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# New Filter for Color Image Edge Detection Based on Combination Laplace Filter and Markov Basis

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**ABSTRACT:** Edge detection refers to the process of identifyingand locating sharp discontinuities in an image. So, edge detection is a vital step in imageanalysis and it is the key of solving many complex problems. In this paper we suggested new filter(s)based on combination Laplace filters and the elements of Markov Basis Bused for edge detection in color images. The results of using this filter can be color imageor binary image according to the value in the center of the filter.From the simulation results, and by comparing these results with other methods it was obvious that the edge detection using new filter is more efficient than the traditional methods.

**KEYWORDS**: edge detection, image processing, Markov basis, Laplace filter, color image.

## I. INTRODUCTION

Edge detection is a very important area in the field of Computer Vision. Edge detection is a type of image segmentation techniques which determines the presence of an edge or line in an image and outlines them in an appropriate way. Generally, an edge is defined as the boundary pixels that connect two separate regions with changing image amplitude attributessuch as different constant luminance and tristimulus values in an image[1].

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 [2].There are many ways to perform edge detection. However, the majority of different methods may be grouped into two categories:

**Gradient based Edge Detection:**The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image.

**Laplacian based Edge Detection:**The Laplacian method searches for zero crossings in the second derivative of the image to find edges. An edge has the one-dimensional shape of a ramp and calculating the derivative of the image can highlight its location.

## II. RELATED WORKS

*K.K. Thanammal1 and J.S. Jaya Sudha,* describes edgedetection algorithms for image segmentation using various computing approaches whichhave got great fruits. Experimental results prove that Canny operator is better thanPrewitt and Sobel for the selected image. Subjective and Objective methods are used toevaluate the different edge operators. The performance of Canny, Sobel and Prewitt EdgeDetection are evaluated for detection of edges in digital images. [3]

*Andreas Koschan,* introduced approaches arebased on the Sobel operator, the Laplace operator, theMexican Hat operator, different realizations of the Cumanioperator, and the Alshatti-Lambert operator. Furthermore,it present an new algorithm for implementing theCumani operator. All operators have been applied toseveral synthetic and real images. The results in

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this paper showed that the quality of the resultsincreases if Gaussian masks of larger width are used in thederivation process instead of simple 3 x 3 masks assuggested in the other papers. Moreover, multiresolutionapproaches can be applied to color imageswhen using Gaussian masks with different standarddeviations in the edge detection scheme.[4]

*Li and Lei*[5] proposed an improved method based on wavelet modulus maximum edge detectionalgorithm. They proposed a technique for automatic determination of function for eliminating noise threshold using clustering technique. In their experiment, they utilized B-spline wavelet and improved k-meansclustering algorithm.

*Ganguly et al.* [6] introduced another approach for edge detection using artificial features of theimage as the feature set and using k-means clustering algorithm for clustering to detect clearly the edgesof the objects present in the image in question. It uses busyness, mean, variance and entropy as artificialfeatures for clustering algorithm.

## III. COLOREDGE DETECTION

Most edge detection schemes are based on finding maximain the first derivative of the image function or zerocrossingsin the second derivative of the image function.The difficulty in extending derivative approaches to colorimages arises from the fact that the image function isvector-valued. Whenever the gradients of the imagecomponents are computed, the question remains of how tocombine them into one result. Several approaches alreadyexist for color edge detection. Perhaps the simplest one isto apply Sobel masks to the three color channelsindependently and to combine the results using logicaloperation. A more sophisticated approach is suggested byCumani. He computes the zero-crossings in the seconddirectional derivative of a color image that is considered asa two-dimensional vector field.[4]

## IV. THE MARKOV BASIS

Let $I$ be a finite set of $n = |I|$ elements, we call an element of $I$ a cell and denoted by $\boldsymbol{i} \in I$, $\boldsymbol{i}$ is often multi-index $\boldsymbol{i} = i_1 \dots i_m$. A non-negative integer $x_i \in \mathbb{N} = \{1, 2, \dots\}$ denotes the frequency of a cell $\boldsymbol{i}$. The set of frequencies is called **acontingency table**and denoted as$\boldsymbol{x} = \{x_i\}_{i \in I}$. With an appropriate ordering of the cell, we treat a contingency table$\boldsymbol{x} = \{x_i\}_{i \in I} \in \mathbb{N}^n$ as a $n$-dimansional column vector of non-negative integers. Note that a contingency table can also be considered as a function from $I$ to $\mathbb{N}$ defined as $\boldsymbol{i} \longmapsto x_i$.

**Definition [7]**

n-dimensional column vector of integers $Z = \{z_i\}_{i \in I} \in \mathbb{Z}^n$ is called move if it is in the kernel of A (i.e. AZ=0).

**Definition [8]**

Let $A^{-1}[\boldsymbol{t}] = \{\boldsymbol{x} \in \mathbb{N}^n : A\boldsymbol{x} = \boldsymbol{t}\}$. A set of finite moves $B$ is called **Markov basis** if for all $\boldsymbol{t}$, $A^{-1}[\boldsymbol{t}]$ constitutes one $B$ equivalence class.

**Remark [7]**

We found the Markov basis $\boldsymbol{B}$and toric ideal for $\frac{n^2-3n}{3} \times 3 \times \frac{n}{3}$ - contingency tables with fixed two dimensional marginals when $n$ is a multiple of 3 greater than or equal 6.

**Remark[7]**

Let $n$ be a multiple of 3 such that $n \geq 6$, and let $\boldsymbol{x}_j \in A^{-1}[t]$, $j = 1, \dots, l$ be the representative elements of the set of $3 \times \frac{n}{3}$ −contingency tables and $\mathbf{B} = \{\boldsymbol{z}_1, \mathbf{z}_2, \dots, \mathbf{z}_l\}$ such that each $\boldsymbol{z}_m, m = 1,2, \dots l$, is a matrix of dimension $3 \times \frac{n}{3}$ has two columns either$((1,-1,0)', (-1,1,0)')$,$((1,0,-1)', (-1,0,1)')$, or $((0,1,-1)', (0,-1,1)')$ and the other columns are zero denoted by $+\boldsymbol{z}_m$, or it has two columns$((-1,1,0)', (1,-1,0)')$, $((-1,0,1)', (1,0,-1)')$ or $((0,-1,1)', (0,1,-1)')$ and the other columns are zero denoted by $-\boldsymbol{z}_m$, like

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$$\begin{bmatrix}1&-1&0\\-1&1&0\\0&0&0\end{bmatrix},\begin{bmatrix}1&-1&0\\0&0&0\\-1&1&0\end{bmatrix},\begin{bmatrix}0&0&0\\1&-1&0\\-1&1&0\end{bmatrix},$$
$$\begin{bmatrix}-1&1&0\\1&-1&0\\0&0&0\end{bmatrix},\begin{bmatrix}-1&1&0\\0&0&0\\1&-1&0\end{bmatrix},\begin{bmatrix}0&0&0\\-1&1&0\\1&-1&0\end{bmatrix}.$$

Also, we can write all elements of $\boldsymbol{B}$as one-dimensional column vectoras follow:

$\boldsymbol{z_m} = (z_1, \dots, z_n)', m = 1, \dots, l$and$z_j = 1$ or $-1$ or $0$ such that

If $j = 1, 2, \dots, \frac{n}{3}$

$$z_j = \begin{cases} 1 & if z_{j+\frac{n}{3}} + z_{j+\frac{2n}{3}} = -1 \; and \sum_{\substack{i=1\\ i\neq j}}^{\frac{n}{3}} z_i = -1 \\ -1 & if z_{j+\frac{n}{3}} + z_{j+\frac{2n}{3}} = 1 \; and \sum_{\substack{i=1\\ i\neq j}}^{\frac{n}{3}} z_i = 1 \\ 0 & if z_{j+\frac{n}{3}} + z_{j+\frac{2n}{3}} = 0 \; and \sum_{\substack{i=1\\ i\neq j}}^{\frac{n}{3}} z_i = 0 \end{cases} \quad (1)$$

If$j = \frac{n}{3} + 1, \frac{n}{3} + 2, \dots, \frac{2n}{3}$

$$z_j = \begin{cases} 1 & if z_{j-\frac{n}{3}} + z_{j+\frac{n}{3}} = -1 \; and \sum_{\substack{i=\frac{n}{3}+1\\ i\neq j}}^{\frac{2n}{3}} z_i = -1 \\ -1 & if z_{j-\frac{n}{3}} + z_{j+\frac{n}{3}} = 1 \; and \sum_{\substack{i=\frac{n}{3}+1\\ i\neq j}}^{\frac{2n}{3}} z_i = 1 \\ 0 & if z_{j-\frac{n}{3}} + z_{j+\frac{n}{3}} = 0 \; and \sum_{\substack{i=\frac{n}{3}+1\\ i\neq j}}^{\frac{2n}{3}} z_i = 0 \end{cases} \quad (2)$$

If$j = \frac{2n}{3} + 1, \frac{2n}{3} + 2, \dots, n$

$$z_s = \begin{cases} 1 & if z_{j-\frac{2n}{3}} + z_{j-\frac{n}{3}} = -1 \; and \sum_{\substack{i=\frac{2n}{3}+1\\ i\neq j}}^{n} z_i = -1 \\ -1 & if z_{j-\frac{2n}{3}} + z_{j-\frac{n}{3}} = 1 \; and \sum_{\substack{i=\frac{n}{3}+1\\ i\neq j}}^{n} z_i = 1 \\ 0 & if z_{j-\frac{2n}{3}} + z_{-\frac{n}{3}} = 0 \; and \sum_{\substack{i=\frac{n}{3}+1\\ i\neq j}}^{n} z_i = 0 \end{cases} \quad (3)$$

**Theorem [7]**

The number of elements in $\boldsymbol{B}$ equals to $\frac{n^2-3n}{3}$.

We can find the Markov basis from equations $(1)$, $(2)$ and $(3)$. Then the number of moves is $\frac{n^2-3n}{3} = \frac{9^2-3\times 9}{3} = 18$ elements in the set

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$$Z_1 = \begin{bmatrix} 1 & -1 & 0 \\ -1 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, Z_2 = \begin{bmatrix} 0 & 0 & 0 \\ 1 & -1 & 0 \\ -1 & 1 & 0 \end{bmatrix}, Z_3 = \begin{bmatrix} 1 & 0 & -1 \\ -1 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix}, Z_4 = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & -1 \\ -1 & 0 & 1 \end{bmatrix}$$

$$Z_5 = \begin{bmatrix} 0 & 1 & -1 \\ 0 & -1 & 1 \\ 0 & 0 & 0 \end{bmatrix}, Z_6 = \begin{bmatrix} 0 & 1 & -1 \\ 0 & 0 & 0 \\ 0 & -1 & 1 \end{bmatrix}, Z_7 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & -1 \\ 0 & -1 & 1 \end{bmatrix}, Z_8 = \begin{bmatrix} 1 & -1 & 0 \\ 0 & 0 & 0 \\ -1 & 1 & 0 \end{bmatrix}$$

$$Z_9 = \begin{bmatrix} 1 & 0 & -1 \\ 0 & 0 & 0 \\ -1 & 0 & 1 \end{bmatrix}, Z_{10} = \begin{bmatrix} -1 & 1 & 0 \\ 1 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, Z_{11} = \begin{bmatrix} 0 & 0 & 0 \\ -1 & 1 & 0 \\ 1 & -1 & 0 \end{bmatrix}, Z_{12} = \begin{bmatrix} -1 & 0 & 1 \\ 1 & 0 & -1 \\ 0 & 0 & 0 \end{bmatrix}$$

$$Z_{13} = \begin{bmatrix} 0 & 0 & 0 \\ -1 & 0 & 1 \\ 1 & 0 & -1 \end{bmatrix}, Z_{14} = \begin{bmatrix} 0 & -1 & 1 \\ 0 & 1 & -1 \\ 0 & 0 & 0 \end{bmatrix}, Z_{15} = \begin{bmatrix} 0 & -1 & 1 \\ 0 & 0 & 0 \\ 0 & 1 & -1 \end{bmatrix}, Z_{16} = \begin{bmatrix} -1 & 1 & 0 \\ 1 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$Z_{17} = \begin{bmatrix} -1 & 1 & 0 \\ 0 & 0 & 0 \\ 1 & -1 & 0 \end{bmatrix}, Z_{18} = \begin{bmatrix} -1 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & -1 \end{bmatrix}.$$

## V. PROPOSED FILTERSFOREDGEDETECTION

The current proposalGenerations new filters based on combination Laplace filters and the elements of Markov Basis B.The following steps used to create new filters:

### *A. Filter Generation*

**Step1**

use Laplace filter which is:

$$l(x,y) = \begin{bmatrix} -1 & -2 & -1 \\ -2 & 12 & -2 \\ -1 & -2 & -1 \end{bmatrix}$$

**Step 2**

Also we use the Markov basis elements $Z_i$, where i = 1, 2, 3, …, 18 to combine them with Laplace filter.

**Step3**

Add the Laplace filter elements to each of Markov basis elements $Z_i$, as follow:
$Z_i' = l(x,y) + Z_i(x,y), Z_i \in B,\ i = 1,2,3,\ldots,18.$

**Step4**

Adding one to each value in the center of created filter ($Z'_i$), this will help to process the color image and the resulted image will be colored image instead of binary image:

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$$Z_i^* = Z_i' + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad , \qquad i = 1,2,\dots,18$$

At this case we get the following filters:

$$Z_1^* = \begin{bmatrix} 0 & -3 & -1 \\ -3 & 14 & -2 \\ -1 & -2 & -1 \end{bmatrix}, Z_2^* = \begin{bmatrix} -1 & -2 & -1 \\ -1 & 12 & -2 \\ -2 & -1 & -1 \end{bmatrix}, Z_3^* = \begin{bmatrix} 0 & -2 & -2 \\ -3 & 13 & -1 \\ -1 & -2 & -1 \end{bmatrix}, Z_4^* = \begin{bmatrix} -1 & -2 & -1 \\ -1 & 13 & -3 \\ -2 & -2 & 0 \end{bmatrix}$$

$$Z_5^* = \begin{bmatrix} -1 & -1 & -2 \\ -2 & 12 & -1 \\ -1 & -2 & -1 \end{bmatrix}, Z_6^* = \begin{bmatrix} -1 & -1 & -2 \\ -2 & 13 & -2 \\ -1 & -3 & 0 \end{bmatrix}, Z_7^* = \begin{bmatrix} -1 & -2 & -1 \\ -2 & 14 & -3 \\ -1 & -3 & 0 \end{bmatrix}, Z_8^* = \begin{bmatrix} 0 & -3 & -1 \\ -2 & 13 & -2 \\ -2 & -1 & -1 \end{bmatrix}$$

$$Z_9^* = \begin{bmatrix} 0 & -2 & -2 \\ -2 & 13 & -2 \\ -2 & -2 & 0 \end{bmatrix}, Z_{10}^* = \begin{bmatrix} -2 & -1 & -1 \\ -1 & 12 & -2 \\ -1 & -2 & -1 \end{bmatrix}, Z_{11}^* = \begin{bmatrix} -1 & -2 & -1 \\ -3 & 14 & -2 \\ 0 & -3 & -1 \end{bmatrix}, Z_{12}^* = \begin{bmatrix} -2 & -2 & 0 \\ -1 & 13 & -3 \\ -1 & -2 & -1 \end{bmatrix}$$

$$Z_{13}^* = \begin{bmatrix} -1 & -2 & -1 \\ -3 & 13 & -1 \\ 0 & -2 & -2 \end{bmatrix}, Z_{14}^* = \begin{bmatrix} -1 & -3 & 0 \\ -2 & 14 & -3 \\ -1 & -2 & -1 \end{bmatrix}, Z_{15}^* = \begin{bmatrix} -1 & -3 & 0 \\ -2 & 13 & -2 \\ -1 & -1 & -2 \end{bmatrix}, Z_{16}^* = \begin{bmatrix} -1 & -2 & -1 \\ -2 & 12 & -1 \\ -1 & -1 & -2 \end{bmatrix}$$

$$Z_{17}^* = \begin{bmatrix} -2 & -1 & -1 \\ -2 & 13 & -2 \\ 0 & -3 & -1 \end{bmatrix}, Z_{18}^* = \begin{bmatrix} -2 & -2 & 0 \\ -2 & 13 & -2 \\ 0 & -3 & -1 \end{bmatrix}.$$

### *B. Edge Detection*

To detection the edges in an image, we use the following steps :

**Step 1**

Let $f(x, y)$ be color image with dimension$m \times n \times 3$.

**Step 2**

Image de-noising by using media filter.

**Step 3**

We process each band of color image ($RED\ (R)$,$GREEN\ (G)$ and$BLUE\ (B)$ ) as a separated image (matrix) to detect the edge, and later we recombine them to get true color image with edge highlights.

**Step 4**

The input filter $Z_i^*(x, y)$is one of (18) filters which previously created, with dimension $3 \times 3$ .

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**Step 5**

Convolute each image band with filter suggested in step 3, the result is three new images ($R_{1,}$ $G_1$, $B_1$).

**Step 6**

Combine the three image bands ($R_{1,}$ $G_1$, $B_1$) to rebuild the true color image.

**Step 7**

Display the resulted image.

## VI. THERESULTS

The best way to test the new suggested filter is by comparing it's with other known filters and taking different problems which face the edge detections algorithms. We test two type of suggested filters one of them take the color image and the result is also color image with edge highlight, the other filter also take the color image as input image and the result is binary image as most of traditional filters did.

1. Figure 1 shows the ability of the edge detectors to handle corners as well as a wide range of slopes in edge on the circle. The Canny edge detector becomes fairly confused at corners due to the Gaussian smoothing of the image. Also, since the direction of the edge changes instantly, corner pixels looks in the wrong directions for its neighbors. The Marr-Hildreth edge detector fails to detect many prominent edges [9]. While the suggested filter detect the corner and all the edges efficiently.

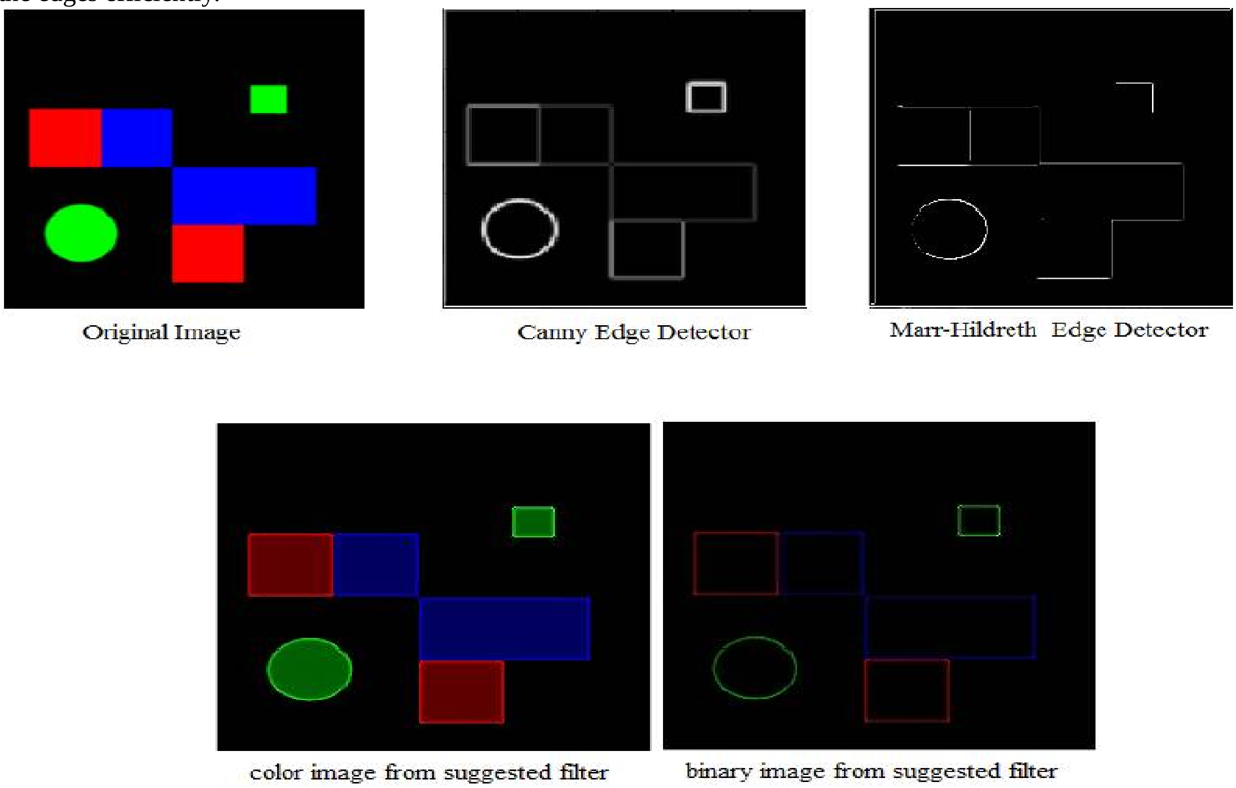


Fig. 1: Test the suggested filter for corner handling..

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2. The visual comparison of the following images inFigure 2 can lead us to the subjective evaluation of the performances of selected edge detectors. Applying these two methods to a noisy image shows that with noisy images, second derivative operators, like Canny, exhibit better performance but require more computations because of smoothing an image with a Gaussian function first and then computing the gradient [9].

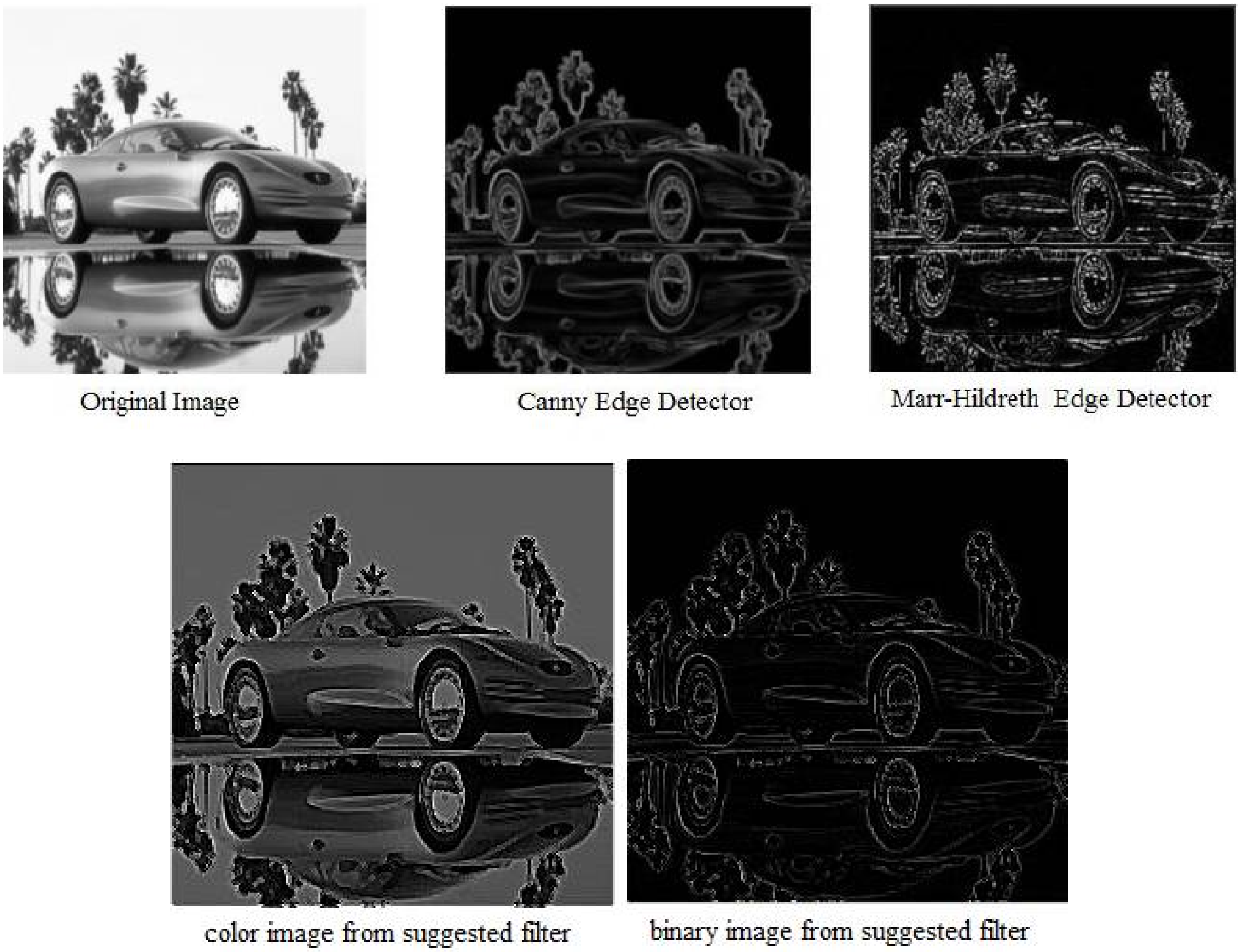


Fig. 2: Testing noisy image

3. Figure 3 is a picture of a shoreline. Both the edge detectors had problems detecting the different ridges of the cliff. The foam of the waves also provided some inconsistent results. There are a lot of discrepancies in color at these locations, but no clear edges [9]. The suggested filter exhibit clear lines and consistence results with regards to foam waves.

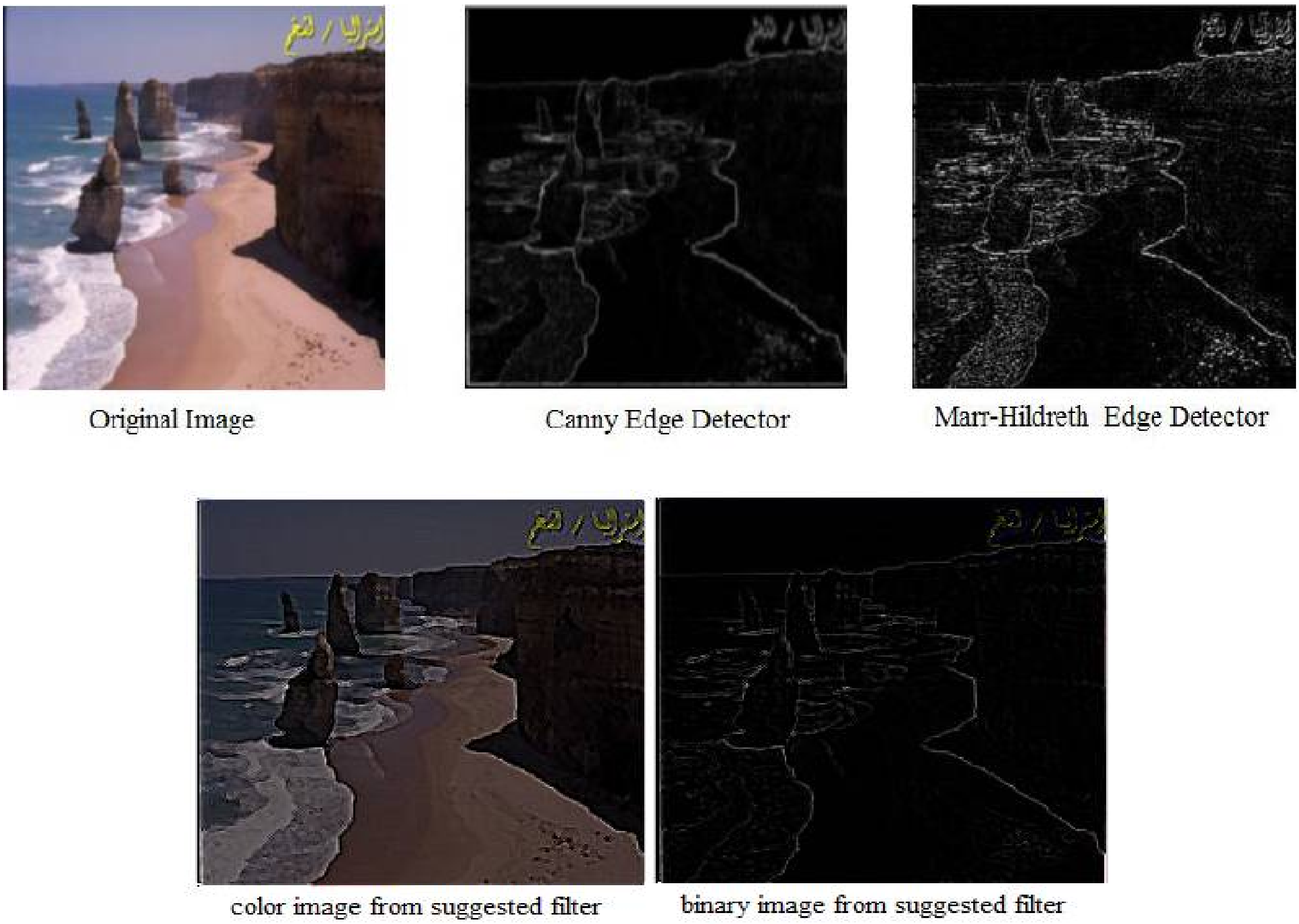


Fig. 3.Test image of a shoreline.

4. Fig.4. more accurately shows the capabilities of each edge detector. The Marr-Hildreth detector perceives many edges, but they are too spotty and wide to really identify any features. The Canny edge detector gives nice outlines of the table, the vase, and many of the flowers on the border. Features in the middle of the arrangement are missed, but some are recovered with the addition of color. For example, the red flower in the center and the leaves to its right are found. In the suggested filter the edges more clear and generally the image more obvious and less spots [9].

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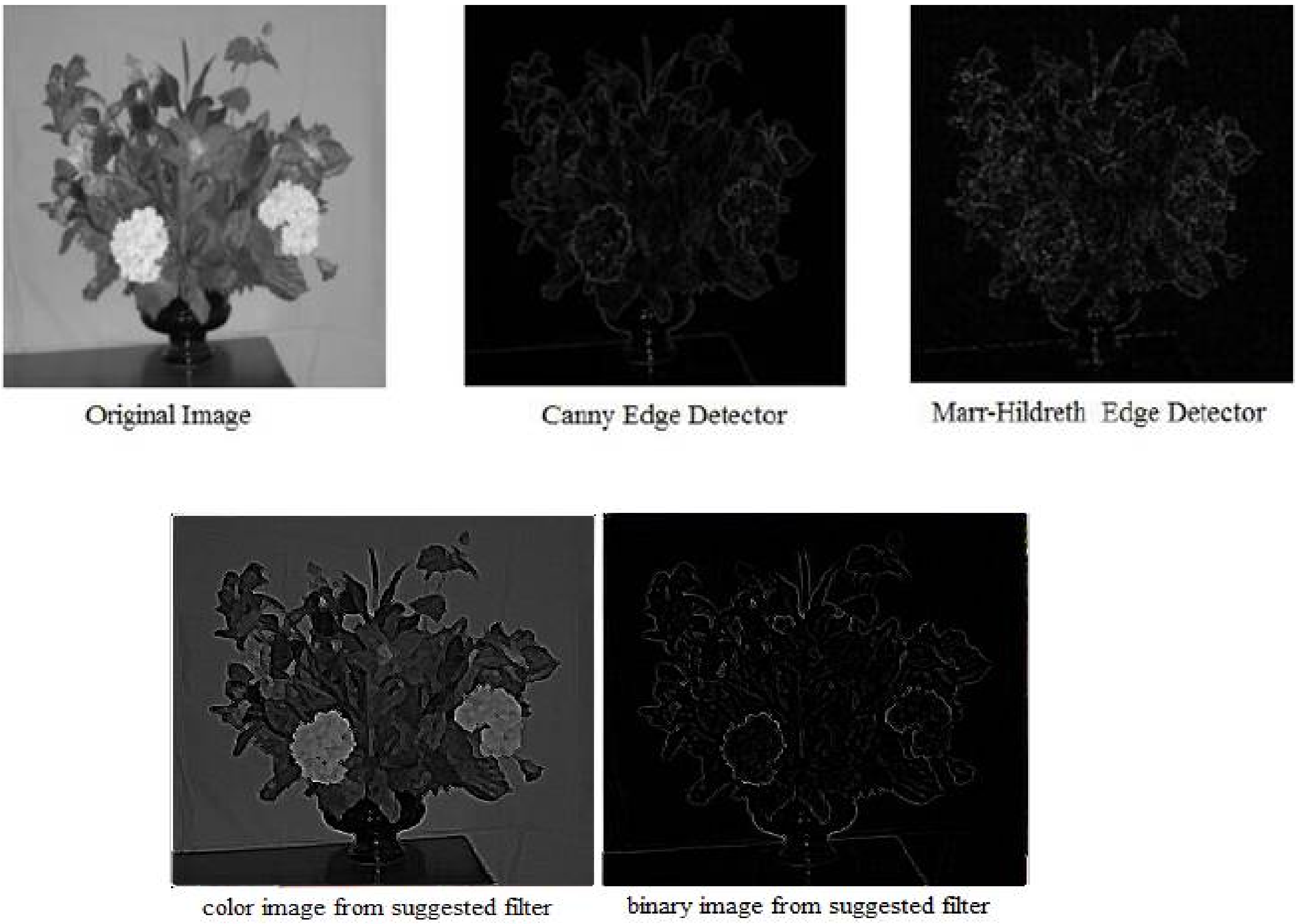


Fig. 4.Test image with different lines features.

5. In the Fig. 5. [10] we test the slop lines and corners by using many edge detection algorithms and compared them with suggested filter. It is very clear that the suggested filter have high performance and detect the edges more accurately.

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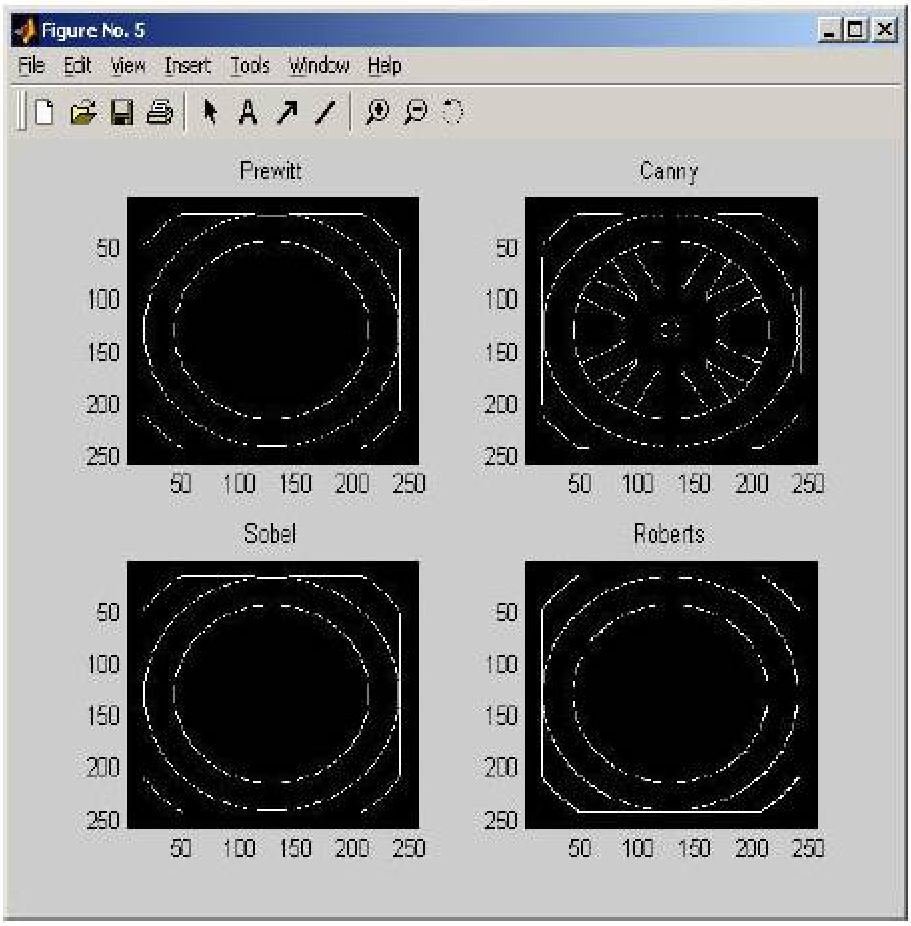
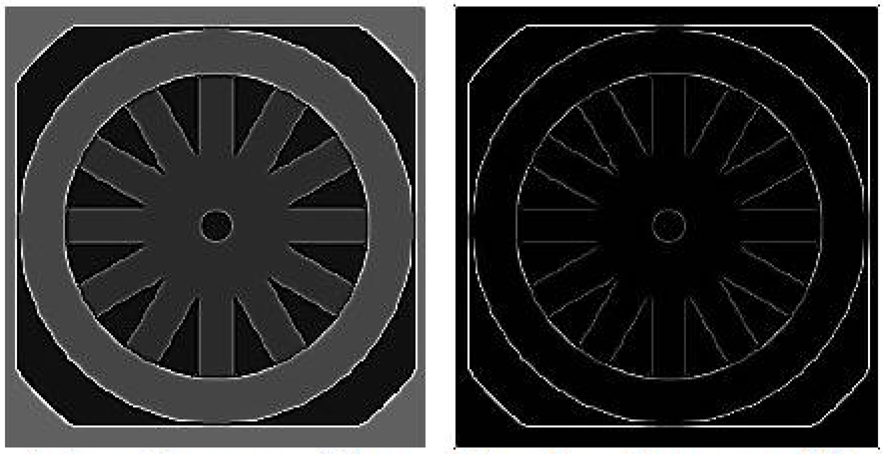
origin image

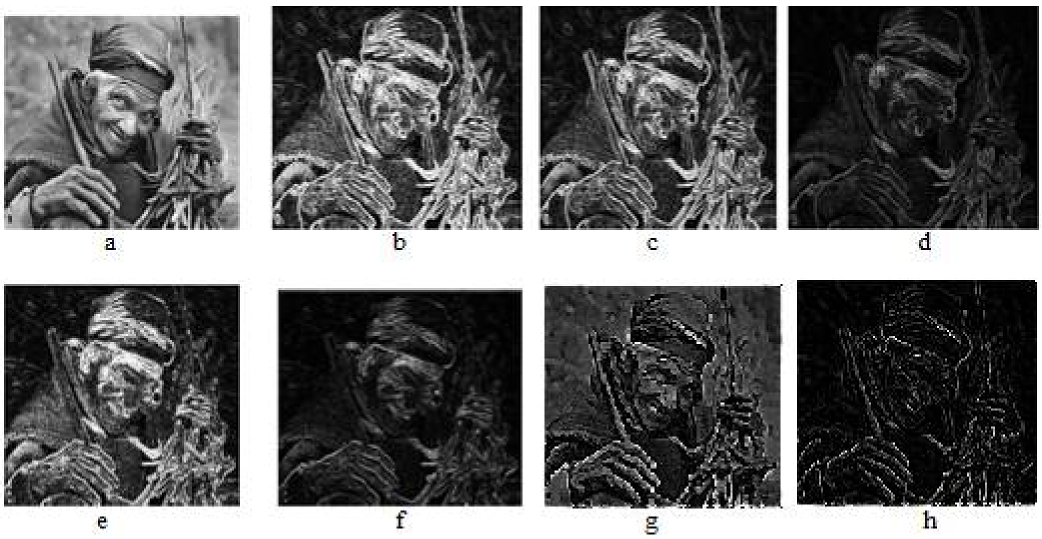




color image from suggested filter    binary image from suggested filter

Fig. 5. Test images with slop lines and corners

6. Comparing edge detection for many edge detection algorithms [10] and the suggested algorithm.




a) origin image. b) Sobel. c) Prewitt. d) Robert. e) Laplacian f) Laplacian of Gaussian. g) suggested filter (color). h) suggested filter (binary)

Fig. 6.Compare suggested algorithm with many other algorithms.

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7. Many edge detection algorithms [2] compared with suggested filter.

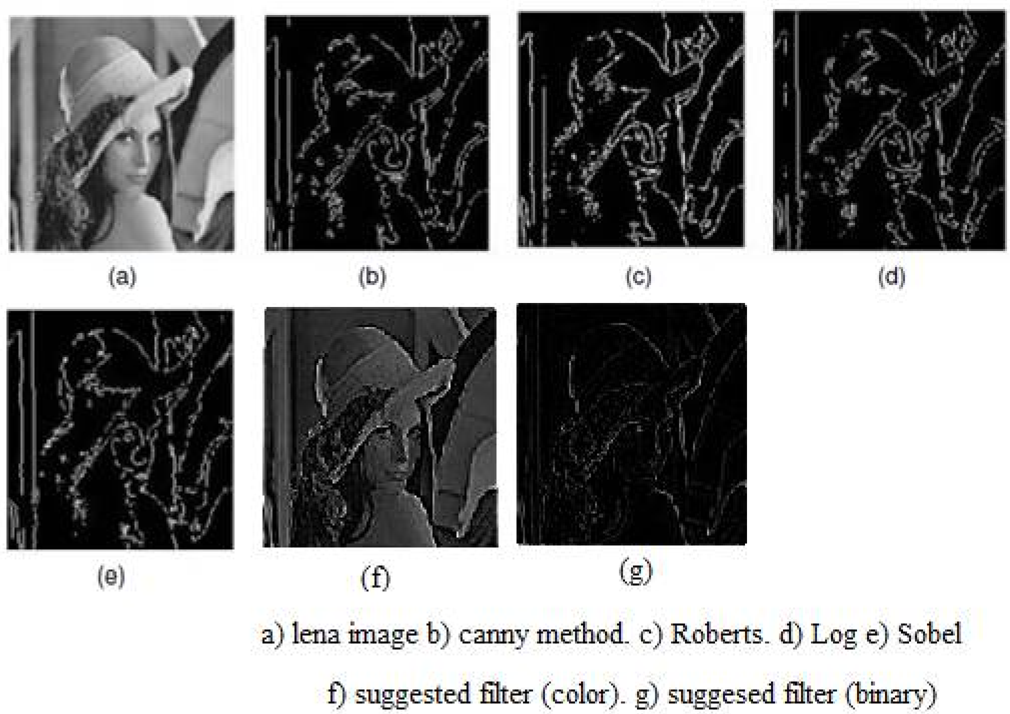
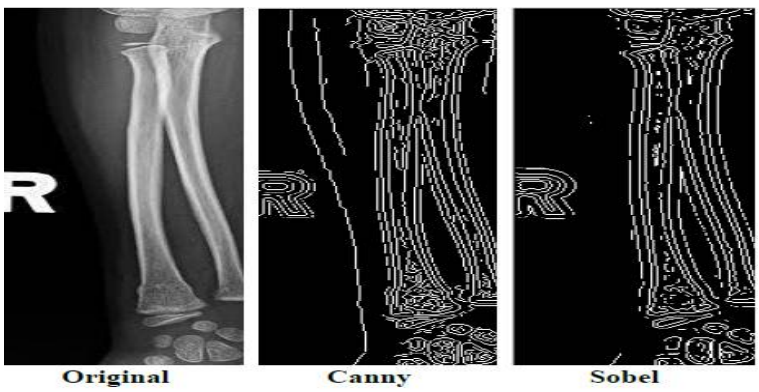



Fig. 7.Comparing of edge detection techniques on Lena image.

8. Comparing edge detection filters for x-ray images [11]. It is compared with suggested filter.



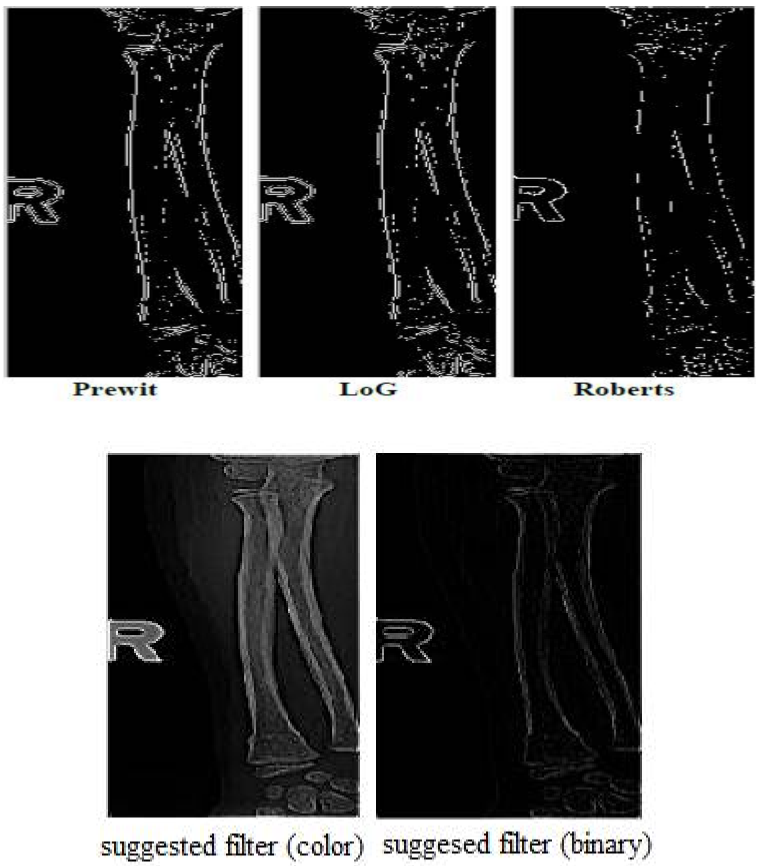



Fig. 8.Test with x-ray image.

9. Number of edge detection algorithms tested with images contains organized shapes [4]. Suggested filter also tested with same image to compare results with other algorithm results.

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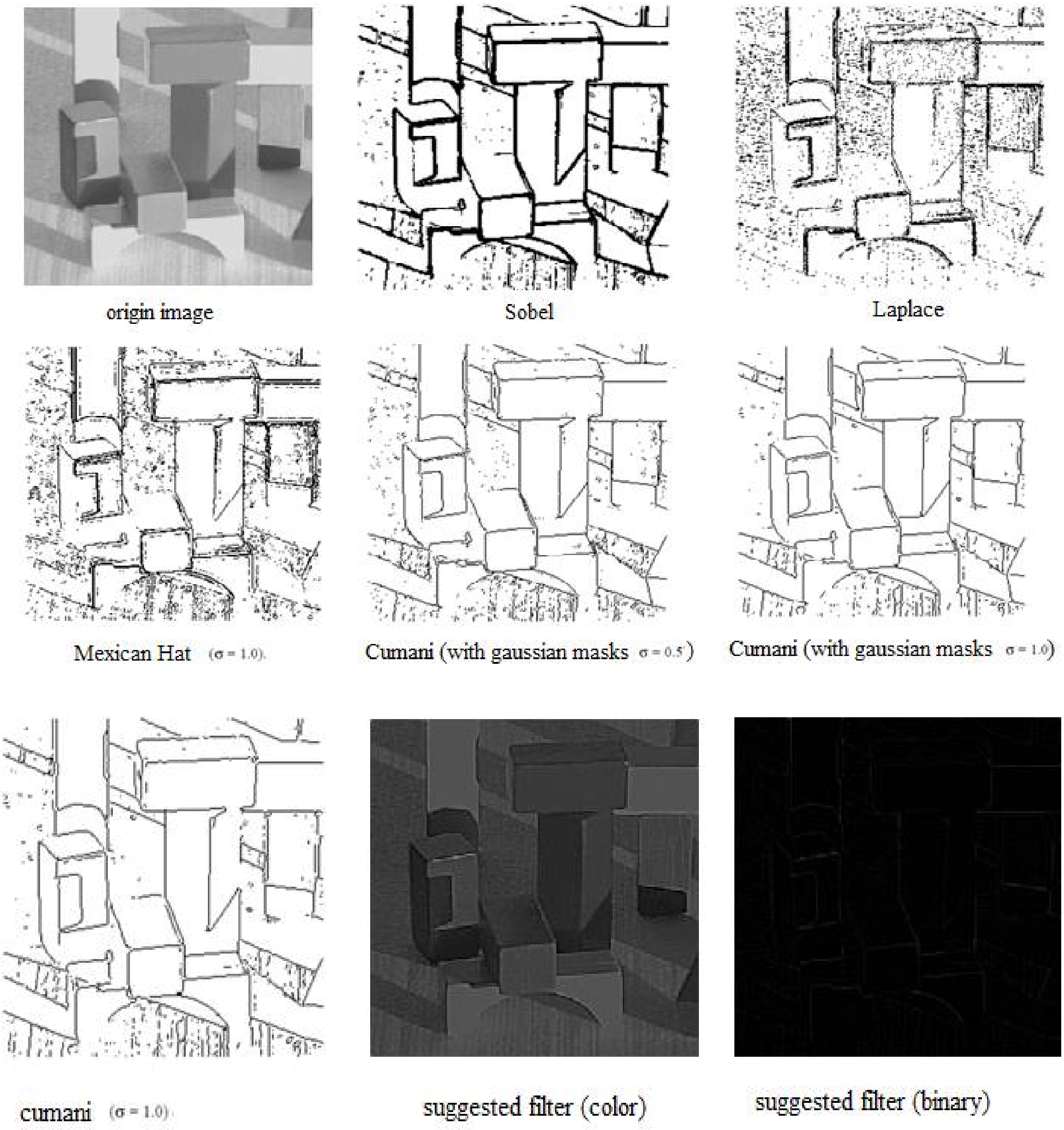


Fig. 9.Test with organized shapes image.

## VII. CONCLUSION

From the simulation results, it is concluded that the edge detection using suggested filter is more efficient thanthe traditional methods. The results of suggested filter comparedwith different methods of edge detection, it is concluded that the suggested filter edge detection is better than the traditional methods. In this work, edges of imagesdetected by using combination of Laplace filter and Markov bases compared with traditional method like Canny, Marr-Hildreth, Prewitt,

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Sobel, Roberts, Laplacian, Laplacian of Gaussian, Log edge, Cumani operator, and Mexican Hat operator methods. Many color images with different types of edge tested.

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