these problems, we have also implemented non-linear median filter.

In the field Digital image processing, the term noise is referred as a disturbance that distorts the information present in the image. It is usually an unwanted signal that can create a variation in image intensity levels of pixels which cause degradation of image quality. The noise is introduced in image automatically due to acquisition process where the optical image is converted into a series of electronic signals. During this process, unwanted signals may be added into original series of electronic signals. There may be certain other unavoidable situations such as mechanical problem, out of focus blur, motion, in appropriate illumination. The most of time noise is added during transmission process such as scanning of image using scanner, converting one image format into another format, wireless network transmission of image etc. During transmission process, noisy channel and error due to measurement process may introduce unwanted signals into data stream which results in noised image. The other possible reasons may be sensitivity of image sensors or motion cause noising during capturing process due to malfunctioning of pixel elements in the camera sensors, faulty memory locations, or timing errors in the digitization process.

In literature, the noise is categorised into different categories some of them are listed in a tabular form along with description:

Gaussian Noise	Gaussian noise [2] is evenly distributed over the image. This means that each and every pixel in the image have values which is considered as sum of true values plus noise value from gaussian distribution . The Gaussian noise is given as $$P(z) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(z-\bar{z})/2\sigma^2}$$ Where, z represents gray levels. Σ represents standard deviation.
Uniform Noise:	In uniform noise [3], the gray level values of the noise are evenly distributed across a specific range in an image. The following equation can be used to express uniform noise: $$P(z) = \begin{cases} \frac{1}{b-a} & if\ a \le z \le b \\ 0 & otherwise \end{cases}$$ Where mean μ= (a+b) /2 and variance $\sigma^2 = (b-a)^2/12$
Impulse Noise/Salt and Pepper Noise:	A noise pixel [4] has only two possible values, one has high value and another has low value. In this way, each pixel has probability less than 0.1. The noised pixels give Salt and Pepper appearance to the image. It appears as sprinkle of both light and dark spot in image. The following equation defines impulse noise in an image. $$P(z) = \begin{cases} Pa & for\ z = a \\ Pb & for\ z = b \\ 0 & otherwisw \end{cases}$$ Where a, b represent different gray levels [0,255] in image, if b>a, intensity b will appear as light dot in image and intensity a will appear as dark dot in image. The variables Pa, Pb are noise probability levels, if Pa or Pb is zero then impulse noise is called unipolar noise otherwise probability is zero.
Multiplicative Noise/Speckle Noise:	Multiplicative noise [5] is a single dependent form of noise whose magnitude is related to the value of the original pixel. It is generally found in medical images such as Ultrasound images. The following equation defines multiplicative noise: w(x, y) = s(x, y)× n(x, y) Where s(x,y) is the original signal, n(x,y) denotes the noise introduced into the signal to produce the corrupted image (x,y), and (x,y) represents the pixel location.

Table1: Classification of Noises

NOISE REDUCTION METHODS

The goal of denoising is to remove the noise while retaining as much as possible original information of the image. The denoising of the image can be done in two ways: linear filtering and nonlinear filtering. In the case of linear filtering, the noise reduction algorithm is applied for all pixels of the image linearly without knowing about noisy pixel and non-noisy pixel. Whereas, nonlinear filters are applied on pixels surrounded by noisy pixels. The following diagram shows the categorization of linear and nonlinear filters:

Mean Filter:	The mean filter is a spatial domain filter and has high speed processing as compared to transform domain filtering. It is a traditional way to remove noise from digital image to employ statistical formulas like: arithmetic mean, geometric mean, harmonic mean and contra-harmonic mean. The computation of mean filter is performed on sub image sometime called mask/window which is a rectangular region consider around pixel to be noised.
Arithmetic Mean Filter:	It is an averaging filter [6] that has used neighbourhood pixel values around pixel to be denoised. The arithmetic mean computes the average value of a neighbourhood and places the average value at the centre. The following mathematical equation can be used to

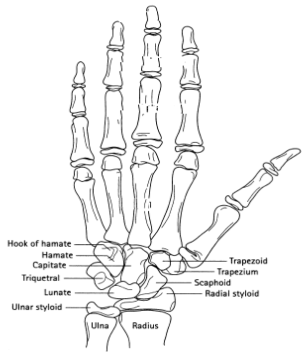
	represent arithmetic mean filter: $f(x, y) = 1/mn \Sigma g(s, t)$ where $(s, t) \epsilon S_{xy}$ The arithmetic filter smooths the image but blurring is increased.
Geometric Mean Filter:	In this filter [7], a window is considered around pixel to be noised and neighbourhood pixel is considered for computation of geometric mean. The centre pixel of window is replaced by the product of pixels with raised to power 1/(mXn) the neighbourhood of the window. The following mathematical equation can be used to represent geometric mean filter: $f(x, y) = [\cap \Sigma g(s, t)]^{1/mn}$ where $(s, t) \epsilon S_{xy}$ It is better than arithmetic mean filter but it lose some important image information during filtering.
Harmonic Mean Filter:	In the harmonic mean filter [8], the concept of sliding window is used in which a window is considered around pixel to be noised and neighbourhood pixel is considered for computation of harmonic mean. The mathematical harmonic mean is calculated on the basis of gray values of neighbourhood pixels within the window region. Let us consider S_{xy} represents pixels values within rectangular window of size mXn. The following mathematical equation is used to represent harmonic mean filter: $f(x, y) = mXn/ \Sigma 1/g(s, t)$ where $(s, t) \epsilon S_{xy}$ The harmonic filter works well for gaussian noise as well as salt noise.
ContraHarmonic Mean Filter:	Let us consider S_{xy} represents pixels values within rectangular window of size mXn. The rectangular window is considered around a pixel to be noised and its neighbourhood pixels are consider for contra-harmonic computation. The following mathematical equation[9] is used to represent contra-harmonic mean filter: $f(x, y) = \Sigma g(s, t)^{q+1} / \Sigma g(s, t)^{q}$ where $(s, t) \epsilon S_{xy}$ Where q is called order of filter. It place significant role in filtration as with positive value of q. The filter performs well on pepper noise. When the value of q is negative, it works well for salt noise. But both cannot eliminate simultaneously. It acts as arithmetic mean filter when q=0.
Order Statistics Filter:	The order static filter [10] is based on ordering of gray scale values of neighbourhood pixels of window consider around pixel to be noised. It will replace the value of the centre pixel by performing ranking of pixels in neighbourhood. The methods to find out ranking of gray values of neighbourhood pixels are median, max/min, mid-point and alpha-trimmed mean.
Median Filter:	In median filter [10], a sliding window concept is used in which a square window called mask is used to surround the pixel to be denoised. Generally, mask size of 3X3 is used. Let us consider (x, y) is a location of pixel to be noised. The pixel value is changed to median of all pixels in the window of locations {(x+1, y), (x-1, y), (x, y-1), (x,y+1), (x+1, y+1), (x-1, y-1), (x-1, y+1), (x+1, y-1)}. It is hardly affected by small number of discrepant values among pixels in neighbourhood. $f(x, y) = median \{g(s, t)\}$ where $(s, t) \epsilon S_{xy}$ During the process, the median is calculated by first sorting all pixel values of neighbourhood into numeric order and replace pixel being consider with middle value. It has been observed that median filter is good for smoothing purpose and it also preserve small and sharp detail. But it does not preserve small size component as compared to neighbourhood pixel values.
Max and Min Filter:	In this filter [10], sliding window of size mXn is used to find out max and min values of neighbourhood pixels to be denoised pixel under consideration. The max and min value is calculated by comparing values in the neighbourhood and resultant value is replaced with pixel under consideration. The following mathematical equation represents max and min filter $f(x, y) = max \{g(s, t)\}$ where $(s, t) \epsilon S_{xy}$ and $f(x, y) = min \{g(s, t)\}$ where $(s, t) \epsilon S_{xy}$

	Where max filter is used for paper noise and it will find the brightest pixel in the sub image. In case of min filter, it will find darkest pixel in the sub image and is useful for salt noise.
Mid-Point Filter:	The midpoint filter [11] computes the mid-point intensity value between the maximum and minimum intensity values in the sub images area S_{xy} of the corrupted image g (x, y). The following mathematical equation represents the mid-point filter: $f(x, y) = 1/2[\max \{g(s, t)\} + \min \{g(s, t)\}]$ where $(s, t) \epsilon S_{xy}$ Mid-point filter is good for gaussian white noise or uniform noise.
Alpha-Trimmed Mean Filter:	Alpha-trimmed mean filter [12] is an averaging filter which finds out averaging within window neighbourhood by deleting the d/2 lowest and d/2 highest gray value intensity levels. Let us consider S_{xy} is the window neighbourhood and gr(s, t) represents remaining (mn-d) pixels. The following mathematical equation represents the Alpha-trimmed filter: $f(x, y) = 1/mn\text{-}d \sum gr(s, t)$ where $(s, t) \epsilon S_{xy}$ Where, the parameter d can range from 0 to mn-1. When d=0, then alpha-trimmed mean filter work as arithmetic mean filter and it acts as median filter when d= (mn-d)/2.

Table2: Different Types of Denoising Filters

IMPLEMENTATION OF NOISED REDUCTION METHODS ON MEDICAL METACARPAL IMAGES

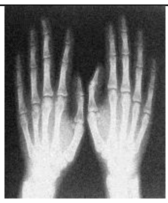
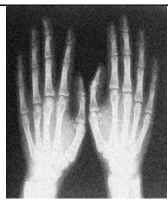
In the present study we have considered the X-Rays medical images particularly metacarpal images. The study of x-ray metacarpal images plays a significant role in the measurement of childhood growth disorders. The assessment [13] is based on analysis of features in an x-ray of a child's left hand and wrist, and compares these with known standards to estimate a child's biological age.



There are two types of bones in hand and wrist:
1. The long bones have a dominant long axis. They include the radius, ulna, and phalanges as shown in Figure. 2. The short bones of the wrist, the carpal bones, are shown in Figure.

Figure1: Left Antinomy of Hand, Right X-Rays Image

In the present study we have implemented following denoising techniques like Arithmetic Mean Filter, Geometric Mean Filter, Harmonic Mean Filter, Contra-Harmonic Mean Filter on Medical Metacarpal Images.

Denoising Technique	**Input Noised Image**	**Output Denoised Image**	**Denoising Technique**	**Input Noised Image**	**Output Denoised Image**
Arithmetic Mean Filter			Min Filter		

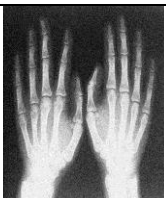
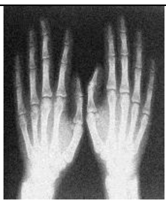
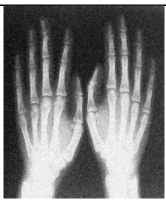
Geometric Mean Filter			Max Filter		
Harmonic Mean Filter			Mid-Point Filter		
Contra Harmonic			Median Filter		

Table3: Implementation of Denoising Methods

Analysis of output using MSE, SNR and PSNR is discussed below:

METHOD	MSE	SNR	PSNR
Arithmetic Mean Filter	820.604	42.235	54.710
Geometric Mean Filter	933.451	40.947	53.422
Harmonic Mean Filter	1019.438	40.065	52.541
Contra Harmonic	2010.691	40.359	41.99
Min Filter	2978.691	29.343	41.819
Max Filter	2883.445	29.668	42.143
Mid-Point Filter	898.855	41.324	53.800
Median Filter	989.731	40.361	52.837

Table4: Statistical Analysis of Denoising Methods

It has been observed from the statistical analysis that non-linear methods show better results as compare to the linear denoising filters.

CONCLUSION

The present study is based on implementation of well-known denoising methods on medical metacarpal images. We have processed the images under visual studio environment and comparison of the processed images is carried out. It has been observed that linear filter give poor results as compared to nonlinear filters. The size of sliding window plays an important role in denoising medical images. If the number of pixels is very large around central pixel than it will increase computational overhead, but on the other part results are more satisfactory. The appropriate size of window is 7X7 in terms of quality of the image and reasonable computational overhead.

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