A Novel Modified Sobel Algorithm for Better Edge Detection of Various Images

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Abstract – Edge detection is one of the crucial aspects of image processing techniques. This edge detection technique is widely used for object identification and segmentation processes. Edge detection mechanism helps a lot in the processes of filtering the unwanted elements in an image. Many edge detection mechanisms namely Sobel edge detection, Prewitt edge detection, Laplacian edge detection, and Roberts edge detection have been used in image processing. In this paper, the various characteristics of above mentioned edge detection algorithms are studied and it has been found that Sobel edge detection algorithm works well compared with other edge detection algorithms. Further, a novel modified Sobel edge detection algorithm is proposed in this paper. The performance of the proposed modified Sobel algorithm is compared with the all the other mentioned edge detection algorithms. The results show that the proposed modified Sobel edge detection take less time to detect the edges of various images.

Index Terms – Image Processing, Edge Detection, Sobel, Prewitt, Laplacian, Roberts, Modified Sobel.

1. INTRODUCTION

Image Processing is the process of utilizing an image as input and generating digital images in the form of output. The images are considered as matrix, whose rows and columns indices identify the points in the image. It is a computer algorithm used to perform image processing techniques in various digital images. Digital image processing has many advantages than the analog image processing. Feature extraction, Pattern recognition, Segmentation, and Image Morphology Operations are widely used techniques of digital image processing [1, 2]. An Edge can be used to extract the features of an image. These features are used for high level computer vision algorithms [3]. Edge detection is a main part of image segmentation. Edges characterize boundaries of two different regions and therefore identifying the edges are the fundamental problems of image processing. Object detection can be achieved through edge detection which has numerous applications like medical image processing, Biometrics and etc. Edges have meaningful features and consist of significant information. Many edge detection algorithms have been developed for detecting the edges of digital images. Gradient based classical operator like Roberts, Prewitt, and Sobel algorithms are used to detect the edges of the images. These algorithms failed to give sharp edges and were highly sensitive to noise image. Laplacian is a second derivative operator used to detect the false edges. Laplacian is very sensitive to noise [4]. This paper introduces the following edge detection algorithms such as Sobel, Prewitt, Laplacian and Roberts. Further, a novel modified Sobel Edge Detection algorithm in proposed in this paper. Modified Sobel edge detection algorithm outperforms well in detecting the edges of various images compared with all other algorithms.

2. RELATED WORK

K. J Anil [1] discussed about the fundamentals of image processing as well as the various types of image processing. The author also has discussed the working process of edge detection in a detailed manner. S. Gopinathan et al [2] discussed the edge detection mechanisms such as Sobel, Laplacian and derived Modified Sobel edge detection as a proposed method. Further, explained about the working process of modified Sobel edge Detection Method and the presented results showed that the method detects the edges better than the existing filters. Samta Gupta et al [3] discussed the Sobel Edge detection algorithm along with the usage of 2D spatial gradient on an image and how to use a dimension for 5*5 Sobel operator function to detect the edges in matlab. Rashmi et al [4] discussed the most commonly used edge detection techniques such as First Order edge detection, Canny edge detection, Gradient based edge operator and Classical operators Such as Sobel, Prewitt, Roberts and Second derivative operators were studied. Each Operator is explained well. The authors concluded that Canny Operator worked well compared with other algorithms. The best was chosen based on the performance of reduced noise as well as sharpen edges etc. Rashi Agarwal [5] discussed and proposed a Bit-Planes Sobel Operator derived from Sobel Operator for better edge detection. Pooja Sharma et al [6] focused mainly on the edge detection techniques and explained different edge detection techniques like Sobel, Prewitt, Laplacian, Roberts, Canny and their working Methodology. R. Muthu Krishnan et al [7]

discussed about the image segmentation process to separate an image into various components and further the authors also discussed the most frequently used edge detection methods for image segmentation. Debomist Ray [8] discussed the types of Edge detection algorithms in Image processing. Mohsen Sharif et al [9] focused on Edge detection and also discussed about the classification of operators such as Gradient Edge Detectors, Zerocrossing, Laplacian of Gaussian, Gaussian Edge detector, Colored Edge detector along with the advantages and disadvantages of Edge Detectors. Further, the Comparison of edge Detectors was performed based on the Signal to Noise Ratio, and Average Risk. Tamilselvi Nagasangar et al [10] discussed the six different edge detection algorithms such as Sobel, Prewitt, Roberts, Log, Zerocross and Canny algorithms and further analyzed these algorithms. The analysis were performed on various types of images and derived which algorithm is best and worst. Finally canny edge detection algorithm obtained higher rank [10]. G.T Shrivakshan et al [11] discussed the comparison of the following algorithms namely Sobel, Prewitt, Roberts, Laplacian, and Canny algorithms and studied the advantages and disadvantages of those algorithms. Canny edged detection is costly operator than other operators and canny outperformed well compared with other operators. Saket Bhardwaj et al [12] discussed the comparison between edge detection techniques to find which edge detection technique gives better result. The algorithms were Sobel, Prewitt, Roberts, Log, Canny, basic declivity edge detector and modified declivity edge detector algorithms are discussed. The computational time depicted that the Modified declivity operator is better than the other algorithms [12]. Subhro Sarkar et al [13] discussed about the classification of edge detectors and presented the analysis of edge detection techniques on medical image processing. The advantages and disadvantages of each operator have been discussed. Canny method gave the suitable results for medical images [13]. Radhika Chandwadkar et al [14] discussed about the comparative study of the Sobel and Canny Edge detection and also discussed the importance of edge detection. The comparison of Sobel and canny represented that canny overcomes the drawbacks of Sobel [14]. AbdulSattar M.khidhir et al [15] discussed the FPGA Base edge detection using Modified Sobel operator to detect the edges in gray scale images. The modified Sobel edge detection produced better results than the existing Sobel Operator [15]. Ireyuwa et al [16] discussed about the various steps involved in edge detection and different edge detection techniques such like Sobel, Prewitt, Roberts and Canny edge detection along with the advantage and disadvantages of edge detection operators. The comparison of all the above edge detection operators showed that the canny edge detection produced the better results [16].

3. SOBEL EDGE DETECTION

In image processing as well as in computer vision the Sobel operator is used. It is also known as Sobel-Feldman operator or Sobel filter. It creates an image emphasizing edges when it is used in edge detection algorithm in image processing. Sobel Operator is used to detect the edges of an image. Sobel operator mask value is given below.

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

Figure 1: 3*3 Convolution mask

This operator as shown in Figure 1 used two 3*3 convolution mask which is used to detect the edges, one mask for the horizontal direction and other for vertical directions. Gradient of an original image is calculated. The gradient of the image is calculated by the following formula,

Gx=((2*C(i+2,j+1)+C(i+2,j)+C(i+2,j+2)) - (2*C(i,j+1)+C(i,j)+C(i,j+2)));

Gy=((2*C(i+1,j+2)+C(i,j+2)+C(i+2,j+2)) - (2*C(i+1,j)+C(i,j)+C(i+2,j)));

The gradient magnitude is given by

B (i, j) =abs (Gx) + abs (Gy);

The angle of the spatial gradient is given by

Θ=arctan (Gx/Gy)

Set the threshold values to the edge detection to find the proper edges of an image. It has been found that at Threshold value T=100 Sharp and accurate edges are determined.

4. MODIFIED SOBEL EDGE DETECTION

In this paper, the Sobel edge detection is considered and a novel modified edge detection is proposed. The proposed modified algorithm is referred as "Modified Sobel Edge Detection". In the proposed modified sobel edge detection method a new procedure is introduced to create the mask values to detect the edges of the images. The derivation of new mask values is based on the sobel edge detection method. The design of a 3*3 convolution mask given in matrix Gx, Gy of proposed modified sobel edge detection is as follows.

0	0	0
-1	-2	-1
1	2	1

Gx

0	-1	1
0	-2	2
0	-1	1

Gy

Figure 2: 3*3 Convolution mask

The Figure 2 shows the mask values of modified Sobel operator. The proposed mask values can be used separately for obtaining the gradient component of images in both orientation i.e. GX and GY.

The proposed mask values are derived from the existing Sobel mask values and the detailed illustration of the proposed mask values are depicted below:

Gx mask value is used to find the horizontal edge detection.

Gy mask value is used to find the vertical edge detection

Gx mask value can be calculated from the following equation

Modified Sobel 1row = Sobel 1Row+Sobel 3 Row

Modified Sobel 2 row = Sobel 1Row+Sobel 2 Row

Modified Sobel 3row = Sobel 2Row+Sobel 3 Row

Gy mask value can be calculated from the following equation

Modified Sobel 1Column = Sobel 1Column+Sobel 3 Column

Modified Sobel 2 Column = Sobel 1 Column +Sobel 2 Column

Modified Sobel 3 Column = Sobel 2 Column +Sobel 3 Column

The proposed kernels can be applied separately to the input images, to calculate the separate measurements of the gradient components in each orientation (Gx and Gy).

i+1,j	i+1,j+1	i+1,j+2
i+2,j	i+2,j+1	i+2,j+2

Gx

Figure 3: Convolution Kernel of Horizontal Direction

The Figure 3 shows the convolution kernel of horizontal Direction of edges. This kernel is used to find the edges of horizontal direction.

Where

Gx=((C(i+2,j)+C(i+1,j)+2*C(i+2,j+1)) -
(C(i+1,j+2)+2*C(i+1,j+1)+C(i+2,j+2)));

The above formula is used to find the Gx values of horizontal direction. This formula is framed from Figure 3. The value of Gx can be obtained as illustrated below:

First, calculate the summation of the second row first column and third row first and second column from the Figure 3. Similarly, calculate the summation of the second row second and third column and third row third column from the Figure 3. Finally, the Gx can be calculated by subtracting the both summation results. The resultant value is placed in the first row and first column of the 3*3 output matrix. This process is repeated until all the portions of the output matrix are placed with the results. The size of the input and output matrices are same.

	i,j+1	i,j+2
	i+1,j+1	i+1,j+2
	i+2,j+1	i+2,j+2

Gy

Figure 4: Convolution Kernel of Vertical Direction

The Figure 4 shows the convolution kernel of horizontal Direction of edges. This kernel is used to find the edges of horizontal direction.

Where

Gy=((C(i,j+1)+2*C(i+1,j+1)+C(i,j+2)) -
(C(i+2,j+2)+2*C(i+1,j+2)+C(i+2,j+1)));

The above formula is used to find the Gx values of horizontal direction. This formula is framed from Figure 4. The value of Gy can be obtained as illustrated below:

First, calculate the summation of the first row second c and third column and second row second column from the Figure 4. Similarly, calculate the summation of the second row third column and third row second and third column from the Figure 4. Finally, the Gy can be calculated by subtracting the both summation results. The resultant value is placed in the first row and first column of the 3*3 output matrix. This process is repeated until all the portions of the output matrix are placed with the results. The size of the input and output matrices are same.

The gradient magnitude is given by

B (i, j) =abs (Gx) + abs (Gy);

B (i, j) =sqrt (Gx. ^2+Gy. ^2);

B (i, j) =Gx +Gy;

The gradient magnitude is obtained from the sum of Gx and Gy values. This gradient magnitude is used to detect the edges in both directions.

Steps for modified Sobel edge detection algorithm

Step 1: Read the input image.

Step2: Calculation of Gx by combining the mask values and input image

Step 3: Calculation of Gy by combining the mask values and input image

Step 4: Find the gradient by calculating the summation of Gx and Gy.

Step 5: Set the threshold value T.

Step 6: Edges are detected for the given input image.

5. RESULTS AND DISCUSSIONS

5.1. Input Images (Butterfly, Human, Kidney, Lungs)

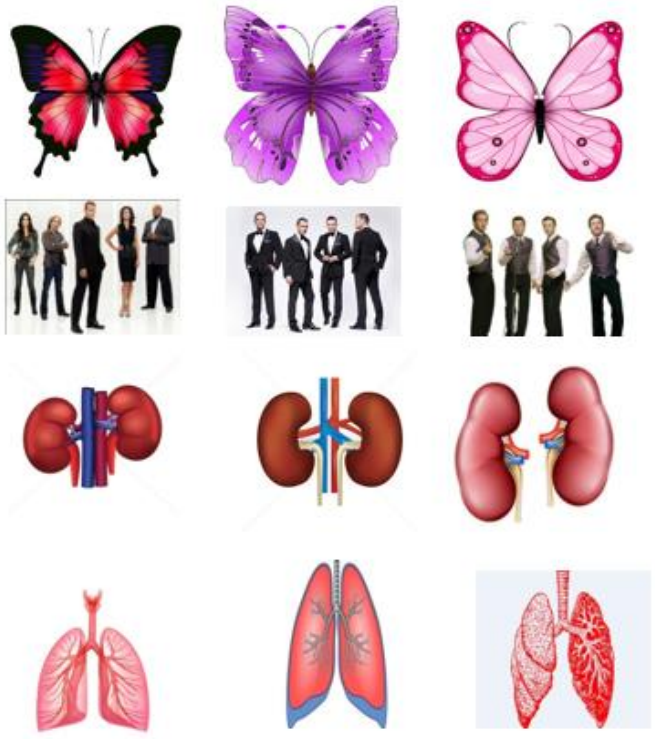

Figure 5: Input Images

The Figure 5 shows the various input images that are used to validate the proposed edge detection. The input image categorized into four groups namely Butterfly, Human, Kidney, and Lungs. Three sets of images are considered for each category to validate the proposed method. The list of images shown in Figure 5 are tested for the following algorithms.

- Sobel Edge Detection
- Modified Sobel Edge Detection
- Prewitt Edge detection
- Laplacian Edge Detection
- Roberts Edge Detection.

5.2. Sobel Edge Detection (Butterfly, Human, Kidney, Lungs)

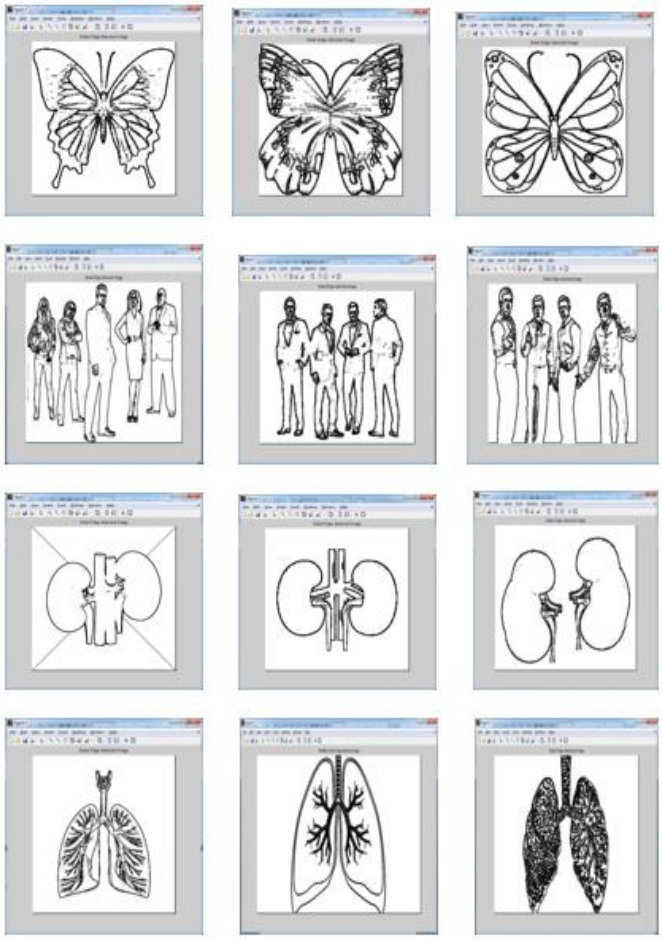

Figure 6: Sobel Edge Detection

Sobel Edge detection is used to detect the edges of the input images such as butterfly, Human, Kinney, and Lungs. The threshold value is set as 100 for sobel algorithm to detect the accurate edges of the given input images. The result of sobel edge detection for various input images are shown in Figure 6.

5.3. Modified Sobel Edge Detection (Butterfly, Human, Kidney, Lungs)

Modified Sobel Edge detection is used to detect the edges of the input images such as butterfly, Human, Kinney, and Lungs. The threshold value is set as 100 for modified sobel algorithm to detect the accurate edges of the given input images. The result of modified sobel edge detection for various input images are shown in Figure 7.

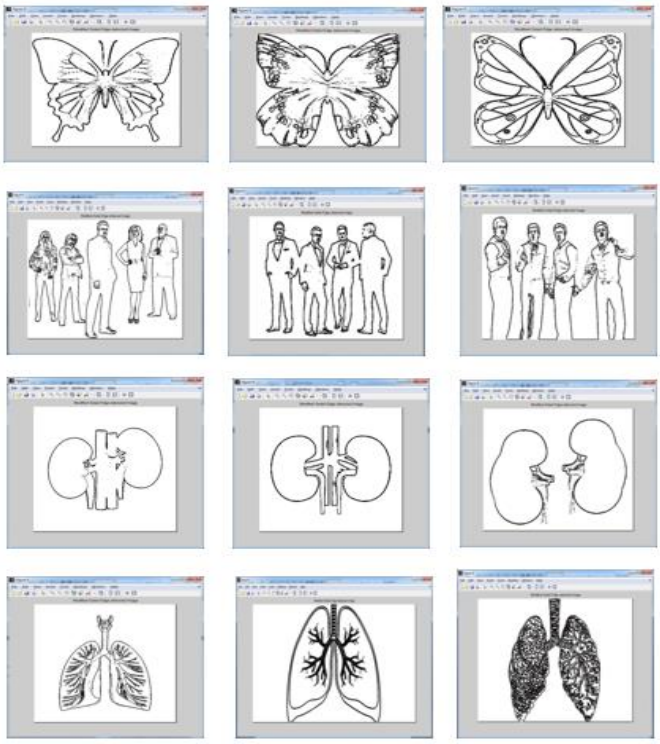

Figure 7: Modified Sobel Edge Detection

5.4. Prewitt Edge Detection (Butterfly, Human, Kidney, Lungs)

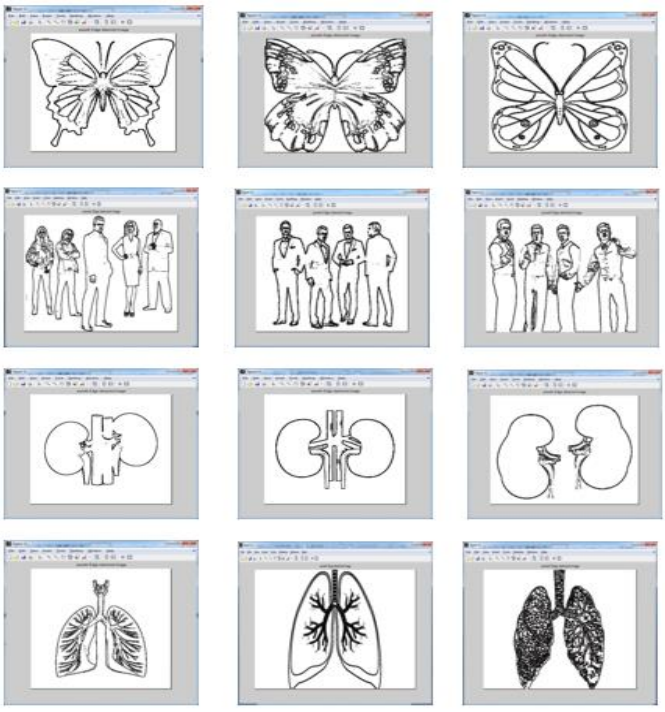

Figure 8: Prewitt Edge detection

Prewitt Edge detection is used to detect the edges of the input images such as butterfly, Human, Kinney, and Lungs. The threshold value is set as 100 for Prewitt algorithm to detect the accurate edges of the given input images. The result of Prewitt edge detection for various input images are shown in Figure 8.

5.5. Laplacian Edge Detection (Butterfly, Human, Kidney, Lungs)

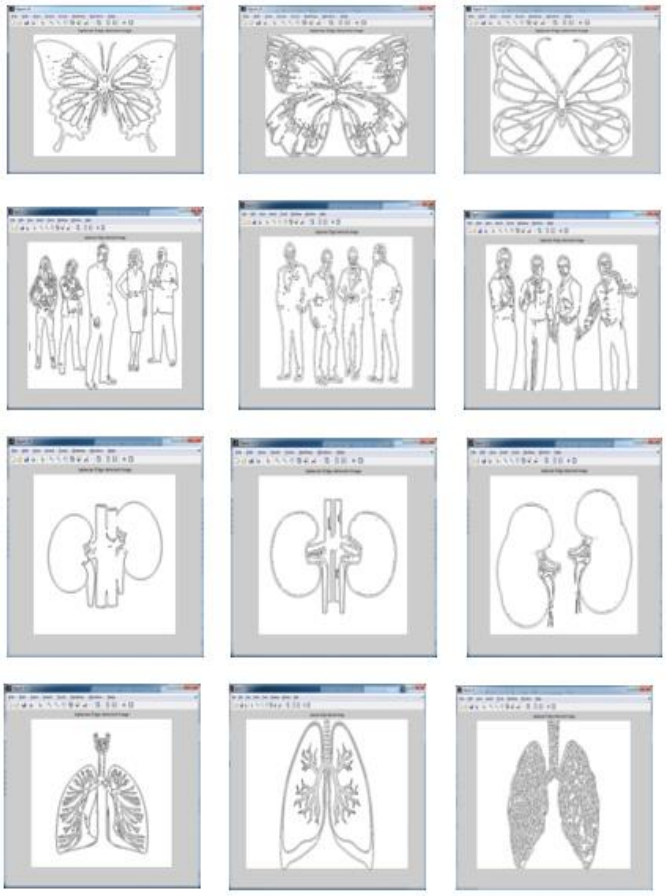

Figure 9: Laplacian Edge detection

Laplacian Edge detection is used to detect the edges of the input images such as butterfly, Human, Kinney, and Lungs. The threshold value is set as 100 for Laplacian algorithm to detect the accurate edges of the given input images. The result of Laplacian edge detection for various input images are shown in Figure 9.

5.6. Roberts Edge Detection (Butterfly, Human, Kidney, Lungs)

Roberts Edge detection is used to detect the edges of the input images such as butterfly, Human, Kinney, and Lungs. The threshold value is set as 100 for Roberts algorithm to detect the accurate edges of the given input images. The result of Roberts edge detection for various input images are shown in Figure 10.

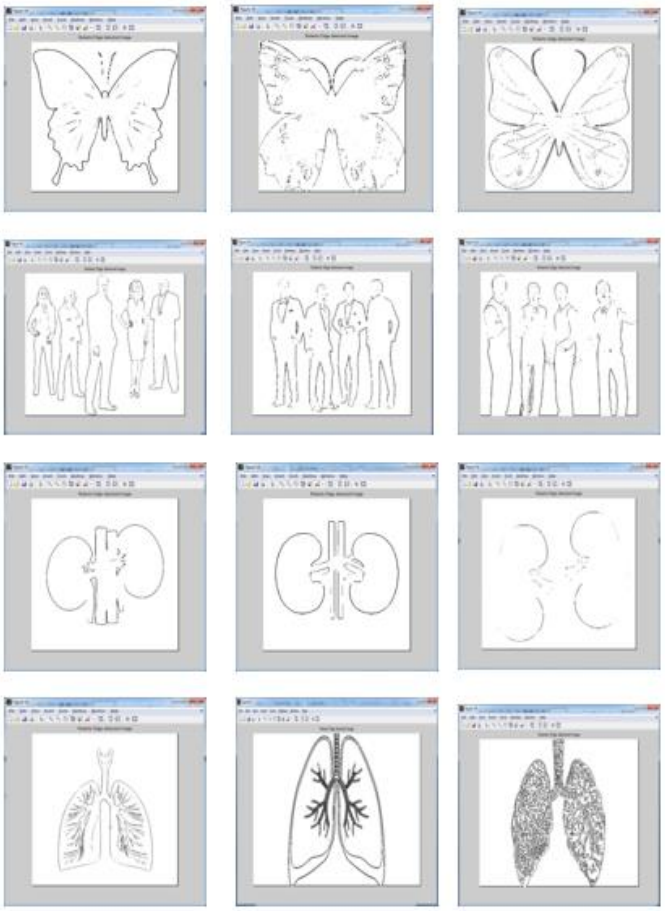

Figure 10: Roberts Edge detection

5.7. Average Time for Edge Detection

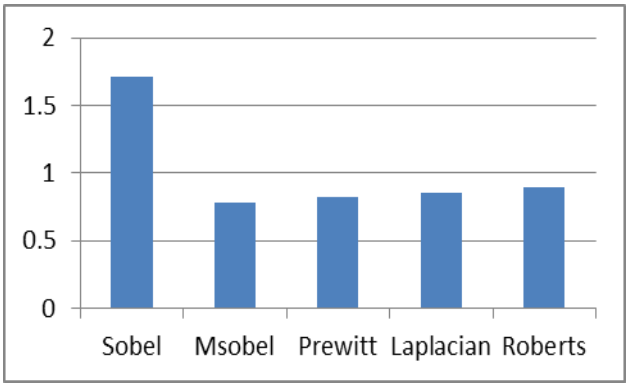

Figure 11: Average Time of Edge Detection of Butterfly Images

Figure 11 shows the average time taken to detect the edges of the input images in the butterfly category for the five algorithms such as Sobel, Modified Sobel, Prewitt, Roberts, and Laplacian. The evaluation of the results depict that the modified sobel edge detection takes less average time to detect the edges compared with the other edge detection algorithms.

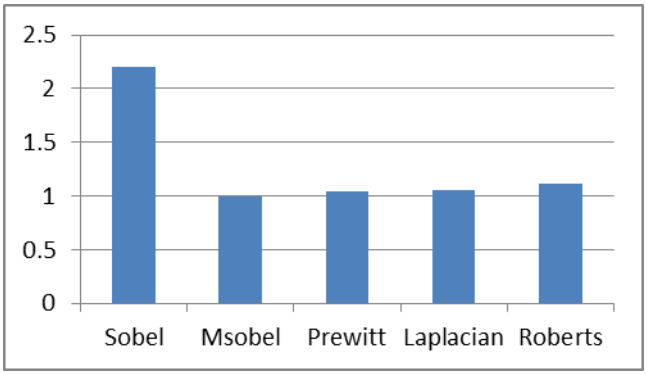

Figure 12: Average Time of Edge Detection of Butterfly Images

Figure 12 shows the average time taken to detect the edges of the input images in the human category for the five algorithms such as Sobel, Modified Sobel, Prewitt, Roberts, and Laplacian. The evaluation of the results depict that the modified sobel edge detection takes less average time to detect the edges compared with the other edge detection algorithms.

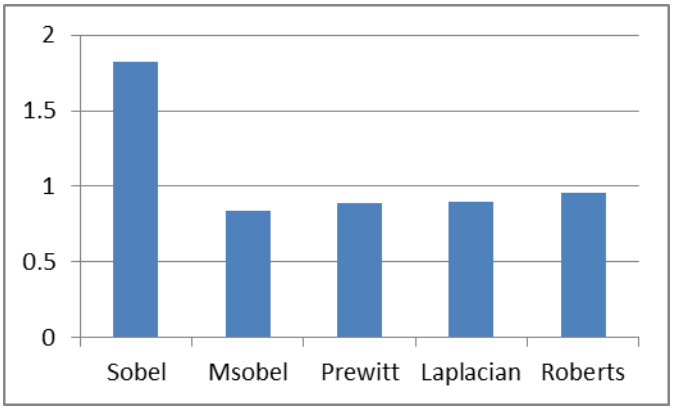

Figure 13: Average Time of Edge Detection of Kidney Images

Figure 13 shows the average time taken to detect the edges of the input images in the Kidney category for the five algorithms such as Sobel, Modified Sobel, Prewitt, Roberts, and Laplacian. The evaluation of the results depict that the modified sobel edge detection takes less average time to detect the edges compared with the other edge detection algorithms.

Figure 14 shows the average time taken to detect the edges of the input images in the Lungs category for the five algorithms such as Sobel, Modified Sobel, Prewitt, Roberts, and Laplacian. The evaluation of the results depict that the modified sobel edge detection takes less average time to detect the edges compared with the other edge detection algorithms.

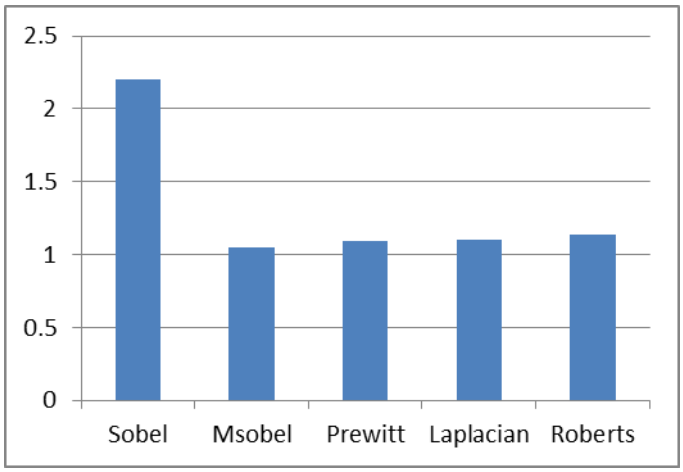

Figure 14: Average Time of Edge Detection of Lungs Images

6. CONCLUSION

Edge detection plays an important role in image processing. There are many edge detection algorithms do exist namely Sobel, Prewitt, Roberts, and Laplacian. The characteristics of each edge detection algorithms are studied in this paper. Further, a novel modified sobel edge detection algorithm is proposed in this paper. The proposed modified sobel algorithm is derived from the sobel algorithm. That is, new mask values are generated from the sobel algorithm. All the mentioned edge detection algorithms are tested for accurate edge detection on various input images. The obtained results show that modified sobel edge detection takes less time to detect the edges compared with other edge detection mechanisms.

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