



Edge Detection Using Mathematical Morphology and Traditional Techniques

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Abstract—Edge detection is the important step in processing of any digital images for improving the information in the picture so that it can be easily understood by human and to make it suitable and readable for any further processing which works on those images. For Computer vision and Image processing systems to interpret an image, they first must be able to detect the edges of each object in the image. Edge representation of an image drastically reduces the amount of data to be processed, yet it retains important information about the shapes of objects in the scene. In this paper, it has been shown that proposed algorithms using Mathematical Morphology and traditional edge detection algorithms perform better than all these operators under almost all scenarios.

Keywords: edge detection, mathematical morphology, traditional algorithms.

I. INTRODUCTION

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in a scene. Edge detection is the first step taken in many object recognition applications. It basically examines an image and produces a pixel at the boundary of two “colors” [1]. The output image contains all of the pixels that were created during the detection. There are many different algorithms that can perform edge detection, each with their own strengths and weaknesses. Edge detection techniques “focus on identifying continuous adjacent pixels which vary greatly in intensity or colour, because these are likely to mark boundaries, between objects, or an object and the background, and hence form an edge”. Edges themselves are boundaries of object surfaces in a scene that often lead to oriented, localized changes in intensity in an image. Image Processing in any form of signal processing for which the input is an image, such as photograph or video frame; the output of image processing may be either an image or, a set of characteristics or parameters related to the image [2]. Image processing involves changing the nature of an image in order to either 1) Improve its pictorial information for human interpretation, or 2) Make it more suitable for automatic machine perception. These two aspects represent two separate but equally important applications of image processing. A procedure that satisfies condition 1- a procedure that makes an image look better- may be the very worst procedure for satisfying condition 2. Human like their images to be sharp, clear and detailed; machine prefer their image to be simple and uncluttered.

II. MATHEMATICAL MORPHOLOGY

Binary images may contain numerous imperfections. In particular, the binary regions produced by simple thresholding are distorted by noise and texture. Morphology relates to structure or form of objects. Morphological filtering simplified segmented images by smoothing out object outlines using filling small holes, eliminating small projections [3]. Morphological image processing pursues the goals of removing these imperfections by accounting for the form and structure of the image. These techniques can be extended to grayscale images. Mathematical morphology is a new mathematical theory which can be used to process and analyze the images [4-8]. It is mathematical in the sense that the analysis is based on theory, topology, and lattice algebra, function and so on [9]. Another use of it is to filter image. It is a well known non-linear filter for image enhancement [10, 11]. It analyzes the images using set theory instead of mathematical modeling and analysis. Morphological operations rely only on the relative ordering of pixel values, not on their numerical values, and therefore are especially suited to the processing of binary images. Morphological operations can also be applied to grayscale images such that their light transfer functions are unknown and therefore their absolute pixel values are of no or minor interest. Medical images edge detection is an important work for object recognition of the human organs, and it is an essential pre- processing step in medical image segmentation. The work of the edge detection decides the result of the final processed image [12].

Traditional Operators

Some traditional operators are as below [13]:

A. First order derivative / gradient methods are as follows:

- 1) Roberts operator
- 2) Sobel operator

- 3) Prewitt operator
- B. Second order derivative:
 - 1) Laplacian
 - 2) Laplacian of Gaussian
 - 3) Difference of Gaussia
- C. Optimal edge detection:
 - 1) Canny edge detection

Sobel operator is used in image processing techniques particularly in edge detection. The Sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical and is therefore relatively inexpensive in terms of computations. Mathematically, the operator uses two 3×3 kernels which are convolved with the original image to calculate approximations of the derivatives - one for horizontal changes, and one for vertical. Prewitt operator edge detection masks are the one of the oldest and best understood methods of detecting edges in images. Basically, there are two masks, one for detecting image derivatives in X and one for detecting image derivative in Y. To find edges, a user convolves an image with both masks, producing two derivative images (dx and dy). The strength of the edge at given location is then the square root of the sum of the squares of these two derivatives. The Prewitt edge detector is an appropriate way to estimate the magnitude and orientation of an edge. Although differential gradient edge detection needs a rather time consuming calculation to estimate the orientation from the magnitudes in the x- and y-directions, the Prewitt edge detection obtains the orientation directly from the kernel with the maximum response. The set of kernels is limited to 8 possible orientations; however experience shows that most direct orientation estimates are not much more accurate.

Roberts edge detection method is one of the oldest method and is used frequently in hardware implementations where simplicity and speed are dominant factors.

Canny edge detection operator was developed by John F. Canny in 1986 and uses a multistage algorithm to detect a wide range of edges in images. Stages of the Canny algorithm are noise reduction and non-maximum suppression.

III. MORPHOLOGICAL OPERATORS

Some mathematical morphological operators are as below [14, 15]:

- A .Erosion: Shrinking the foreground.
- B. Dilation: Expanding the foreground.
- C.Closing: Removing holes in the foreground.
- D. Opening: Removing stray foreground pixels in background.

Table 1: Comparison of traditional techniques.

Operator	Advantages	Disadvantages
Classical (Sobel, Prewitt, Robert)	Simplicity, Detection of edges and their orientations	Sensitivity to noise, Inaccurate
Zero-Crossing (Laplacian, Second directional derivative)	Detection of edges and their orientations. Having fixed characteristics in all directions	Responding to some of the existing edges, Sensitivity to noise.
Laplacian of Gaussian(LOG) (Marr-Hildreth)	Finding the correct places of edges, Testing Wider area around the pixel.	Malfunctioning at the corners, curves and where the gray level intensity function varies. Not finding the orientation of edge because of using the Laplacian filter.
Gaussian(Canny, Shen-Castan)	Using probability for finding error rate, Localization and response. Improving signal to noise ratio, Better detection specially in noise conditions	Complex Computations, False zero crossing, Time consuming

A. Dilation:

The dilation process is performed by laying the structuring element **B** on the image **A** and sliding it across the image in a manner similar to convolution. The difference is in the operation performed. The different steps of dilation are:

1. If the origin of the structuring element coincides with a 'white' pixel in the image, there is no change; move to the next pixel.
2. If the origin of the structuring element coincides with a 'black' in the image, make black all pixels from the image covered by the structuring element.

The Notation is as under:

$$A \oplus B \quad (1)$$

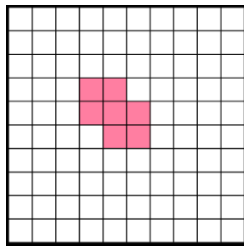


Fig. 1 Original [17]

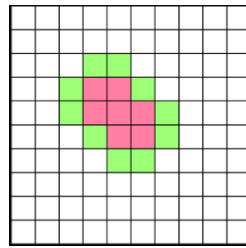


Fig. 2 Applied Mask [17]

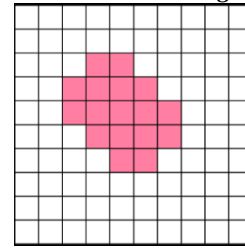


Fig. 3 Applied Mask [17]

B. Erosion:

The erosion process is similar to dilation, but we turn pixels to 'white', not 'black'. As before, slide the structuring element across the image and then follow these steps:

1. If the origin of the structuring element coincides with a 'white' pixel in the image, there is no change; move to the next pixel.
2. If the origin of the structuring element coincides with a 'black' pixel in the image, and at least one of the 'black' pixels in the structuring element falls over a white pixel in the image, then change the 'black' pixel in the image (corresponding to the position on which the center of the structuring element falls) from 'black' to a 'white'.

The Notation is as under:

$$A \ominus B \quad (2)$$

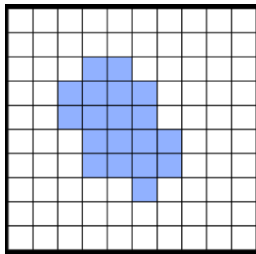


Fig. 4 Original [17]

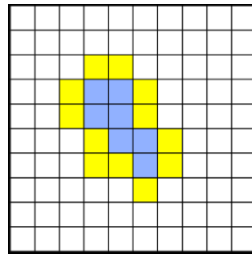


Fig. 5 Applied Mask [17]

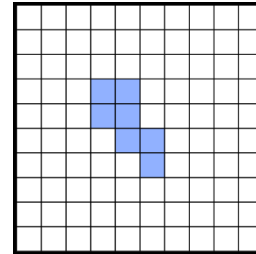


Fig. 6 Eroded image [17]

C. Opening and Closing:

These two basic operations, dilation and erosion, can be combined into more complex sequences. The most useful of these for morphological filtering are called opening and closing [15]. *Opening* consists of an erosion followed by a dilation and can be used to eliminate all pixels in regions that are too small to contain the structuring element. In this case the structuring element is often called a probe, because it is probing the image looking for small objects to filter out of the image.

The Opening process is as below:

$$A \circ B = (A \ominus B) \oplus B \quad (3)$$

The Closing Process is as below:

$$A \cdot B = (A \oplus B) \ominus B \quad (4)$$

Erosion filters the inner image while dilation filters the outer image. Opening generally smoothes the contour of an image, breaks narrow gaps. As opposed to opening, closing tends to fuse narrow breaks, eliminates small holes, and fills gaps in the contours. Therefore, morphological operation is used to detect image edge, and at the same time, denoise the image.

IV. STRUCTURING ELEMENT

Morphological techniques probe an image with a small shape or template called a structuring element. The structuring element is positioned at all possible locations in the image and it is compared with the corresponding neighborhood of pixels. Some operations test whether the element "fits" within the neighborhood, while others test whether it "hits" or intersects the neighborhood. A structuring element is simply a binary image that allows us to define arbitrary neighborhood structures. The structuring element is a small binary image, i.e. a small matrix of pixels, each with a value of zero or one. The matrix dimensions specify the size of the structuring element. The pattern of ones and zeros specifies the shape of the structuring element. An origin of the structuring element is usually one of its pixels, although generally the origin can be outside the structuring element [16].

Different structuring elements are as follows:

$$SE1 = \begin{matrix} 1 & 1 \\ 1 & 1 \end{matrix} \quad SE2 = \begin{matrix} 1 & 0 \\ 0 & 1 \end{matrix} \quad (45 \text{ degree})$$

$$SE3 = \begin{matrix} 0 & 1 \\ 1 & 0 \end{matrix} \quad (135 \text{ degree})$$

Structuring Element of 3X3 matrix is as follows:

SE1= 1 1 1
 1 1 1
 1 1 1

SE2= 1 1 1
 0 0 0
 1 1 1
 (180 degree)

SE3= 1 0 1
 1 0 1
 1 0 1
 (90 degree)

SE4= 0 1 1
 1 0 1
 1 1 0
 (135 degree)

SE5= 1 1 0
 1 0 1
 0 1 1
 (45 degree)

Structuring Element of 5X5 matrix is as follows:

SE1= 1 1 1 1 1
 1 1 1 1 1
 1 1 1 1 1
 1 1 1 1 1 1 1 1 1
 1 1 1 1 1

SE2= 1 1 1 1 1
 1 1 1 1 1
 0 0 0 0 0
 1 1 1 1 1

degree)

(180

SE3= 1 1 0 1 1
 1 1 0 1 1
 1 1 0 1 1
 1 1 0 1 1
 1 1 0 1 1
 (90 degree)

SE4= 0 1 1 1 1
 1 0 1 1 1
 1 1 0 1 1
 1 1 1 0 1
 1 1 1 1 0
 (135 degree)

SE5= 1 1 1 1 0
 1 1 1 0 1
 1 1 0 1 1
 1 0 1 1 1
 0 1 1 1 1
 (45 degree)

V. EXISTING MEASURES OF QUALITY METRICS

For image quality measurement there are basically two approaches:-

- 1) Subjective measurements
- 2) Objective measurements.

Subjective measurements are the result of human experts providing their opinion of the image quality and objective measurements are performed with mathematical algorithms. For applications in which images are ultimately to be viewed by human beings is the only “correct” method of quantifying visual image quality i.e. through subjective evaluation. In practice, however, subjective evaluation is usually too inconvenient, time-consuming and expensive. The goal of research in objective image quality assessment is to develop quantitative measures that can automatically predict perceived image quality. To validate the efficiency of this edge Detection Operator we have defined some statistical criteria of image performance. Additionally to subjective visual evaluation, it is desirable to present quantitative measure. The parameters which are used in estimation of performance are PSNR, RMSE, IF, MSSIM.

Table 2: Showing various parameters for quality measurement.

S. No.	TYPE	DESCRIPTION
1	MSE (Mean Square Error)	$\frac{1}{MN} \sum_{i=1}^M \sum_{j=1}^N (x(i,j) - y(i,j))^2$

2	PSNR (Peak Signal to Noise Ratio)	$10\log_{10} \frac{(2n-1)^2}{\sqrt{MSE}}$
3	AD (Average Difference)	$\frac{1}{MN} \sum_{i=1}^M \sum_{j=1}^N (x(i,j) - y(i,j))^2$
4	MD(Maximum Difference)	$\text{MAX} x(i,j) - y(i,j) $
5	MAE (Mean Absolute Error)	$\frac{1}{MN} \sum_{i=1}^M \sum_{j=1}^N x(i,j) - y(i,j) $
6	NK(Normalized Cross-Correlation)	$\frac{\sum_{i=1}^M \sum_{j=1}^N x(i,j)Xy(i,j)}{\sum_{i=1}^M \sum_{j=1}^N x(i,j)^2}$
7	SC (Structural Content)	$\frac{\sum_{i=1}^M \sum_{j=1}^N y(i,j)^2}{\sum_{i=1}^M \sum_{j=1}^N x(i,j)^2}$
8	IF(Image Fidelity)	$\frac{\sum_{i=1}^M \sum_{j=1}^N (x(i,j) - y(i,j))^2}{\sum_{i=1}^M \sum_{j=1}^N x(i,j)}$
9	PMSE(Peak Mean Square Error)	$\frac{1}{MN} \frac{\sum_{i=1}^M \sum_{j=1}^N (x(i,j) - y(i,j))^2}{(\text{MAX}(x(i,j)))^2}$
10	SSIM(Structural Similarity Index Metrics)	$\frac{(2X\bar{x}\bar{y} + C1)(2X\sigma_{xy} + C2)}{(\sigma_x^2 + \sigma_y^2 + c2)X ((\bar{x})^2 + (\bar{y})^2 + c1)}$

VI. ALGORITHMS

FIRST ALGORITHM USING TRADITIONAL TECHNIQUES:

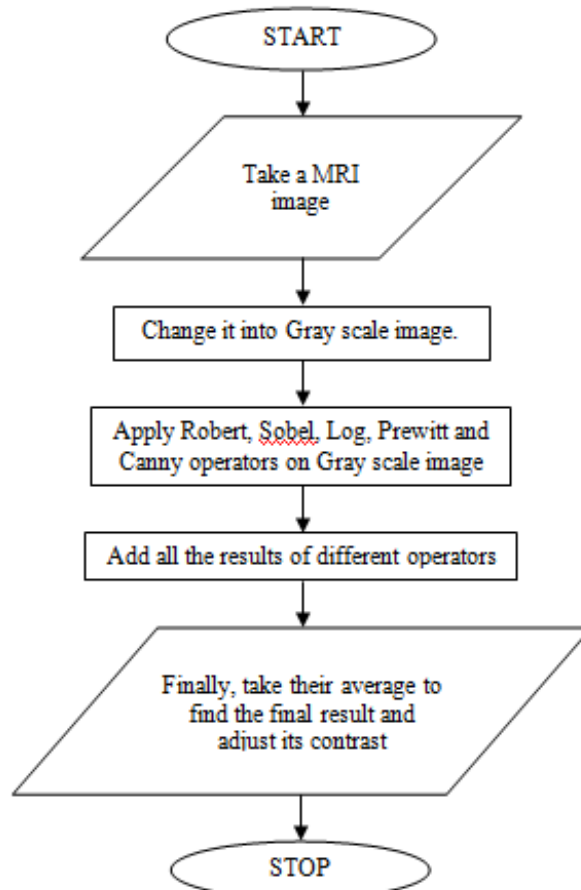


FIG 7: FLOW CHART OF FIRST METHOD

Second algorithm using Mathematical morphology

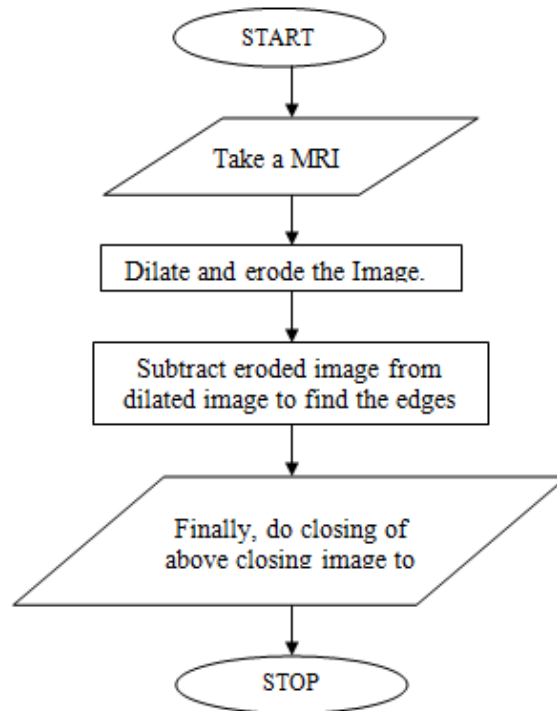
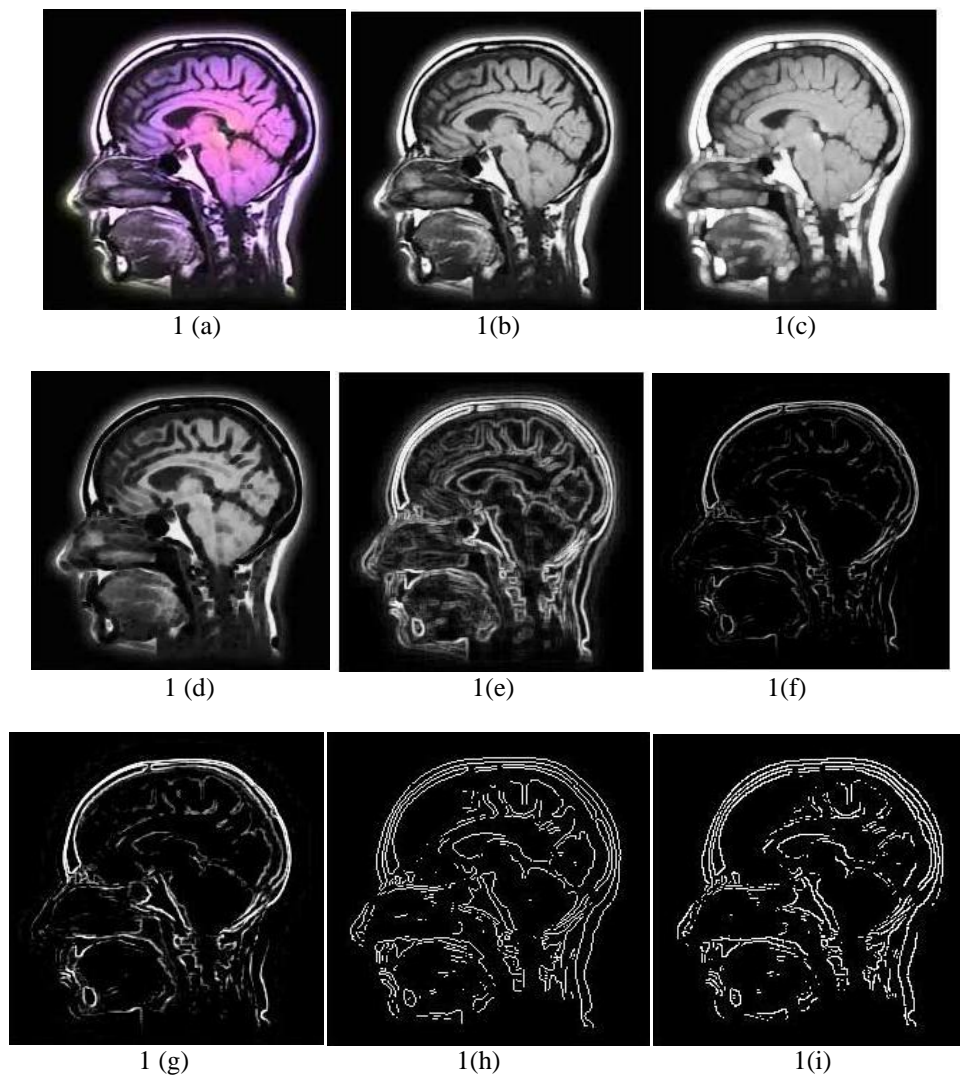


Fig 8 Flow Chart of second method.

VII. RESULTS

First Image:



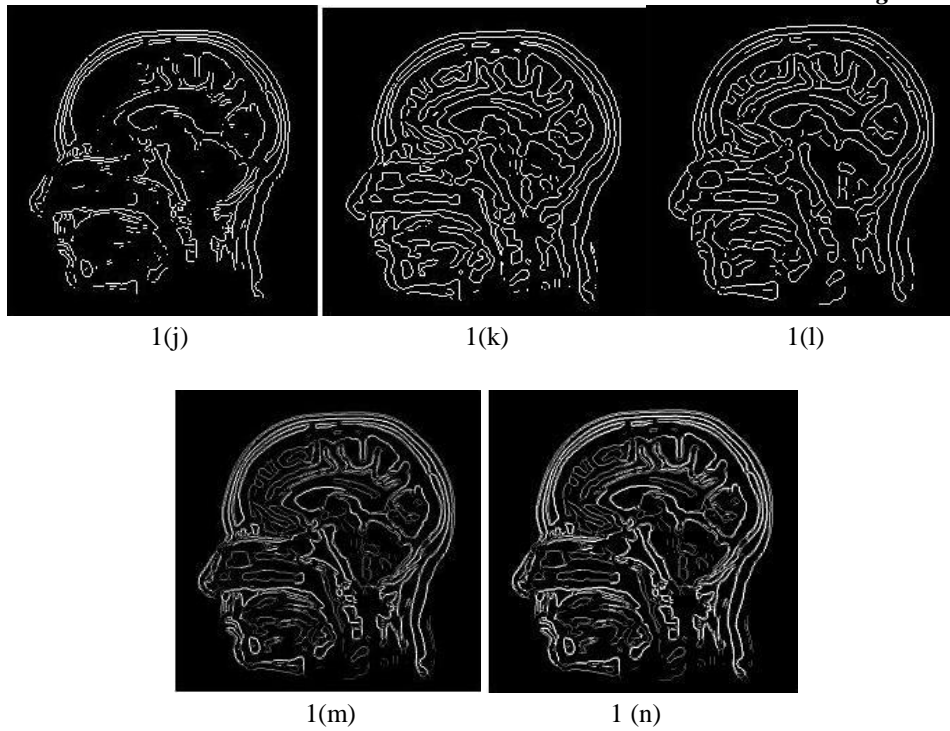
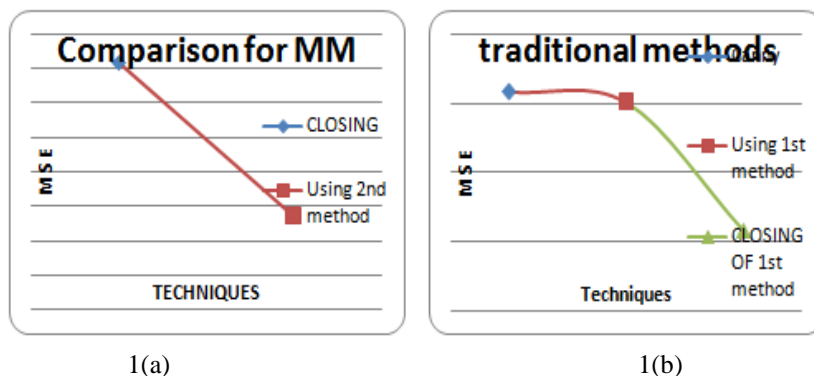


Fig 9: Different processes on first image 1 (a) Original 1(b) Converted into gray scale 1(c) Dilation of gray image 1 (d) erosion of gray image 1(e) Closing of gray image 1(f) Resultant image 1 (g) contrast adjustment of resultant image 1(h) Edges obtained by Sobel operator 1 (i) Edges obtained by Robert operator 1(j) Edges obtained by Prewitt operator 1(k) Edges obtained by LOG operator 1 (l) Edges obtained by Canny operator 1(m) Resultant image 2 using traditional methods 1(n) contrast adjustment of resultant image.

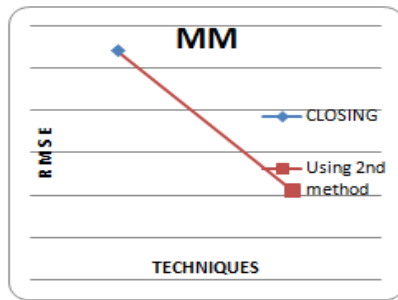
Table 3: Results of First figure showing comparison of different methods using various parameters.

Parameters	MSE	RMSE	AD	PSNR	MAE	NK	SC	IF
CLOSING	4817.2	69.4061	-20.6633	41.7835	20.6633	4717.8	0.9387	-70.5616
Resultant image 1	4367.3	66.0858	-15.1236	41.9964	15.1236	5026	0.9547	-63.8785
Canny	9508	97.6089	-67.3152	40.3005	67.3152	9.1299	0.00015	-140.628
Resultant image 2	9500	97.6048	-67.2237	40.3028	67.2237	9.3922	0.00032	-140.522
CLOSING of Resultant image 2	9408	97.4806	-67.095	40.3083	67.0956	22.5871	0.00073	-140.163

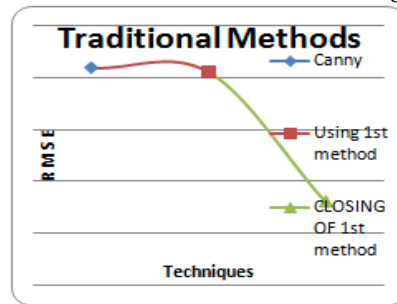
Graph 1 below shows comparison of various parameters for first image using different edge detection techniques:



The above graphs show the comparison of Mean Square Error for the proposed method and the previous techniques. Graphs show a decrease in MSE for the new approach in both the methods.

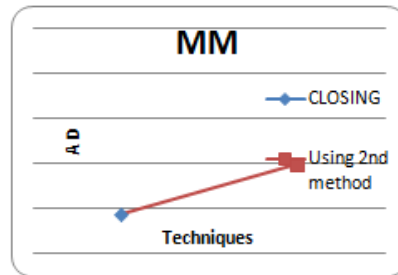


1(c)

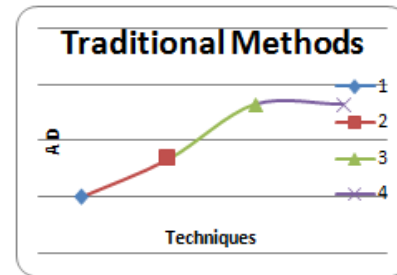


1(d)

These graphs show a decrease in RMSE which means diminish of noise from the image. Hence, by proposed algorithm significant information can be collected.

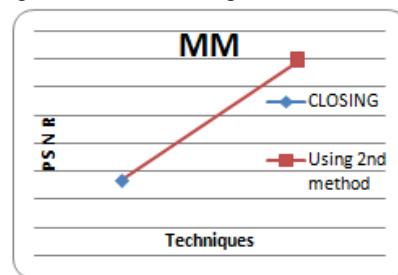


1(e)

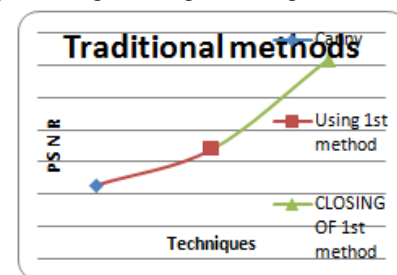


1(f)

By seeing the above graphs, it can be concluded that average difference is falling. It means resultant image is more relevant to original image i.e. resultant image is closer to original image having clear edges and more information.

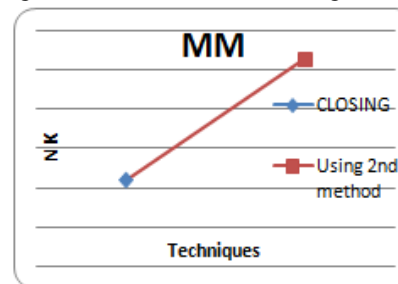


1(g)

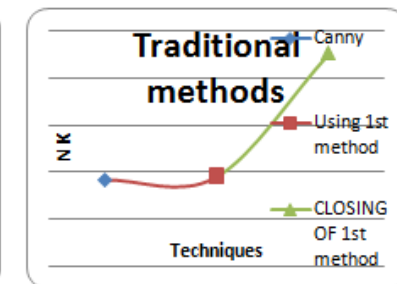


1(h)

PSNR is increasing from 41.75 to 42 in MM and 40.3 to 40.308 in traditional methods. It is concluded that signal information is increasing. Hence, noise is diminishing.

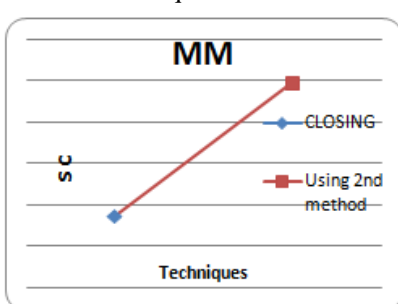


1(i)

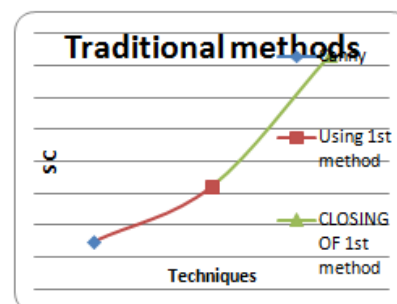


1(j)

Cross correlation factor is greater than ever used MM and traditional techniques. It is increasing from 4700 to 5050 in MM and 10 to 23 in traditional techniques.

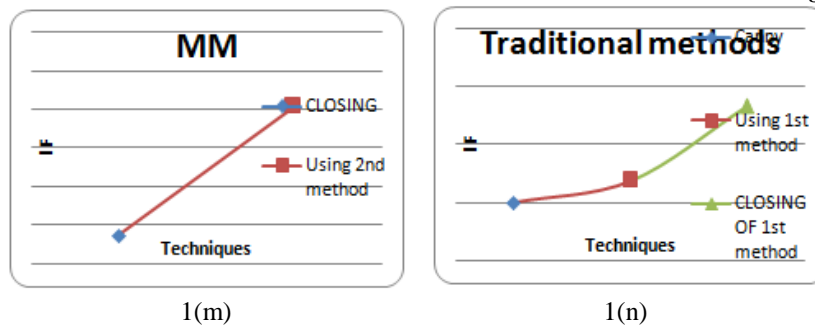


1(k)



1(l)

From the above graphs, it can be concluded that SC value is increasing significantly in both the methods using proposed algorithms.



IF factor is rising for both methods.

Graph 1:(a) Representation of results of MSE using MM. (b) Representation of results of MSE using Traditional methods (c) Representation of results of RMSE using MM (d) Representation of results of RMSE using Traditional methods (e) Representation of results of AD using MM (f) Representation of results of AD using Traditional methods (g) Representation of results of PSNR using MM (h) Representation of results of PSNR using Traditional methods (i) Representation of results of NK using MM (j) Representation of results of NK using Traditional methods (k) Representation of results of SC using MM (l) Representation of results of SC using Traditional methods (m) Representation of results of IF using MM (n) Representation of results of IF using Traditional methods.

VIII. CONCLUSION

Above figures shows the results of simulation in MATLAB and it can be concluded that the results of Mathematical Morphology are much better than the traditional methods. Closing is giving better result than the Canny operators. Moreover, our proposed algorithms are having good results than the basic methods of Mathematical Morphology and traditional techniques. The edges are continuous and the weak edges are also clearly visible.

The above table shows comparison of various techniques w.r.t. parameters. Here, we can see that MSE, RMSE and MAE are decreasing. Whereas AD, PSNR, NK, SC and IF are increasing. It means that by using the proposed method mean square error is decreasing whereas our peak signal to noise ratio is increasing.

The above table shows comparison of various techniques w.r.t. parameters. Here, it can be seen that MSE, RMSE and MAE are decreasing. Whereas AD, PSNR, NK, SC and IF are increasing. It means that by using the proposed method mean square error is decreasing whereas the peak signal to noise ratio is increasing. Hence, proposed algorithms are best for edge detection.

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