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Analysis of Edge Detection Algorithms and Denoising Filters on Digital X-Ray Images

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Abstract:
Image Enhancement is one of the preprocessing steps that have to be performed in all images for enhancing the given image in order to improve the quality of that image. One of the most important tasks in image processing is the removal of noise from an image. The greatest challenge is that while denoising, edges of images should be preserved and originality of image must not be compromise. In this paper we made an attempt to analyze performance of various filters over different types of noise and evaluate performance of various edge detecting algorithms. Digital x-ray image is taken as input and various noises are added to it. For each kind of noise (Salt & pepper, Gaussian, Speckle and Poisson) different types of filters (Mean, Median, Weiner and Gaussian) are applied and the parameters such as Mean Square Error, Average Difference and Structural Content are measured. Next, the input image is imposed on various edge detection algorithms and then comparison is done. Time taken by each algorithm (Canny, Sobel, Log, Roberts and Prewitt) to detect edge is measured in seconds. Finally suitable denoising filter and edge detecting algorithm are identified for digital x-ray image.

Key words: *Image preprocessing, Denoising Filters, Edge Detection Algorithms, Performance Parameters*

1. Introduction
The advantages of Digital Image Processing are flexibility, repeatability and the protection of original data accuracy. Image processing consists of various steps, such as Image preprocessing, Image Segmentation, Feature Extraction and Image classification. Image preprocessing includes scaling, Magnification, Reduction, Rotation, Mosaic and some Image Enhancement techniques like Contrast stretching, Noise filtering and Histogram modification. Image Segmentation is the process of subdividing an image into constitute region. Segmentation should stop when the object of interest in an application has been separated. Image segmentation involves techniques such as Threshold based segmentation, Region based segmentation and Edge detection. Feature extraction refers to the extraction of parameters or characteristic of the image. Image classification is the process of grouping images based on some parameters. The existing research works emphasized on removing noise and edge detection from remote sensing images, Transmission Electron Microscopy images, and Blood smear images. The content of this paper is organized as follows: section 2 describes the types of filters which will be applied for removing noise, section 3 describes the types of noise, section 4 describes the various edge detection techniques, section 5 describes the results and discussions made and section 6 highlights the conclusion and future work and section 7 lists the references.

2. Filtering Algorithms
Image processing is one of the most popular research areas when compared to all other fields. Image preprocessing is an important activity to be performed in the initial stage of every work. Filtering algorithms play vital role in image preprocessing. Image Denoising is not only for improving the quality of the image but is also used to remove some amount of noise from an image. In other words, without denoising, results will be improper or even irrelevant. Image filtering algorithms should preserve edges while removing the noise.

2.1. Median Filter
Median filter is an efficient and effective method that can be denoised by suppressing the isolated noise without blurring of edges. Initially, all pixel values are sorted in numerical order and the middle pixel value is taken to replace all other values.

2.2. Mean Filter

Mean filter is also called as convolution filter or average filter. It follows a procedure to create mask for all the pixels in the image. The values of pixel that falls under the mask are considered to be new pixel. Mean filter replaces each pixel value in an image with the mean value of its neighbors, including itself. Mean value is calculated by averaging the sum of all pixel values.

2.3. Wiener Filter

Wiener filter removes noise by inverts blurring. The major aim of this filter is to minimize the mean square error between original image and filtered image. In terms of mean square error, wiener filter is optimal which can be used to execute inverse filtering and noise smoothing.

2.4. Gaussian Filter

Gaussian filter is separable which allows fast computation and it is a non uniform low pass filter. The kernel coefficients diminish with increasing distance from the kernel's centre. Central pixels have higher weighting than those on the periphery.

3. Noise Types

Basically unwanted pixels in an image are referred to as noise. In other words pixels variation in an image is also called as noise. Noises are classified based on size, location, blur and pixel shift. Temperature also plays major role to induce noise in image sensor due to leakage. The image processed with noise affects the results of entire work, but in some cases noises are purposely added for some purpose such as "dithering", it improves the image perceptually. Mostly noises arise during image acquisition.
Different types of noise are listed below:

3.1. Gaussian Noise

Gaussian noise is represented as a bell shaped curve in the frequency spread spectrum because it follows Gaussian distribution. It is a type of statistical noise and also called as random variation impulsive noise or normal noise.

3.2. Salt-and-Pepper Noise

The image with salt and pepper noise contains white and black pixels. In other words salt and pepper noise can be defined as if it has bright pixels in dark regions and dark pixels in bright regions. Most of the images obtained from digital transmission may have salt and pepper noise. It is also called as spike noise or impulsive noise.

3.3. Poisson Noise

Poisson noise follows Poisson distribution and it is induced by quantum fluctuations of an image from an image sensor. Noises at different pixels are independent of each other so it is called photon shot noise. Most of the radiography images are subjected to a Poisson noise.

3.4. Speckle Noise

Speckle noise is very difficult to remove because it increases the mean gray level of local area in an image. Image recognition and interpretation would become difficult when this noise appears in the image. Mean and variance of single pixel is proportional to the mean and variance of local area in an image.

4. Edge Detection Algorithms

Edge detection in an image can be performed in many ways. Each and every edge detection algorithm follows some procedure to detect edges. However it can be classified into two types: Gradient and Laplacian. Gradient follows first derivative method and Laplacian follows second derivative method to detect edges. Roberts, Prewitt and Sobel algorithms come under gradient category. In other words, edge detection algorithms can be classified in two types: linear and non linear. Performance of edge detection algorithm should be measured in terms of identifying quality of edge detection. There are some criteria to measure the performance of edge detection algorithms such as speed of edge detection, mathematical measurement, applications and implementation requirements.
Basically edge detection algorithms should contain some common functionality:

- Edge Localization Accuracy (ELA) which refers that location of edge that should be very close as possible to the
- correct position.
- Always edges are detected after performing threshold operation in image. Some time high threshold values may lead
- to false edge detection. Good detection is the major and important characteristic in edge detection. In results, number
- of false edges should be minimal.
- Edge detection algorithm can detect edges in image even if it contains noise which refers to noise sensitivity.
- Efficiency of an algorithm refers to easy implementation and separate processing.
- Edge detection algorithms should be fast so as to be usable in image processing applications.
- Post processing is an important activity in edge detection because it is used to reduce noise and suppress non
- maximum edges.

4.1. Canny

Canny algorithm follows five procedures to detect edge in the region of interest. First, smoothing process is done by blurring image in order to remove noise. Second, large magnitudes are marked from region of interest. Third, maximum intensity values are marked as edges. This process can be called as "Non maximum suppression". Fourth, double thresholding is applied in order to identify the potential edges. Finally, Edges are detected by suppressing method or hysteresis.

4.2. Sobel

Basically Sobel edge detection algorithm is slower then Roberts algorithm because it follows computation on approximation of the gradient of the image intensity function.

4.3. Log

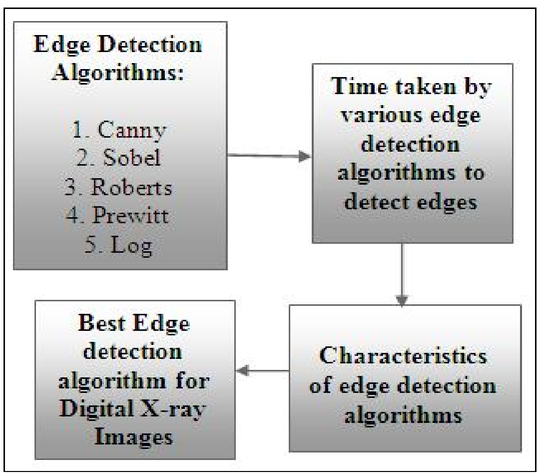
Laplacian of Gaussian (Log) edge detection algorithm performs image smoothing using Gaussian smoothing filter to detect the edges of image with intensity difference between the pixel values.

4.4. Roberts

The Roberts Edge filter is used to detect edges by applying a horizontal and vertical filter in sequence. Both the filters are applied to the image and summed to form the final result.

4.5. Prewitt

Prewitt operator is similar to the Sobel operator and is used for detecting vertical and horizontal edges in images.



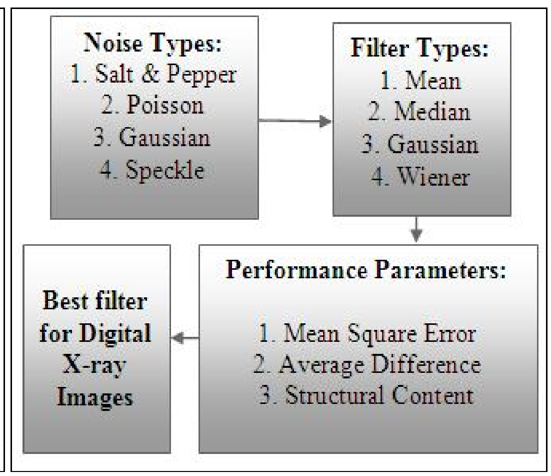


Figure 1: Flow diagram of Edge detection algorithms

Figure 2: Flow diagram of denoising filters

5. System Design & Results

In this work Performance of various edge detection algorithms are evaluated. The original bone image taken as input and various edge detection algorithms are applied on it.

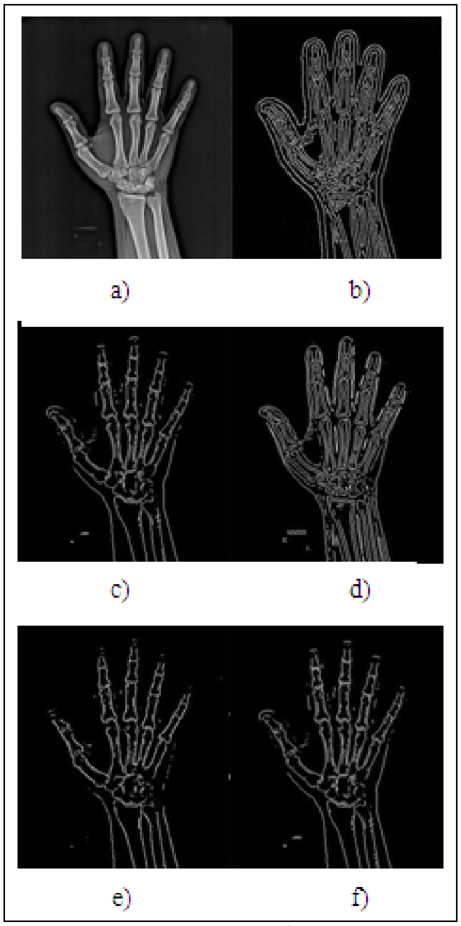


*Figure 3: a) Original Image, b) Image After applying Canny Algorithm,
c) Image After applying Sobel Algorithm, d) Image After applying Log Algorithm,
e) Image After applying Roberts Algorithm, f) Image After applying Prewitt Algorithm*

Speed/ Algorithm	Time (Seconds)
Canny	4.9613
Sobel	0.8032
Log	1.8089
Roberts	0.7899
Prewitt	0.8254

Table 1: Time taken by various edge detection algorithms measured in seconds

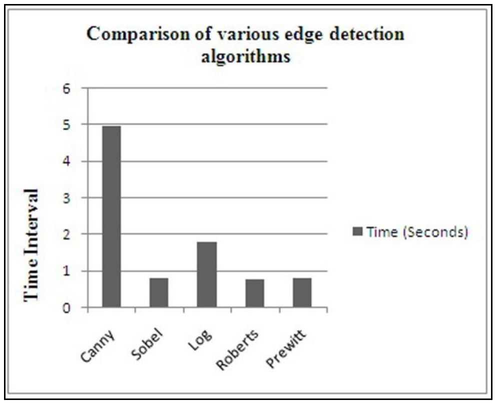


Figure 4: Time taken by various edge detection algorithms

Figure 4 represents the graph that is plotted between types of edge detection algorithms and time taken by each algorithm which is obtained from Table I.

Performance of various edge detection algorithms are evaluated by measuring the time taken by each algorithm in detecting edges. Even though canny algorithm takes more time to detect edges when comparing all other algorithms, Canny is treated as best performing algorithm based on some criteria such as good visual inspection, insensitive to noise and minute edge detection.

In this work 30 images are taken for analysis. Four types noises are applied in digital x-ray images and four types of filters are applied in noisy images in order to remove noise and enhance the quality of images accurately. Then performances of these filters are evaluated by measuring image quality metric parameters. These performance parameters are measured by comparing original image and denoised image.

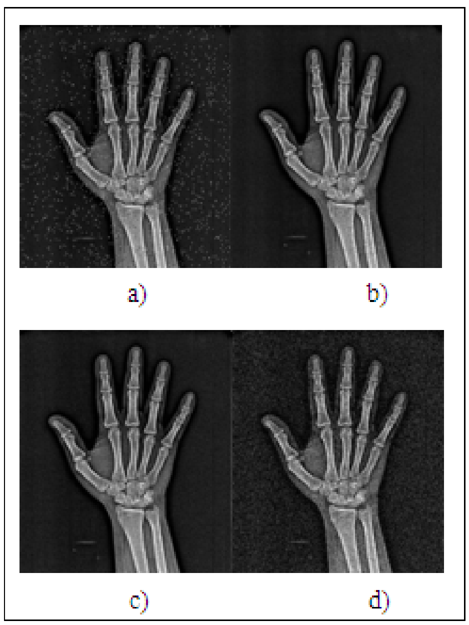


Figure 4: a) Image with Salt and Pepper Noise, b) Image with Speckle Noise, c) Image with Poisson Noise, d) Image with Gaussian Noise

Figure 4 represents bone images with Salt and Pepper noise, Speckle noise, Poisson noise and Gaussian noise. These noises are added to the bone images in a particular ratio.

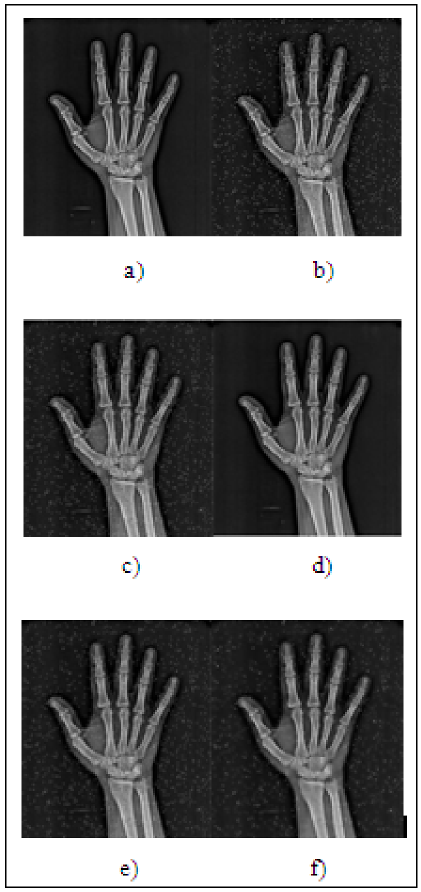


Figure 5: a) Original Image, b) Image with Salt and Pepper Noise, c) Image After applying Mean filter, d) Image After applying Median filter, e) Image After applying Gaussian filter, f) Image After applying Weiner filter

In figure 5, (a) represents the original images that are collected from the laboratories. (b) Salt and Pepper noise is added to the original image in order to measure the performance of various filters by applying filtering algorithms. Results of each performance parameters are listed below:

In this paper, in order to show how the images appears before adding noise, after adding noise and denoising, salt and pepper noise is added on the image and denoised using various filters. Even though only one example is shown here, experiments are conducted for various other noises such as Poisson noise, Gaussian noise and Speckle noise.

5.1. Mean Square Error (MSE)

Mean square error is given by

$$MSE = 1/MN \sum_{i=1}^{M} \sum_{j=1}^{N} ([g(i,f) - f(i,j)])^2$$

Where M and N are pixels in the horizontal and vertical dimensions of image, g denotes noise image and f denotes filtered image. The lowest mean square error represents best quality image.

5.2. Average Difference (AD)

Average difference is calculated by

$$AD = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} g(i,j) - f(i,j)$$

For the image quality measures, if a value of the AD is very low for an image of a particular noise type then it is the best quality image.

5.3. Structural Content (SC)

Structural content is calculated by

$$SC = \sum_{i=1}^{M}\sum_{j=1}^{N}(g(i,j) * g(i,j)) / \sum_{i=1}^{M}\sum_{j=1}^{N}(f(i,j) * f(i,j))$$

The similarity between original and filtered image is identified by structural content.

Filter/ Noise	Mean Filter	Median Filter	Weiner Filter	Gaussian Filter
Salt & Pepper	9.3718	3.2755	6.0936	7.8662
Gaussian	75.3123	60.5937	63.472	61.7429
Speckle	16.5047	31.97	47.2493	14.3465
Poisson	10.4016	13.2529	16.7197	9.7664
Gamma	75.318	10.6572	63.5297	61.7541

Table 2: Mean Square Error Values

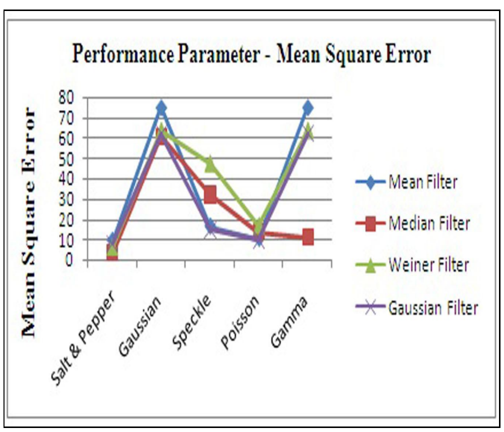
Filter/ Noise	Mean Filter	Median Filter	Weiner Filter	Gaussian Filter
Salt & Pepper	2.1959	0.0137	2.2014	2.1954
Gaussian	2.2668	0.386	2.283	2.2658
Speckle	0.0415	0.2312	0.0104	0.043
Poisson	0.0271	0.1838	0.0042	0.0288
Gamma	2.2728	0.3977	2.289	2.2715

Table 3: Average Difference Values

Filter/ Noise	Mean Filter	Median Filter	Weiner Filter	Gaussian Filter
Salt & Pepper	0.9744	1.0022	0.9508	0.9456
Gaussian	0.9821	0.9856	0.9886	0.9786
Speckle	1.0045	1.0051	0.9976	0.9941
Poisson	1.0043	1.0046	1.0032	1.0038
Gamma	0.9819	0.9852	0.9882	0.9814

Table 4: Structural Content Values

Table II represents MSE values of various types of filters when applied on various noisy images. Comparison shows that MSE value of Median filter values is very low when compared to other filters. Table III represents AD values of various types of filters when applied on various noisy images. A comparison show that AD value of Median filter values is low when compared to other filters. Table IV represents SC values of various types of filters when applied on various noisy images. A comparison show that SC value of Median filter values is high when compared to other filters.



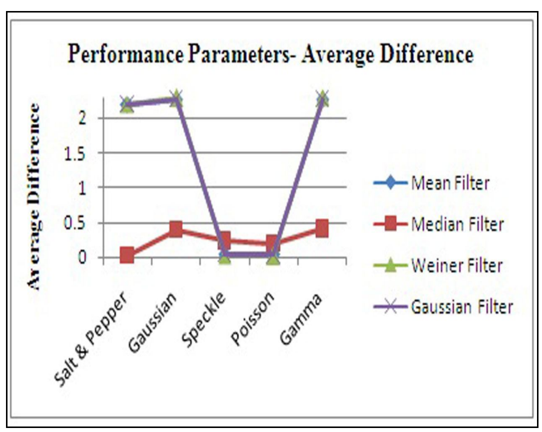


Figure 6: Performance of various filters in terms of MSE
Figure 7: Performance of various filters in terms of AD

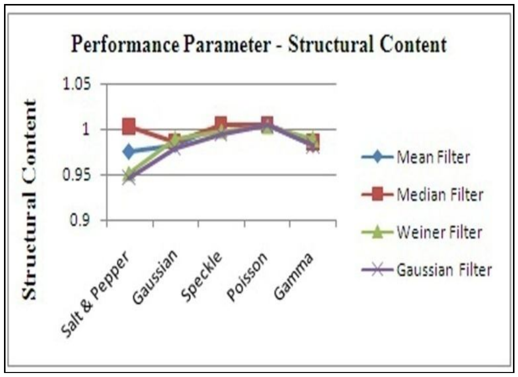


Figure 8: Performance of various filters in terms of SC

Figure 6 represents the graph that is plotted between types of noises and Mean Square Error value which are obtained from Table I. Figure 7 represents the graph that is plotted between types of noises and Average Difference value which are obtained from Table I. Figure 8 represents the graph that is plotted between types of noises and Structural Content value which are obtained from Table 1.

In this paper performance is evaluated with only three parameters such as Mean Square Error, Average Difference and Structural Content for various noises over various filters. There are many other parameters such as Peak to signal noise ratio, Normalized Correlation and Normalized Absolute Error can be used to evaluate the performance of various noises over various filters.

6. Conclusion

The performances of various kinds of filters over different noise types were analyzed and it is clear that Median filter and Gaussian filter gives the best performance over almost all the types of noise examined. On comparing these two filters it is seen that median filter shows average performance on all types of noise. From the comparison of various types of edge detection, it can be seen that the canny edge detector is an efficient algorithm in identifying the edges clearly even though canny takes more time when compared to others edge detection algorithms. Future work can be done for diagnosing Rheumatoid Arthritis using Bone Mineral Density with help of the values obtained from this work.

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