



Research article

An improved edge detection algorithm for X-Ray images based on the statistical range

Anil K. Bharodiya^{a,*}, Atul M. Gonsai^b^a UCCC & SPBCBA & SDHG College of BCA & I.T., BCA Department, Udhna, Surat, Gujarat, India^b Department of Computer Science, Saurashtra University, Rajkot, Gujarat, India

ARTICLE INFO

Keywords:

Computer science
Medical imaging
Image processing
Edge detection
X-ray
PSNR
MSE
RMSE
Orthopaedics

ABSTRACT

Edge detection is the prior stage to object recognition and considered as a pillar for image processing task. It is a process to detect such locations from images in terms of pixels where their intensity changing is abruptly. There are many types of images such as medical images, satellite images, articular images, industrial images, general purpose images etc. X-Ray is a type of medical image in which electronic radiation is passed into the human body to capture image of inner parts for better disease diagnoses by orthopaedics or radiologist. In this research paper, we have proposed an improved method to detect edges from human being's X-Ray images based on Gaussian filter and statistical range. Gaussian filter is used for image preprocessing and enhancement. Whereas, Statistical range is used to calculate difference between maximum and minimum pixels from every 3X3 image matrix partition. These two can work to detect edges from X-Ray images. We have also presented a comprehensive comparison of our proposed method with four existing latest methods/algorithms of edge detection. Apart from X-Ray images, experiments have also been conducted on human X-Ray images to detect edges. Further, we have found that our proposed method is superior in terms of MSE, RMSE, PSNR and computation time to detect edges from X-Ray images of human being.

1. Introduction

Computer Aided Diseases Diagnoses (CADD) is a continuous process of innovation and creation of new ideas to ease human life. The ultimate goal of CADD is to diagnose diseases from medical images in digital form [1]. There are many bio-medical imaging technologies available in modern days such as Radiography (X-Ray image), CT-Scan, ECG, Ultrasound, MRI, etc. All these medical imaging are best suited depending on the type of diseases to be detected from human body [1, 2]. The X-Ray, usually suggested by orthopaedics, is easily available and low cost imaging technology solution to capture image of injured bone parts of human body. The following Figs. 1(a) and 1(b) depicts X-Ray images of human right and left hand respectively.

To design a comprehensive CADD system for human X-Ray images, one needs to understand the basic methodology of image processing. Edge detection is one of the crucial pre-processing stages of digital image processing. It, basically, aims at identifying points in the image where the contrast and brightness changes abruptly [3]. In edge detection stage, the input is the original image and output is image in the form edges based on selected algorithm or method. This pre-processing stage is very crucial

for next stages of digital image processing such as segmentation, feature extraction and image interpretation.

Edge detection is the stage before image segmentation and feature or ROI extraction. It should be completed with high accuracy, low noise and in minimum computational time to achieve overall success of targeted tasks for example to detect fracture from digital X-Ray image. P.M.K.Prasad et al. [4] and paper [5] have discussed that there are two categories of traditional edge detection operators such as first order derivative/gradient based (Roberts, Prewitt and Sobel) and second order derivative (Laplacian, Laplacian of Gaussian and Difference of Gaussian). Canny edge detection can be optimal or running standard. As per paper [6] these operators are noise sensitive because they have high frequency amplification property.

In this paper, we have proposed a method to detect edges from X-Ray image of human being's arm based on Gaussian filter and statistical range. We have also shown that the proposed algorithm also detects edges much effectively on other types of standard image dataset. Further, we have also presented a comprehensive comparison of our proposed method with four existing latest methods/algorithms of edge detection based on MSE, RMSE, PSNR and computational time parameters. The

* Corresponding author.

E-mail address: anilbharodiya@gmail.com (A.K. Bharodiya).

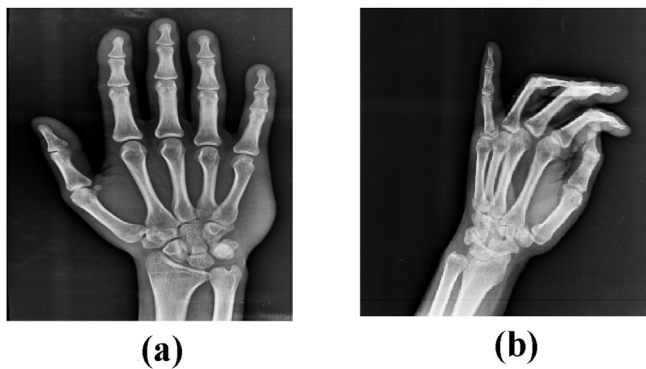


Fig. 1. (a) Right hand of human being. (b) Left Hand of human being.

paper is organized as follows: Section 2 discusses related work on latest edge detection methods. Section 3 describes methodology of edge detection from X-Ray images which includes background of statistical range, flowchart of proposed method and discussion on comparison parameters. Section 4 describes an algorithm for proposed method and pseudocode of an algorithm. In Section 5, we have conducted experiments in terms of comparison and discussed experimental results. Finally, the paper is concluded in Section 6 with future attempts to be made.

2. Related work

In modern days, many researchers have shown their interest in edge detection methods on various types of images. Following paragraphs discuss about related work on some latest edge detection methods from digital images.

Biswas and Hazra [3] have proposed an edge detection method based Modified Moore-Neighbor. This algorithm operates in two steps, namely modified Moore-Neighbor algorithm followed by range filtering to detect the edges. It takes long time to compute edges. Menga et al. [7] have proposed an edge detection method based on local adaptive canny method. It has more advantages as compared to global thresholding. Researchers [8] have also used canny algorithm along with gradient, length, and directional change of the edges for edge detection from noisy images. Zhang et al. [9] have designed an improved Sobel edge detection algorithm. This algorithm increases edge detection angle and hence it has more sufficient gradient calculation which increases detection accuracy and more edges are detected in the image. Lin and Wang [10] have devised WL operator as an edge detector based on a mathematical form of local variance. This operator is efficient for edge detection in medical images. Romani et al. [11] have introduced edge detection method based on RBF interpolation. The RBF interpolation is built-upon the compactly supported C2 Wendland function. They have implemented this method on X-Ray and standard images but accuracy and computational time are not much improved. Shubhangi et al. [12] have conducted a comparative study on Edge Detection of Femur Bones in X-Ray images. By comparing images obtained from various edge detection operators they have concluded that Laplace operator is best. But, they have not considered any standard parameters.

Jianfang et al. [13] have implemented a parallel image edge detection algorithm based on the Otsu-Canny Operator on the Hadoop Platform. The Otsu algorithm is used to optimize the Canny operator's dual threshold and improve the edge detection performance. The proposed approach takes less running time as compared to Canny, Parallel Canny and Otsu-Canny algorithms. As per paper [13] Canny operator is widely used to detect edges in images. However, as the size of the image dataset increases, the edge detection performance of the Canny operator decreases and its runtime becomes excessive. Gaurav and Ghanekar [14] have proposed a novel steganography algorithm based on local reference edge detection technique and exclusive disjunction (XOR) property is proposed. It exhibits better embedding capacity (bpp) compared to

existing steganography techniques retaining the values of PSNR and structural similarity (SSIM).

Yuan et al. [15] have proposed an optical edge detection method based on computational ghost imaging (CGI) with structured illuminations. By using this method edge can be detected from any direction. The test discussed in this paper shown that, SNR is larger than SSGI [16] using Sobel Operator. Kumar et al. [17] have proposed CWT and DWT based novel edge detection algorithms for wideband spectrum sensing in CRNs. To achieve good detection performance at poor SNR scenario, a moving average filtering strategy is adopted at different levels of DWT. They have not considered RF spectrum with the fading and shadowing effects of the real wireless channel. Dorafshan et al. [18] have presented comparison between the performance of common edge detectors and deep convolutional neural networks (DCNN) for image-based crack detection in concrete structures. Accuracy of edge detection methods calculated on 19 HD images, and found that, LOG was the most accurate with 98% and Roberts and Gaussian achieved 95% accuracy. In paper [19], a new edge detection method based on Neutrosophic Set (NS) structure via using maximum norm entropy (EDA-NMNE) is proposed. Average FOM and PSNR results for NORM entropy are 0.92 and 32.42, respectively which are higher than EDA-C, EDA-S, EDA-VAACO and EDA-ACWE methods. Azeroual and Afdel [20] have combined advantages of Faber Schauder Wavelet (FSW) and Otsu threshold to detect edges in a multi-scale way with low complexity. They have proposed 3 steps method for edge detection as bilateral filter, FSW extrema based coefficients selection based on Otsu threshold and finally, predictive algorithm to link edge points.

Mathur et al. [21] have proposed a novel approach to detect brain tumor from MRI images using k-means clustering, mamdani fuzzy inference system and sobel edge detector. It gives exact location of tumor based on appropriate threshold selection. However, it demands to set fuzzy rules to generate high accuracy. Akinlar and Topal [22] have developed a tool ColorED and paper [23] discussed about linear quaternion systems for color image edge detection but, these are not well suitable for medical images because they take much time to calculate ground truth edges. Kruggel [24] has presented an Acuity measure in Medical images. This measure is useful in automatic assessment of image quality. Linda and Jiji [25] have developed a method for Hairline breakage detection in X-Ray images using data fusion using two steps as anisotropic diffusion & wavelet for pre-processing and Expectation Maximization (EM) algorithm for segmentation. They have considered two performance parameters as sensitivity and accuracy.

Sengur et al. [26] have proposed a novel edge detection technique based on the texture feature coding method (TFCM). The TFCM is a texture analysis scheme that is generally used in texture-based image segmentation and classification applications. This scheme is based on transformation of an input image into texture feature image. They have compared result with Prewitt, Sobel, and Canny edge detection algorithms. However, they have not compared result with latest edge detection algorithms. They have not considered noisy images too. Guo and Sengur [27] have proposed neutrosophic edge detection algorithm (NSED) is proposed based on the neutrosophic. They have considered artificial images. Edge detection from medical images is not taken into consideration. They have not compared edge detection result with latest edge detection algorithms.

Gonzalez, Melin and Castillo [28] have developed a method to detect edges from Color Images based on Type-2 Fuzzy Logic. They have analysed different color formats such as Lab, HSV and RGB. The edge computing time is very high in this method. Gonzaleza et al. [29] have presented the optimization of a fuzzy edge detector based on the traditional Sobel technique combined with interval type-2 fuzzy logic. The goal of this paper was to provide ability to handle uncertainty in processing real world images. Edge detection is performed by manipulating Sobel method based on type-2 fuzzy logic. They have conducted experiments only on synthetic images. Gonzaleza et al. [30] have come up with a novel method based an improved Sobel edge detector based on

generalized type-2 fuzzy logic. In this method, they have used synthetic images. Melin et al. [31] have presented an edge detection method based on the morphological gradient technique and generalized type-2 fuzzy logic in theory of alpha planes. They have used only heights and approximation methods for defuzzification process. This algorithm requires an improvement in generalized type-2 fuzzy logic to consider other types of images such as medical images, satellite images etc. Alawad et al. [32] have presented a new method for edge detection based on Fuzzy Logic. This method works on 16 fuzzy templates which represents the edges shapes of possibility dissimilar. In this method, authors have not considered any image parameters related to image quality after edge detection. Comparison with other methods has not been conducted. Nikitha and Myna [33] have presented a Fuzzy Logic Based method for Edge Detection from Color Images. Edge at each pixel of an image is calculated using fuzzy rules around 3×3 spatial masks. Fuzzy inference system designed has 8 inputs, which corresponds to 8 neighboring pixels of an inputted image. Authors have not compared edge detection performance with other latest algorithms.

It is cleared from the above presented extensive literature review, that no method is perfect and suitable for all types of images. A particular edge detection method is subjective in nature because selection of method is highly dependent on type of image to be processed. It gives us relentlessly motivation to work in the field of human X-Ray image edge detection and here, in this paper we have presented a method for edge detection from human X-Ray images.

3. Methodology

In this section, we have discussed methodology of proposed method for edge detection. We have divided it into three sub-sections such as statistical range, considered Parameters for comparison and block diagram.

3.1. Statistical range

In Statistics and mathematics, the range is the difference between the maximum and minimum values of selected data set, matrix or linear data.

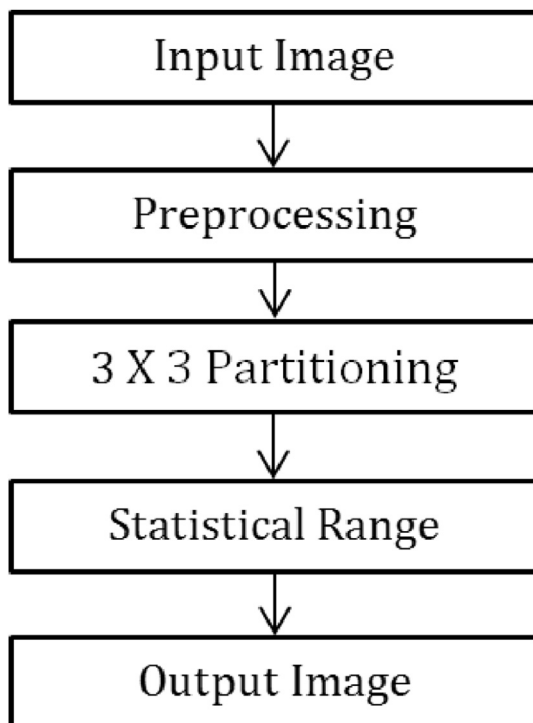


Fig. 2. Flowchart of the proposed method.

The range can act as an edge detector. Each pixel is replaced by range of the gray values in the neighbourhood [34]. Range also provides context for the mean, median and mode. A researcher can better understand about variety of data from range. In this paper, we have considered statistical range from every 3×3 matrix partitions from inputted human X-Ray image. The formula for range calculation is given below [35]:

$$\text{Statistical Range} = \text{Maximum Value} - \text{Minimum Value} \quad (1)$$

3.2. Parameters

Parameters are performance measures for any method or algorithm. In this paper, we have considered four different parameters such as MSE (Mean Square Error), RMSE (Root Mean Square Error) and PSNR (Peak Signal-to-Noise Ratio) as measurements for image quality and computational time parameter as time taken to detect edges from X-Ray images. PSNR (dB) is the ratio between possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. MSE is cumulative squared error between the compressed and the original image. As per papers [3, 36] the formulae to calculate PSNR, MSE and RMSE are given below:

$$\text{PSNR} = 10 \log_{10} \frac{(2^n - 1)^2}{\text{MSE}} \quad (2)$$

$$\text{MSE} = \frac{\sum_{M,N} [I1(m,n) - I2(m,n)]^2}{M \times N} \quad (3)$$

$$\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=0}^n (y_i - y'_i)^2} \quad (4)$$

where, in PSNR (Eq. 2) n is the number of bits of the image say 8 bits in the grayscale image. M and N are the number of rows and columns of image respectively. I is the intensity of image at location m, n . y_i = predicted values for time i of regression dependent variable y'_i . The PSNR value approaches infinity as the MSE approaches zero. A higher PSNR value provides a higher image quality [37]. In MSE (Eq. 3) $I1$ is the intensity of noise free image whereas, $I2$ is the intensity of noisy image. RMSE is a measure of the difference between predicted values and observed values. The smaller MSE and RMSE (μm –micrometre) values, the closer predicted and observed values are [38]. RMSE is the square root of MSE. It means that minimum MSE leads to minimum RMSE and vice versa. The main advantage is that if the target metric is in RMSE, comparison can be done using MSE. Thus, we can optimize MSE instead of RMSE.

3.3. Flowchart

Fig. 2 represents the complete flowchart of proposed method to detect edges from human X-Ray images. This method accepts an X-Ray image as an input. Image may contain noise, improper blurring or out of focus that is why we have pre-processed it. We have applied 2D Gaussian filter to blur X-Ray image and remove detail and noise. Gaussian filter is similar to the mean filter which is used to remove both types noises Gaussian and salt & pepper. It helps to detect false edges due to noise. According to Dunik and Straka [39] the Gaussian filter is depends on two principles. First, the joint conditional predictive state is assumed to be a Gaussian Probability Distribution Function for linear structure and second, for nonlinear functions there should be models to be approximated. The formula for 2D Gaussian filter is given below [40].

$$G(X, Y) = \frac{1}{2\pi\sigma^2} \cdot e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (5)$$

where, x is the distance from the origin in the horizontal axis, y is the distance from the origin in the vertical axis, and σ is the standard

deviation of the Gaussian distribution.

In the next stage, 3×3 partitioning of X-Ray image is obtained on the basis of raster scan strategy. Statistical local range is calculated on the basis of section 3.1 and centre pixel is replaced by range value in 3×3 matrix partition. This process is repeated until last 3×3 partition of the inputted X-Ray image.

We have compared our proposed algorithm with four latest methods/ algorithms such as ModifiedMN [3], Local ACED [7], Improved Sobel [9] and WL Operator [10]. The algorithm ModifiedMN [3] has high edge calculation time and it is highly recommended for standard images. Local ACED [7] algorithm is only useful in particle detection using edges from electron and transmission electron microscopy images. Improved Sobel [9] algorithm is used for edge detection for the calculation of the gradient of less template. The multiplication operation is time-consuming, resulting in complex image and hence edges are not much clear. The edge computation time is also high. The WL operator [10] includes many steps to calculate edges such as quasi high pass filter, thresholding, Quadratic form presentation, combination of first two terms, Isotropic symmetry calculation, Dynamic range calculation, Histogram display and finally, output with edge detection. Hence, this algorithm involves complex statistical and mathematical calculation which increases high calculation time. These points are motivation for us to work in the direction of edge detection not only from medical images such as X-Ray but also from standard images. We have shown that our algorithm is superior in terms edge detection quality, robust to noise and has less edge computation time. In comparative study, we have considered MSE, RMSE, PSNR and Computational time as performance analysis parameters.

This research work was approved by Dr. Rajeshbhai Diyora, Chief Doctor, Madhav Orthopedics Hospital, Surat, Gujarat, India and Dr. Hemantbhai Patel, Doctor, MGGZ Medical Centre, Surat, Gujarat, India. We have collected X-Ray images from these hospitals and openly available imageprocessingplace.com database. We have not revealed any personal or demographic information of the patients. All patients consent has been taken for using their x-ray images for research work. Further, we have not harmed any person, animal or natural resources.

4. Method

An algorithm is a sophisticated series of steps to be processed to arrive at a particular decision for solution of a problem. We have composed an algorithm in following steps to detect edges from the X-Ray images.

Algorithm: Edge Detection from X-Ray Images.

Step-1: Input an X-Ray Image.

Step-2: Gaussian filter.

Step-3: 3×3 partition of an image (Raster scan basis) achieved in step-2.

Step-4: Calculate Statistical Range (Maximum pixel value minus Minimum pixel value from every 3×3 partitions).

Step-5: Replace pixel value in centre of 3×3 partition with pixel value achieved in Step-4.

Step-6: Repeat step-3, step-4 and 5 until last 3×3 image partition.

Step-7: Output with Edge Detection.

In **step-1** an X-Ray image is inputted by the user. **Step-2** does Gaussian filter as discussed in section 3.3 for image smoothening. It also removes noise and false edges from the image. **Step-3** partitions an inputted image into 3×3 matrix image on raster scan basis. In **step-4** we have used statistical range as discussed in section 3.1. This step calculates range of 9 pixel values (3×3 matrix) by subtracting lowest pixel value from highest pixel value. Since an X-Ray image is gray scale, the value of pixel lies between 0 and 255. **Step-5** does replacement of centre pixel value of 3×3 matrix with pixel value achieved in step-4 that is range value. **Step-6** repeats step-3, step-4 and step-5 until last 3×3 partition of an inputted X-Ray image. Finally, **Step-7** displays the output X-Ray image with edge detection.

We have represented above algorithm in pseudo-code as follows. This

can be very easy for programmer to convert this pseudocode into real program for edge detection using proposed algorithm.

```
Pseudocode: Edge Detection from X-Ray Images
READ an X-Ray image
CONVERT an inputted image into gray scale image
DO Gaussian filter on gray scale image
LOOP from first row
  LOOP from first column
    SET LocalMatrix = (3 rows, 3 columns)
    CALCULATE range value of LocalMatrix as
      LRange = Max - Min
    REPLACE center of LocalMatrix by LRange value
  REPEAT UNTIL last column
REPEAT UNTIL last row
DISPLAY modified image as an output of edged image
```

5. Result and discussion

We have compared proposed edge detection algorithm with four latest algorithms such as ModifiedMN [3], Local ACED [7], Improved Sobel [9] and WL Operator [10]. We have developed our own database by collecting X-Ray images in person from two Hospitals such as Madhav Orthopaedics and MGGZ Medical Centre (Surat, Gujarat, INDIA). We have also downloaded some standard images from publically available dataset say imageprocessingplace.com. Fig. 3 and Fig. 4 show 10 different input images including human X-Ray images and some standard images. These images are used as a test dataset to conduct comparison. Figs. 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14 depict edged images (images with edge detection) based on four latest algorithms plus proposed method



Fig. 3. Test input images from 1 to 6 (row wise).



Fig. 4. Test input images from 7 to 10 (row wise).

using input images given in Fig. 3 and Fig. 4. We have used Scilab 5.5.2 (Open Source) as an image processing tool to implement above algorithm given in section 4 to perform edge detection. We have set following machine environment given in Table 1 for calculating MSE, RMSE, PSNR

and edge computation time.

Fig. 3 shows six X-Ray images of human arm. While, Fig. 4 shows four standard images. These images are used as test input images to detect edges based on proposed algorithm.

We have taken 3 parameters for the image quality assessment of edged images namely MSE, RMSE and PSNR which discussed in above section 3.2 in detail. Considering 10 input images given in Fig. 3 and Fig. 4, three parameters are analysed. It is analysed from the Table 2 that MSE value is lower in proposed algorithm in all 10 edged images as compared to other four algorithms. For Example, in input –1, MSE value of proposed algorithm is 3711.80 which is less than remaining four algorithms that is 5012.32, 5335.52, 4129.52 and 5122.74 respectively. In input – 3, MSE value of proposed algorithm is 3669.12 which is less than remaining four algorithms that is 4856.00, 5232.42, 4004.39 and 5087.19 respectively. In input – 10, MSE value of proposed algorithm is 10688.73 which is less than remaining four algorithms that is 17369.02, 18394.57, 13142.41 and 19095.61 respectively. In all other edged images given in Figs. 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14 and as per Table 2 MSE values of proposed algorithm are less than other four algorithms such as as ModifiedMN [3], Local ACED [7], Improved Sobel [9] and WL Operator [10]. Lower MSE and RMSE value promise better image quality [3, 38].

As per Table 2, it is analysed that RMSE value is lower in proposed algorithm in all 10 edged images as compared to other four algorithms. For Example, in input – 2, RMSE value of proposed algorithm is 55.73 which is less than remaining four algorithms that is 62.28, 67.79, 57.29 and 72.22 respectively. In input – 6, RMSE value of proposed algorithm is 99.59 which is less than remaining four algorithms that is 110.01, 107.37, 102.61 and 102.85 respectively. In input – 8, RMSE value of proposed algorithm is 119.75 which is less than remaining four algorithms that is 132.39, 135.15, 127.5 and 138.37 respectively. In all other

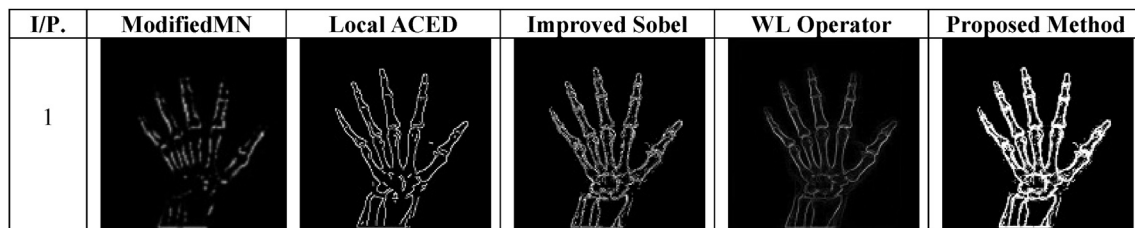


Fig. 5. Comparison of edge detection performance of different algorithms (input image. 1 of Fig. 3).

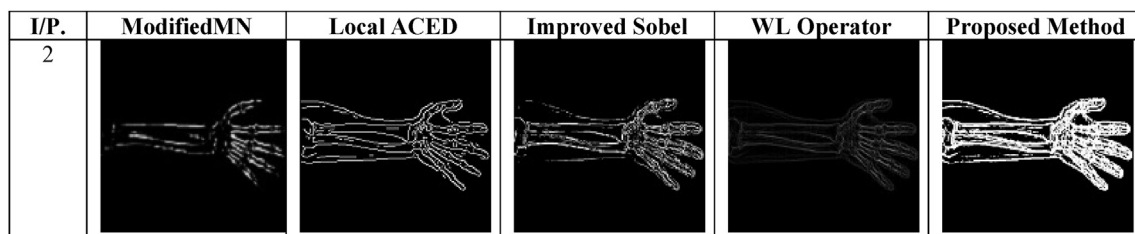


Fig. 6. Comparison of edge detection performance of different algorithms (input image. 2 of Fig. 3).

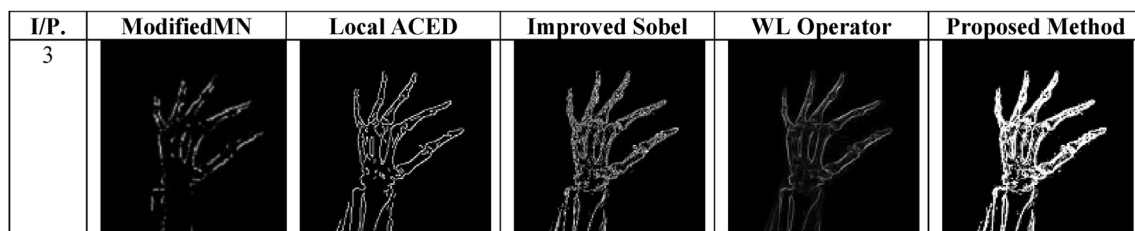


Fig. 7. Comparison of edge detection performance of different algorithms (input image. 3 of Fig. 3).

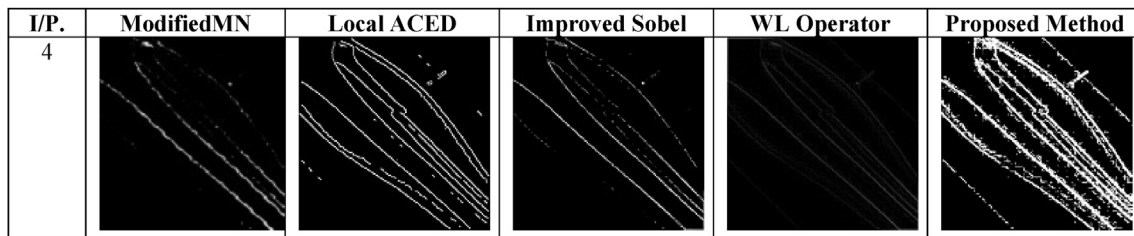


Fig. 8. Comparison of edge detection performance of different algorithms (input image. 4 of Fig. 3).

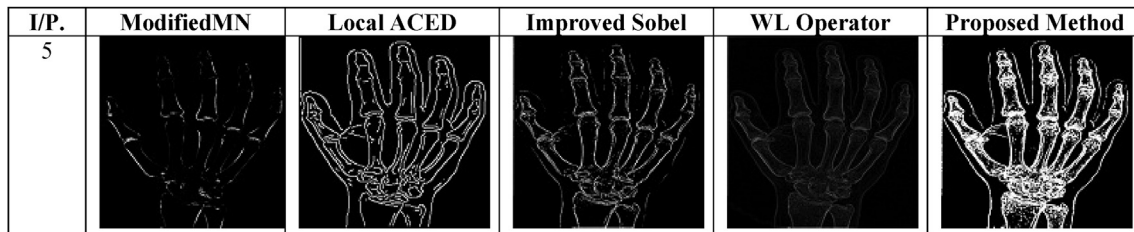


Fig. 9. Comparison of edge detection performance of different algorithms (input image.5 of Fig. 3).

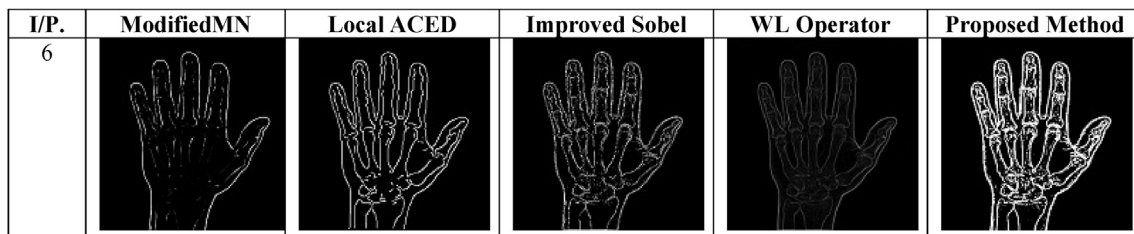


Fig. 10. Comparison of edge detection performance of different algorithms (input image. 6 of Fig. 3).

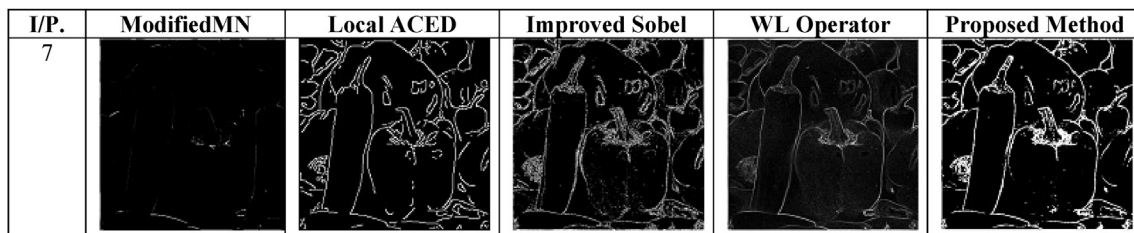


Fig. 11. Comparison of edge detection performance of different algorithms (input image. 7 of Fig. 4).



Fig. 12. Comparison of edge detection performance of different algorithms (input image. 8 of Fig. 4).

edged images given in Figs. 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14 and as per Table 2 RMSE values of proposed algorithm are less than other four algorithms.

We have analysed from Table 3 that PSNR value is higher in proposed algorithm in all 10 edged images as compared to other four algorithms. For Example, in input –1, PSNR value of proposed algorithm is 12.47 dB

which is more than remaining four algorithms that is 11.16 dB, 10.89 dB, 12.01 dB and 11.07 dB respectively. In input – 5, PSNR value of proposed algorithm is 9.87 dB which is more than remaining four algorithms that is 8.90 dB, 8.45 dB, 9.33 dB and 8.68 dB respectively. In input – 10, PSNR value of proposed algorithm is 7.88 dB which is more than remaining four algorithms that is 5.77 dB, 5.52 dB, 6.98 dB and 5.36 dB

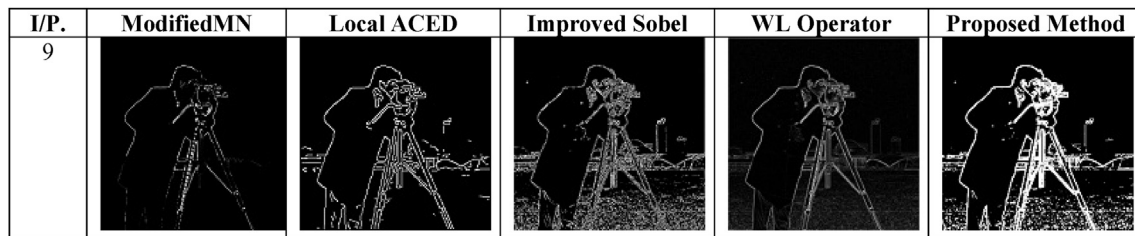


Fig. 13. Comparison of edge detection performance of different algorithms (input image. 9 of Fig. 4).

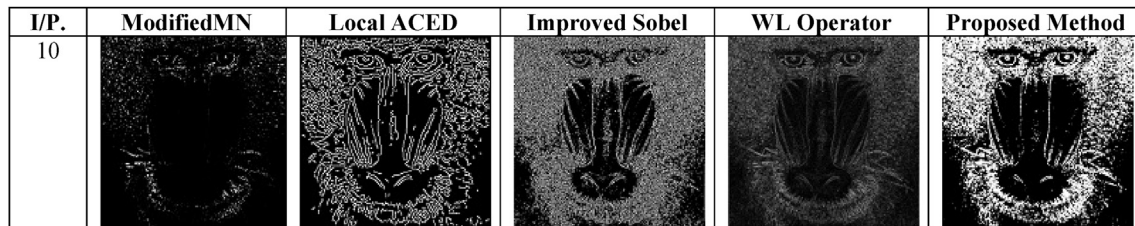


Fig. 14. Comparison of edge detection performance of different algorithms (input image. 10 of Fig. 4).

Table 1

Environment of machine.

Environment of Machine	
Operating System	Windows 7 S P 1 (64 bit)
Image Processing S/W.	Scilab 5.5.2
X-Ray Image Detail	512 * 512, 8 bit grayscale.jpg
Processor	Intel Core i5 1.70 GHz
RAM	4 GB
HDD Capacity	500 GB

respectively. In all other edged images given in Fig. 5–14 and as per Table 3 PSNR values of proposed algorithm are greater than other four algorithms. A higher PSNR value provides a higher image quality [37].

Edge computation time is very important, it is time taken by processor to convert an input image into edged image using particular edge detection algorithm/method. We have calculated computation time in seconds for all five algorithms given in Table 4. It is revealed from the Table 4 that edge computation time is quite lower in proposed algorithm in all 10 edged images as compared to other four algorithms. For Example, in input – 4, computation time of proposed algorithm is 5.94 s which is less than remaining four algorithms that is 300.40 s, 149.82 s, 186.51 s and 14.07 s respectively. In input – 5, computation time of proposed algorithm is 5.49 s which is less than remaining four algorithms that is 298.43 s, 150.98 s, 184.95 s and 14.38 s respectively. In input – 9, computation time of proposed algorithm is 5.54 s which is less than

remaining four algorithms that is 296.23 s, 148.51 s, 179.70 s and 14.26 s respectively. In all other edged images given in Figs. 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14 and as per Table 4 edge computation times of proposed algorithm are less than other four algorithms. Lower processing/computation time for edge detection can produce faster output with edged images.

The average MSE value of proposed algorithm is 9179.09 which is less than other four algorithms that is 11664.59, 12206.98, 10325.63 and 12343.37 respectively. The average RMSE value of proposed algorithm is 92.64 which is less than other four algorithms that is 104.49, 107.17, 98.06 and 107.62 respectively. The average PSNR value of proposed algorithm is 9.17 dB which is more than other four algorithms that is 8.12 dB, 7.87 dB, 8.70 dB and 7.84 dB respectively. The average edge computation time of proposed algorithm is 5.76 s which is less than other four algorithms that is 302.42 s, 149.73 s, 188.84 s and 14.19 s respectively.

6. Conclusion

In this paper, we have presented an efficient method for edge detection from human's arm X-Ray images based on Gaussian filter and statistical range. This method is not only used to detect edges from X-Ray images but also from other standard images as shown in Figs. 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14. The average MSE, RMSE and edge computation time of proposed algorithm are quite less and PSNR value of proposed algorithm is high as compared to ModifiedMN [3], Local ACED [7],

Table 2

Comparison of MSE & RMSE.

Test Input	Edge Detection Methods									
	ModifiedMN		Local ACED		Improved Sobel		WL Operator		Proposed Method	
	MSE	RMSE	MSE	RMSE	MSE	RMSE	MSE	RMSE	MSE	RMSE
1	5012.32	70.80	5335.52	73.04	4129.52	64.26	5122.74	71.57	3711.80	60.92
2	3879.21	62.28	4595.93	67.79	3282.44	57.29	5215.55	72.22	3105.29	55.73
3	4856.00	69.69	5232.42	72.34	4004.39	63.28	5087.19	71.32	3669.12	60.57
4	12270.40	110.77	12882.76	113.5	11976.27	109.44	13288.28	115.27	11500.91	107.24
5	8437.02	91.85	9374.07	96.82	7640.90	87.41	8890.31	94.29	6757.05	82.20
6	12101.22	110.01	11527.96	107.37	10529.60	102.61	10578.99	102.85	9917.88	99.59
7	17548.07	132.47	17825.22	133.51	15905.62	126.12	18016.23	134.22	13212.60	114.95
8	17528.07	132.39	18266.38	135.15	16255.89	127.5	19145.12	138.37	14339.26	119.75
9	17644.57	132.83	18634.95	136.51	16389.24	128.02	18993.68	137.82	14888.26	122.02
10	17369.02	131.79	18394.57	135.63	13142.41	114.64	19095.61	138.19	10688.73	103.39
Avg.	11664.59	104.49	12206.98	107.17	10325.63	98.06	12343.37	107.62	9179.09	92.64

Table 3
Comparison of PSNR.

Test Input	Edge Detection Methods (PSNR in dB)				
	ModifiedMN	Local ACED	Improved Sobel	WL Operator	Proposed Method
1	11.16	10.89	12.01	11.07	12.47
2	12.28	11.54	13.00	10.99	13.24
3	11.30	10.98	12.14	11.10	12.52
4	7.28	7.06	7.38	6.93	7.56
5	8.90	8.45	9.33	8.68	9.87
6	7.34	7.55	7.94	7.92	8.20
7	5.72	5.65	6.15	5.61	6.95
8	5.73	5.55	6.05	5.34	6.60
9	5.70	5.46	6.02	5.38	6.44
10	5.77	5.52	6.98	5.36	7.88
Avg.	8.12	7.87	8.70	7.84	9.17

Table 4
Comparison of edge computation time.

Test Input	Edge Detection Methods (Computation Time in Seconds)				
	ModifiedMN	Local ACED	Improved Sobel	WL Operator	Proposed Method
1	300.20	154.72	207.31	13.85	6.15
2	305.86	148.98	199.81	14.38	5.57
3	331.16	149.57	189.21	15.21	5.60
4	300.40	149.82	186.51	14.07	5.94
5	298.43	150.98	184.95	14.38	5.49
6	307.23	148.17	186.53	14.04	6.52
7	297.14	148.67	187.37	14.12	5.55
8	316.04	148.39	186.42	13.87	5.65
9	296.23	148.51	179.70	14.26	5.54
10	271.46	149.48	180.59	13.74	5.57
Avg.	302.42	149.73	188.84	14.19	5.76

Improved Sobel [9] and WL Operator [10] methods/algorithms. By considering Figs.3 and 4 and Tables 1, 2, 3, and 4, we have derived that proposed algorithm for edge detection from human X-Ray images is superior in MSE, RMSE, PSNR and processing time parameters as compared to other four methods/algorithms. MSE values of proposed algorithm are 21.31%, 24.80%, 11.10% and 25.64% less than other four algorithms respectively. RMSE values of proposed algorithm are 11.34%, 13.56%, 5.53% and 13.92% less than other four algorithms respectively. PSNR values of proposed algorithm are 11.45%, 14.18%, 5.13% and 14.50% more than other four algorithms respectively. Edge computation times of proposed algorithm are 98.10%, 96.15%, 96.95% and 59.41% less than other four algorithms respectively. It is clear from Figs. 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14 that proposed algorithm detects less false edges as compared to other methods. In short, our algorithm is robust to noise, better visual quality and minimum processing time. This is because we have used Gaussian filter for image pre-processing and enhancement and statistical range to calculate edges. The proposed algorithm can be used in medical field to develop CADD or DSS based on human X-Ray images or other types of digital images. Researchers can add more features in proposed method to increase PSNR and decrease MSE, RMSE and edge computation time. More comparison algorithms and parameters can be added to evolve and analyse proposed method.

Declarations

Author contribution statement

Anil K. Bharodiya: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Atul M. Gonsai: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Funding statement

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

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

We thank Dr. Hemantbhai Patel of MGGZ Medical Centre and Dr. Rajeshbhai Diyora of Madhav Orthopaedics for their guidance related to X-Ray imaging and providing digital X-Ray images in soft copy.

References

- [1] A.K. Bharodiya, A.M. Gonsai, 'Research Review on feature extraction methods of human being's X-Ray image analysis', *Natl. J. Sys. Inf. Technol.* 11 (1) (2018) 9–22. <http://srinca.edu.in/NJSIT.html>.
- [2] M. Park, B. Kang, S.J. Jin, et al., Computer aided diagnosis system of medical images using incremental learning method, *Expert Syst. Appl.* 36 (2009) 7242–7251.
- [3] S. Biswas, R. Hazra, Robust edge detection based on Modified Moore-Neighbor', *Optik, Int. J. Light Electron Opt.* 168 (2018) 931–943.
- [4] P.M.K. Prasad, D.Y.V. Prasad, G. Sasibhushana Rao, Performance analysis of orthogonal and biorthogonal wavelets for edge detection of X-ray images, *Procedia Comput. Sci.* 87 (2016) 116–121.
- [5] S. Bhardwaj, A. Mittal, A survey on various edge detector techniques, *Procedia Technol.* 4 (2012) 220–226.
- [6] H. Li, X. Liao, C. Li, et al., Edge detection of noisy images based on cellular neural networks, *Commun. Nonlinear Sci. Numer. Simul.* 16 (2011) 3746–3759.
- [7] Y. Menga, Z. Zhang, H. Yin, et al., Automatic detection of particle size distribution by image analysis based on local adaptive canny edge detection and modified circular Hough transform, *Micron* 106 (2018) 34–41.
- [8] H.O. Lawend, A.M. Muad, A. Hussain, Robust edge detection based on canny algorithm for noisy images, *J. Theor. Appl. Inf. Technol.* 95 (19) (2017) 5104–5114. <http://www.jatit.org/volumes/Vol95No19/17Vol95No19.pdf>.
- [9] K. Zhang, Y. Zhang, P. Wang, et al., An improved sobel edge algorithm and FPGA implementation, *Procedia Comput. Sci.* 131 (2018) 243–248.
- [10] W. Lin, J. Wang, Edge detection in medical images with quasi high-pass filter based on local statistics, *Biomed. Signal Process. Control* 39 (2018) 294–302.
- [11] L. Romani, M. Rossini, D. Schenone, Edge detection methods based on RBF interpolation, *J. Comput. Appl. Math.* 349 (2018) 532–547.
- [12] D.C. Shubhangi, S.C. Raghavendra, P.S. Hiremath, Edge detection of Femur bones in X-ray images – a comparative study of edge detectors, *Int. J. Comput. Appl.* 42 (2) (2012) 13–16.
- [13] C. Jianfang, C. Lichao, M. Wang, et al., Implementing a parallel image edge detection algorithm based on the otsu-canny operator on the Hadoop platform, *Comput. Intell. Neurosci.* 3 (2018) 1–12.
- [14] K. Gaurav, U. Ghanekar, Image steganography based on Canny edge detection, dilation operator and hybrid coding, *J. Inf. Secur. Appl.* 41 (2018) 41–51.
- [15] S. Yuan, D. Xiang, X. Liu, et al., Edge detection based on computational ghost imaging with structured illuminations, *Opt. Commun.* 410 (2018) 350–355.
- [16] L. Wang, L. Zou, S. Zhao, Edge detection based on subpixel-speckle-shifting ghost imaging, *Opt. Commun.* 407 (2018) 181–185.
- [17] A. Kumar, S. Saha, R. Bhattacharya, Wavelet transform based novel edge detection algorithms for wideband spectrum sensing in CRNs, *Int. J. Electron. Commun. (AEÜ)* 84 (2018) 100–110.
- [18] S. Dorafshan, R. Thomas, M. Maguire, Comparison of deep convolutional neural networks and edge detectors for image-based crack detection in concrete, *Constr. Build. Mater.* 186 (2018) 1031–1045.
- [19] E. Sert, D. AVCI, A new edge detection approach via neutrosophy based on maximum norm entropy, *Expert Syst. Appl.* 115 (2018) 499–511.
- [20] A. Azeroual, K. Afdel, Fast image edge detection based on faber schauder wavelet and Otsu threshold, *Heliyon* 3 (12) (2017), e00485, 1–19.
- [21] N. Mathur, S. Mathur, D. Mathur, A novel approach to improve sobel edge detector, *Procedia Comput. Sci.* 93 (2016) 431–438.
- [22] C. Akinlar, C. Topal, ColorED: color edge and segment detection by edge drawing (ED), *J. Vis. Commun. Image Represent.* 44 (2017) 82–94.
- [23] S. Yasmin, S. Sangwine, Multi-directional colour edge detector using LQS convolution, *IET Image Process.* 12 (7) (2018) 1111–1116.
- [24] F. Kruggel, A simple measure for acuity in medical images, *IEEE Trans. Image Process.* 27 (11) (2018) 5225–5233.
- [25] H. Linda, W. Jiji, Hairline breakage detection in X-ray images using data fusion, *Multimed. Tools Appl.* 77 (13) (2018) 17207–17222.

- [26] A. Sengur, S. Guo, M. Ustundag, et al., A novel edge detection algorithm based on texture feature coding, *J. Intell. Syst.* 24 (2) (2015) 235–248.
- [27] Y. Guo, A. Sengur, A novel image edge detection algorithm based on neutrosophic set, *Comput. Electr. Eng.* 40 (2014) 3–25.
- [28] C.I. Gonzalez, P. Melin, O. Castillo, Edge detection method based on general type-2 fuzzy logic applied to color images, *Information* 8 (3) (2017) 104.
- [29] C.I. Gonzalez, P. Melin, J.R. Castro, et al., Optimization of interval type-2 fuzzy systems for image edge detection, *Appl. Soft Comput.* 47 (2016) 631–643.
- [30] C.I. Gonzalez, P. Melin, J.R. Castro, et al., An improved sobel edge detection method based on generalized type-2 fuzzy logic, *Soft Comput* 20 (2) (2016) 773–784.
- [31] P. Melin, C.I. Gonzalez, J.R. Castro, et al., Edge-detection method for image processing based on generalized type-2 fuzzy logic, *IEEE Trans. Fuzzy Syst.* 22 (6) (2014) 1515–1525.
- [32] M.A. Alawad, F.D.A. Rahman, O.O. Khalifa, et al., Fuzzy logic based edge detection method for image processing, *Int. J. Electr. Comput. Eng. (IJECE)* 8 (3) (2018) 1863–1869.
- [33] B.S. Nikitha, A.N. Myna, Fuzzy logic based edge detection in color images, *Int. Adv. Res. J. Sci. Eng. Technol.* 2 (2) (2015) 65–69.
- [34] E. Berry, *A Practical Approach to Medical Image Processing*, Taylor & Francis Group, 2008, pp. 63–65.
- [35] ThoughtCo, <https://www.thoughtco.com/what-is-the-range-in-statistics-3126248>, accessed 02 2018.
- [36] S. Biswas, D. Ghoshal, R. Hazra, A new algorithm of image segmentation using curve fitting based higher order polynomial smoothing, *Optik* 127 (2016) 8916–8925.
- [37] A. Hore, D. Ziou, 'Image Quality Metrics: PSNR vs. SSIM', *20th International Conference On Pattern Recognition*, Istanbul, Turkey, 2010, pp. 2358–2361.
- [38] K. Juna, S. Kimb, H. Jic, Estimating pig weights from images without constraint on posture and illumination, *Comput. Electron. Agric.* 153 (2018) 169–176.
- [39] J. Dunik, O. Straka, State estimate consistency monitoring in Gaussian filtering framework, *Signal Process.* 148 (2018) 145–156.
- [40] K. Ito, K. Xiong, Gaussian filters for nonlinear filtering problems, *IEEE Trans. Autom. Control* 45 (5) (2000) 910–927.