Preprocessing of Lower Limb Bone Based on Full Leg CT Scan

Safaa M. Gamal, Nancy M. Salem, Ahmed F. Seddik

Abstract— Nowadays, the medical digital image processing appeared in the diagnosis of various diseases. It considered as one of the most important tools in many disciplines of medicine which help the doctors to take the final decision on treatment or operations based on the processed image. In this paper, the accuracy and performance of various preprocessing filtering methods are compared. The (STD) Standard Deviation, (MSE) Mean Squared Error and (PSNR) Peak Signal-to-Noise Ratio are used to evaluate the performance of filtered images. Results show that Gaussian filter provides better PSNR and lower STD and MSE values. Hence, we nominate that Gaussian filter is an efficient for preprocessing full leg CT medical radiograph images.

Index Terms— Full leg CT, Gaussian filter, Lower limb CT scan, Medical image processing

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1 INTRODUCTION

PROCESSING of of full leg CT medical radiograph image is one of the most effective factors to recognize and understand illiterate lower limb alignment. Choosing an accurate filter for preprocessing is a critical step for proper segmentation of medical radiograph CT images. Measurement of (STD) stander deviation, (MSE) Mean Squared Error and (PSNR) Peak Signal-to-Noise Ratio can help next steps of segmentation to reach the highest percentage of output image when we take value which include low stander deviation, low Mean Squared Error and high Peak Signal-to-Noise Ratio of filtered image.

In the literature, different types of medical radiographic images (X-ray, CT, mammogram and MRI) used to diagnose different parts (bones, lung and different parts of body tissue), either by applying a specific filter or by trial and error with various filters for getting the best preprocessing results. In [1], several types of noise are discussed such Salt and Pepper noise which mostly happened by defeating in capture or transmission process which clarify in image as light and black dots. The median filter is chosen as a preprocessing filter for noise removing then segmentation the image by Soble filter edge detector.

In [2], different methods for body bone segmentation are reviewed including technician mistakes, suggestion preprocessing filter for image preparation and suitable segmentation methods based on previous segmentation experiences. In [3], averaging of image row pixel value is determining by taking ten background portion pixels along the column of the original image. This step acts as a preprocessing step to enhance the contrast and quality of image pixel information and to remove noise before segmentation.

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In [4], new methods for bone segmentation are discussed which include different preprocessing filters with tradeoff between more variety of enhancement pixel information and nomination of Guided filter as the best preprocessing filter. In [5], the importance of preprocessing step whether to remove noise or to enhanc quality and contrast for segmentation of mammogram radiographic image are reviewed. In [6], the preprocessing steps aim to remove the surplus noise parts in radiographic image. So, the chosen of accurate and suitable preprocessing filter is very important to limit the image pixel information without undue effect of noise. In [7], many approaches for preprocessing and segmentation techniques are reviewed. Different filters for preprocessing mammogram images are discussed such as: adaptive median filter, mean filter, Markov random field method, Wavelet methods, median filtering, max, and min filters. In addition to the advantages and disadvantages for every technique.

In [8], Gaussian filter used as a preprocessing step to CT radiographic lung speckle noise followed by contrast enhancement by uniformly rearrange the grayscale pixels values. In [9], a review of different algorithms for preprocessing and segmentation of radiographic image are reviewed. The review discussed the pixel data information distribution, parameters, and the factors that affect the performance of preprocessing and segmentation process. In [10], various preprocessing methods such: Gabor filter, adaptive median filter, morphological operations, mean filter or average filter, image normalization, histogram equalization, weighted median filter, and Weiner filter.

2 METHODOLOGY

Traditionally, the high performance of image processing segmentation starts with chosen the accurate preprocessing step to eliminate noise carefully without missing any gray scale data information [6], [9], [10]. In this paper, ten filters will be compared to achieve the best preprocessing results to be used with full leg CT radiographic image.

2.1 Average Filter

Average filter is a simple filter to be implemented. This method is used to decrease the intensity amount variance between

one pixel and the surrounding pixels in a window to reduce noise. The average filter is achieved by summing window pixel's value then compute averages of the pixel's summation contained in each window then replaces the center value in the window with average value [11].The average pixel value y is described in (1):

$$y = \frac{1}{n} \sum_{i=1}^{n} z(i) \qquad (1)$$

Where n is number of pixels in the window.

2.2 Disk Filter

Disk filter is a circular averaging filter to reduce noise in images by circular averaging between one pixel and the surrounding circular window pixel with the required radius then return within the square matrix of size (2 * radius+1) and replaces the center value in the window with square matrix value [12].

2.3 Gaussian Filter

Gaussian filter is a smoothing filter which had great effect of reducing image noise and image details. The Gaussian function G (x, y) is described in (2):

$$G(x, y; \sigma) = \frac{1}{2\pi\sigma^2} \exp(-\frac{x^2 + y^2}{2\sigma^2}) \qquad (2)$$

where σ is a scalar value [13].

2.4 Laplacian Filter

Laplacian filter is an edge disclosure filter which finds the sharp change pixel area (edges) in image [14]. The Laplacian function L (x, y) is described in (3):

$$L(x, y) = \frac{\sigma^2 I}{\sigma x^2} - \frac{\sigma^2 I}{\sigma y^2} \qquad (3)$$

2.5 LOG Filter

By merging two filter functions; where Gaussian filter smooth the image and Laplacian filter finds areas of rapid change (edges) in images. This two-step process is called the Laplacian of Gaussian (LOG) operation [14]. The Laplacian of Gaussian function LOG (x, y) is described in (4):

$$LOG(x, y) = -\frac{1}{\pi\sigma^4}[1 - \frac{x^2 + y^2}{2\sigma^2}]e^{-\frac{x^2 + y^2}{2\sigma^2}} \qquad (4)$$

where I is image pixel intensity value.

2.6 Guided Filter

Guided filter is an edge preserving filter which carries out image edge smoothly by using a guidance image content to effect the filtering. The difference between the guided filter and other filters is the statistics accounting in the guidance image at the corresponding spatial neighborhood during calculating the pixel output value. The guidance image types vary between (same image, slightly different image and entirely different image)[15].

2.7 Un-sharp Filter

Un-sharp filter is a linear filter which designed by processed

the sum of the (input and scaled detail image) to explicate sharp accentuating edges output image [11], [16]. The Unsharp function f sharp is described in (5):

$$fsharp = f + \alpha(f - h\sigma * f) \qquad (5)$$

where *fsharp* is the output image, f input image, α is a positive value, hσ is impulse response implemented with a matrix.

2.8 Wiener Filter

Wiener filter is linear time-invariant (LTI) filter which used for restoration the image by applying de-burring function to remove image blurring and reproduction an image with known (fixed signal, spectra of noise and additional noise) [17]. The Wiener function g(x, y) is described in (6):

$$g(x, y) = h(x, y) * f(x, y) + \eta(x, y) \qquad (6)$$

where f(x, y) is input image, h(x, y) is degraded function and η(x, y) additive noise.

2.9 Motion Filter

Motion filter is a linear filter that returns an approximate convolved image which corresponds to a horizontal and vertical motion of pixels. Motion filter works to build a straight line with the required length and angle at the coefficient center of h then determine the nearest distance between each coefficient location (i, j) and the constructed Line [11], [12].
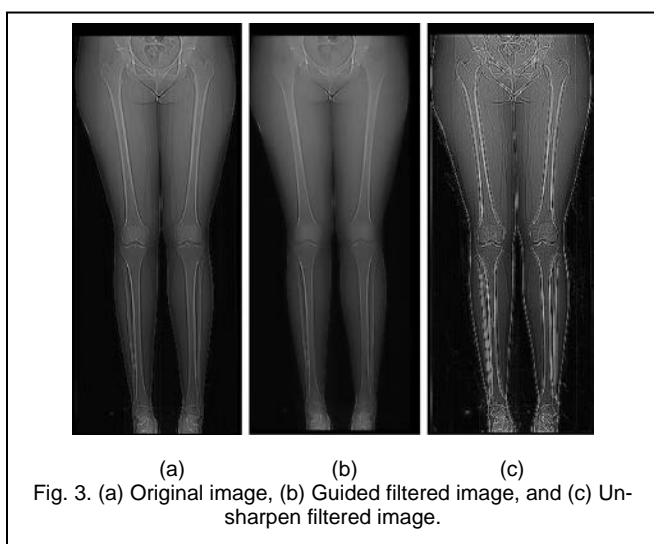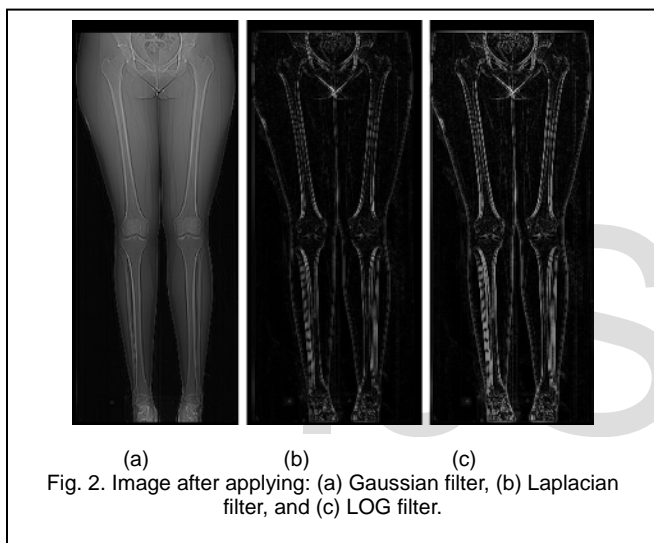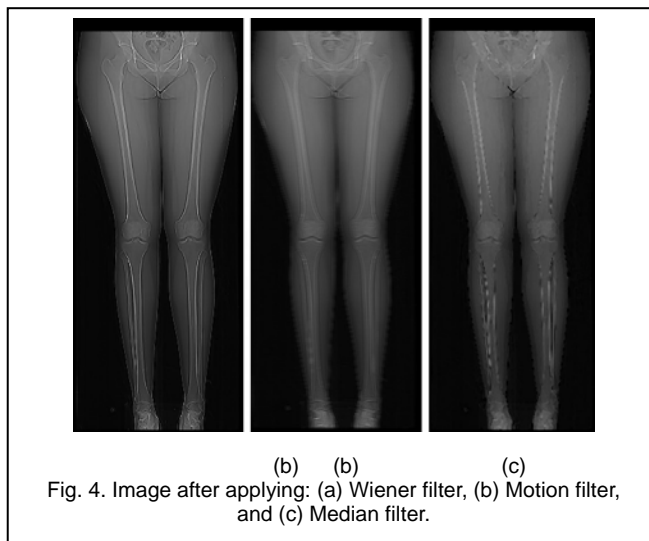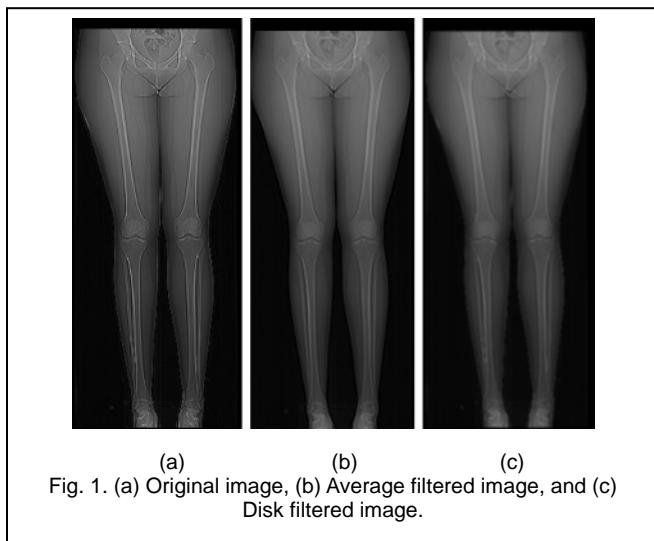
2.10 Median Filter

Median filter is a nonlinear filter used to remove noise without reducing the sharpness of the image and keep preserving edges of image by reducing the amount of intensity variation between one pixel and the surrounding pixel neighbor. Median filter sorts the data values in the window around target sample point and returns the middle value then replaces the center value in the window with returns middle value [11], [13].

3 RESULTS

Evolution of the ten filters (Average - Disk - Gaussian - Laplacian - LOG - Guided - Un-sharp - Wiener - Motion - Median) used in this paper measured by calculating the peak signal-to-noise ratio (PSNR), mean square error (MSE) and standard division (STD) values [18]. Using MATLAB ® 2015 and a set of 35 full leg CT medical radiograph images. Figures 1, 2, 3, and 4 show the original image and results after applying different filters.

3.1 Dataset

A dataset of the CT images collected from local radiographic center. A set of 35 full leg CT images stored in the DICOM format with (512*512) pixel size data from Toshiba Alexion CT scan device. The dataset includes 20 adult females and 15 adult males with different weight, length and age with various lower limb bone diseases such as genu varus, genu valgus, bone deformation and knee replacement.

(a)   (b)   (c)
Fig. 1. (a) Original image, (b) Average filtered image, and (c)
Disk filtered image.

(a)   (b)   (c)
Fig. 2. Image after applying: (a) Gaussian filter, (b) Laplacian
filter, and (c) LOG filter.

(a)   (b)   (c)
Fig. 3. (a) Original image, (b) Guided filtered image, and (c) Un-
sharpen filtered image.

(b)   (b)   (c)
Fig. 4. Image after applying: (a) Wiener filter, (b) Motion filter,
and (c) Median filter.

4.2 Results

Results of applying ten filters are shown in previous figures. Average values for PSNR, MSE and STD for the ten filters are calculated and summarized in Table1. From these results, it is clear that the Gaussian filter gives higher PSNR value and lower MSE and STD value when compared to other filters as simplified in Chart-1.

TABLE 1

RESULTS OF APPLYING DIFFERENT FILTERS

Filter	PSNR	MSE	STD
Average filter	25.398	239.916	9.018
Disk filter	25.275	250.501	8.617
Gaussian filter	73.97	0.004	0.021
Laplacian filter	15.289	2417.99	24.284
Log filter	14.71	2695.28	29.942
Guided filter	36.917	14.176	2.337
Un-sharp filter	24.48	238.87	12.573
Wiener filter	39.791	9.649	1.928
Motion filter	25.689	244.385	8.302
Median filter	24.564	304.81	6.15

5 CONCLUSION

In this paper, different filters were used for preprocessing of full leg CT image to remove CT image noise and enhance contrast of grayscale to produce suitable image for diagnosis or convenient for other processing steps such as segmentation or classification. The performance of different filtering techniques was calculated in terms of PSNR, MSE and STD values. Results show that the Gaussian filter provides the best performance with 73.97 PSNR, 0.004 MSE and 0.021 STD values when compared with other filters.
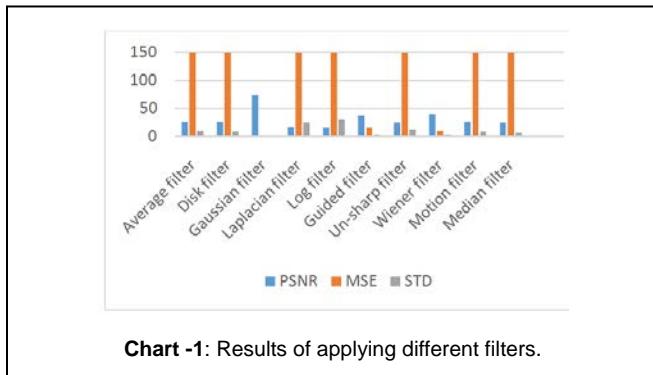
Chart -1: Results of applying different filters.

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