

Modified Edge Detector for Coloured Images

By
Bana Abdul-Rahman Lateef Al-Juboury
(Researcher)
Dr. Luay Adwar Jurj
(Senior Researcher)
Dr. Laith Abdul-Aziz-Al-Ani
(Assistance Prof.)

Abstract

In this paper, a study of the role of colour information in detecting the edges of an image was conducted. Therefore, different colour spaces with components corresponding to the attribute luminance, hue, and saturation (e.g. VHS, and LUV) were implemented.

Two edge detection techniques were applied to each of above colour spaces. These techniques are Sobel operator, and Nonlinear Laplace operator. A proposed nonlinear Laplace operator was implemented, and its encouraging results indicated its better efficiency than the traditional nonlinear Laplace operator. Different approaches were utilized to select a threshold value either manually or automatically. The automatic selection depends on the calculation of mean colour gradient magnitude or on the accumulated histogram. A suggested and implemented mechanism based on using two threshold boundaries to detect edges in colour spaces other than RGB, the results indicated an improvement in the resultant edge image.

1. 1 Introduction

Colour has been proved to be useful information in computer vision

systems since taking out the chromatic information can highly improve the accuracy of the algorithms.

This paper addresses the problem of detecting significant edges in colour images. More specifically, given a scene including objects, which are characterized by homogeneous colours, we want to detect and to extract their contours in the image. In general, a common approach to the edge detection in colour image was started by transform the {R, G, B} image to a new colour space, then applying edge detection techniques, followed by utilizing thresholding methods, and finally retransform the results into {R, G, B} images.

The previous work in colour images and edge detection techniques will be given below with a brief description of each of them:

- Navitia, in 1977, extended the Heuckel operator developed 4 years previous to process colour images. He stated that the result obtained using intensity $I=R+G+B$ and normalized colours ($r = R/I$, and $g = G/I$) was better than those obtained by using R, G and B [Navitia: 77].
- Martelli, in 1981, formulated the edge detection problems as a heuristic search for the shortest path on a graph. The graph nodes (or states) were edge elements defined by two neighboring pixels (e.g. points $A=(i, j)$, $B=(i, j+1)$) define the detected edge element AB. One of the drawbacks of this algorithm is that, once a mistake is made in the midst of the edge

the detected edge could be far off from the desired edge [Fu: 81].

- Imme, in 1989, has introduced a new edge detector, which produces edge mostly one pixel wide and without gaps. The proposed scheme of edge detection can be split into two operations: 1) one-dimensional edge detection, 2) combination of the results of one dimensional edge detection into two dimensional edge image. The evaluation for both methods is that in normal cases they behave equally well, but for difficult cases, the proposed method shows good performance [Imme: 89].
- Canny, in 1986, distinguished three performance criteria in judging the ability of his proposed operator to find edges: (1) Good detection; (2) Good localization; (3) only one response to a single edge. He has proven that in the case of step edges distributed by additive Gaussian white noise with zero Mean, the derivative of Gaussian is very good approximation to the numerically optimal edge detector for these edges. It is sub-optimal according to the above criteria and can be replaced by zero crossing of the second derivative of Gaussian operator applied on the input image [Canny: 86].
- Androutsos et al., in 1997, presented a comparison of the relative subjectively based performance of a group of basic

order statistic and difference vector operator detectors. The suggested that from a subjective standpoint, the most effective colour edge detectors for the cases studied were the difference vector mean, and difference nearest neighbor detectors. These led to the conclusion that, the difference vector nearest neighbor detector provides results which are perceived as favorable by the human eye. In addition the nearest neighbor filter has a limited ability to compensate for the type of environment in which it operates, i.e. it can effectively suppress noise [Androutsos: 97].

Our objective is to propose a solution, which overcome the problems of shades and reflections due to the lighting conditions and objects surface state.

1.2 Colour Space Transformation

Colour transformation is the change of coordinates from one colour system to another. Such a transformation associates to each colour in one system a colour in the other and is therefore called a change of system.

The reason for applying colour space transformation is very varied. The choice of an appropriate colour space can be considered as an important factor for determining the results of processing on colour images (e.g. the quality of edge detection of image) [Gomes: 97].

Different colour space with components corresponding to the attributes Luminance, Hue, and Saturation (YHS, and LUV) was implemented.

1.3 Edge Detector Operators

These kinds of operators can be divided into two classes: first order derivative (Gradient) and second order derivative (Laplacian).

1.3.1 Sobel Operator:

The Sobel edge detection consist of two convolution masks, which look for edge in both the horizontal and vertical directions and then combine this information into a single metrics. The masks are as follows: (Boltard: 82).

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

G_x

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

G_y

The direction lies 90° from the apparent direction of the edge

1.3.2 Nonlinear Laplace Operator:

It is a nonlinear combination of neighborhood pixels. Given a 3x3 neighborhood (N) surrounding the pixel b (x,y), its nonlinear Laplace is:

$$NLLP(x, y) = \{Maximum(N) - b(x, y)\} - \{b(x, y) - Minimum(N)\} \dots\dots\dots(1.1)$$

$$= Maximum (N) - 2*b(x, y) + Minimum(N) \dots\dots\dots(1.2)$$

Where

Maximum (N) is the maximum brightness value in neighborhood [N]. Minimum (N) is the minimum brightness value in neighborhood (N). b

(x, y) is the brightness value at the central position (x, y).

The nonlinear Laplacian adapts its orientation to the local gradient direction, due to its flexibility. It takes the second order derivative in the most relevant direction perpendicular to the local edge direction.

The formal definition ofNLLP operator for arbitrary size and shape: [Vliet: 89].

$$NLLP(x,y) = gradmax(x,y) + gradmin(x,y) \dots\dots\dots(1.3)$$

Where

$$gradmax(x,y) = Max(|(x'y')| |(x'y) edn(x,y)| - I(x,y) \dots\dots\dots(1.4)$$

$$gradmin(x,y) = Min(|(x'y')| |(X'y')edn(x,y)| - I(x,y) \dots\dots\dots(1.5)$$

d n is an N x N square filter centered at (x, y).

1.3.3 Proposed Nonlinear Laplace Operator:

In the present work, the proposed NLLP operator has been suggested and implemented as a 3x3-neighborhood edge detector. This operator works as follows:

- Given the neighborhood N surrounded the pixel at position (x, y) within the image,
- Calculate the difference between the central pixel and its neighbors:

$$DN (i,j) = b (x, y) -N (i, j) \dots\dots\dots(1.6)$$

Where

b (x, y) is the brightness value at central position (x, y). N (i, j) is the brightness value of the neighbor (i.e., b

$(x+i, y+j)$). The proposed nonlinear Laplace is (PNLLP) given by:

$$\text{PNLLP}(x,y) = \text{Max}(D_N) - \text{Min}(D_N) \dots\dots\dots(1.7)$$

Where

Max (D_N) is the maximum difference value.

Min (D_N) is the minimum difference value.

1.4 Thresholding Process

Many edge detectors are implemented to work with the colour images, the results of each of these detectors are three gradient magnitudes to the Red, Green, and Blue colour components. A parallel comparison of each colour channel corresponding to the same threshold will result in setting white value to those pixels with magnitude lower than a specific threshold while leaving those pixels with magnitude greater than the threshold value to their original colour (i.e. edge pixels).

In this work, two types of threshold criteria were adopted. The first one is involved with automatic selection of the value of (T), which is based on the statistical properties of the colour gradient magnitude of the image, where, the mean value multiplied by a factor (named as multiplier factor) was considered as threshold value. The multiplication factor represents the ratio of the edge pixels in the image.

The proposed algorithm for calculating the threshold value by using the second method is demonstrated by Algorithm 1.1.

Algorithm 1.1 Determination of a Threshold value as a multiple mean value

1. Determine the sum of resultant gradient for each colour band (R, G, B) separately.
2. Determine the mean of the gradient value of colour band, as a result of dividing the corresponding sum value by the size of the image (in pixels).
3. Take the average of the three mean gradient values.
4. Input the multiplication factor (the estimated weighting of edge pixels mostly greater than 2).
5. Determine the threshold as a multiplication of the gradient average by the multiplication factor.

The second way to find a threshold automatically is by using the histogram. It consists of the stages illustrated in Algorithm (1.2).

Algorithm 1.2: Determination of a Threshold value by using Accumulated histogram

1. Determine the sum of resultant gradient magnitude for each colour (R, G, B) separately.
2. Calculate the histogram of each gradient colour band.
3. Take the maximum gray level value of the histogram for each colour band (R, G, B).
4. Set the counter to the maximum gray level value in the histogram (i.e. $k=255$).
5. Calculate the average of the three bands.
6. Divide the average by the size of image.
7. If it is less than the ratio of the edges in the image then decrease the counter and accumulate the histogram value in current position and the previous one.
8. This process repeats until the result of accumulation becomes greater than the ratio of edges in image.
9. If it is greater than take the value of the counter as thresholding value.

1.5 Results and Discussion

Edge detection is usually a subjective task. Unfortunately numerical data or a scheme useful in providing an effective means to precisely compare and evaluate the performance of edge detectors is very hard to attend. As a result, it is often more convenient to rate various detectors using subjective tests.

Two colour images shown were used in the experiments. The names of these images are (a) Lenna with 256 colour (8-bitplan) (b) geometry blocks with 24-bitplan. They were digitized with 256x256 spatial resolution.

RGB colour space deals with fixed threshold value. When the transformation from RGB to any perceptual colour space (e. g. VHS), it can easily separate the chromatic values (hue and saturation) from achromatic value (intensity). The HVS (Human Visual System) discrimination performance changes in its sense of colour, and this change depends on the intensity (i.e. it can not easily recognize between two dark red and dark blue colours) so, to deal with these colour space a dynamic thresholding is needed.

When the edge detectors applied on real images (like, Lenna and geometry blocks image) in any perceptual colour space using fixed threshold value, it is found that the dark region in the resulted images will not be detected properly (i.e. much noise will appear in it). When the threshold value increases the noise might be removed but this is at the expense of missing some edges as

shown in figure (1.1). So two threshold boundary values (T_H & T_L) must be applied, where $T_L < T_H$. These two values depend on the intensity distribution of the image. In this work, a linear relationship was suggested to deal with these threshold boundaries. The suggested relationship is simply:

$$T = T_H - \frac{T_H - T_L}{255} I \quad \text{..... 1.8}$$

Where

T_H is the higher threshold boundary.

T_L is the lower threshold boundary.

$I = \frac{R+G+B}{3}$ is the intensity value.

It is obvious from equation (1.8) that, when $I=255$ then $T=T_L$ and when $I=0$ then $T=T_H$ (i.e. when the intensity is high then T take the lowest threshold value and vice versa).

In the implementation of the above thresholding equation, the T value was compared only with the hue and saturation components, while the intensity is always compared with the low threshold (T_L).

Equation (1.8) above is suitable for manual thresholding. Since the automatic selection of the threshold depends on the mean value of the gradient image then equation (1.8) is changed as below:

$$T = M - \frac{M - M_0}{255} I \quad \text{..... (1.9)}$$

Where

M is the threshold value, which depends on the statistical properties of the colour gradient magnitude, and the

algorithm for determining it is mentioned previously.

M_H represents the high mean value derived from the 3-channels of the input image and it's 6 (or more) times greater than the mean value, it is changed from detector to other, but with different type and from image to

another image depending on the mean value.

The following, is an illustration of the results of each edge detector that are implemented in the basic RGB colour space and also in the VHS, and LUV colour spaces.

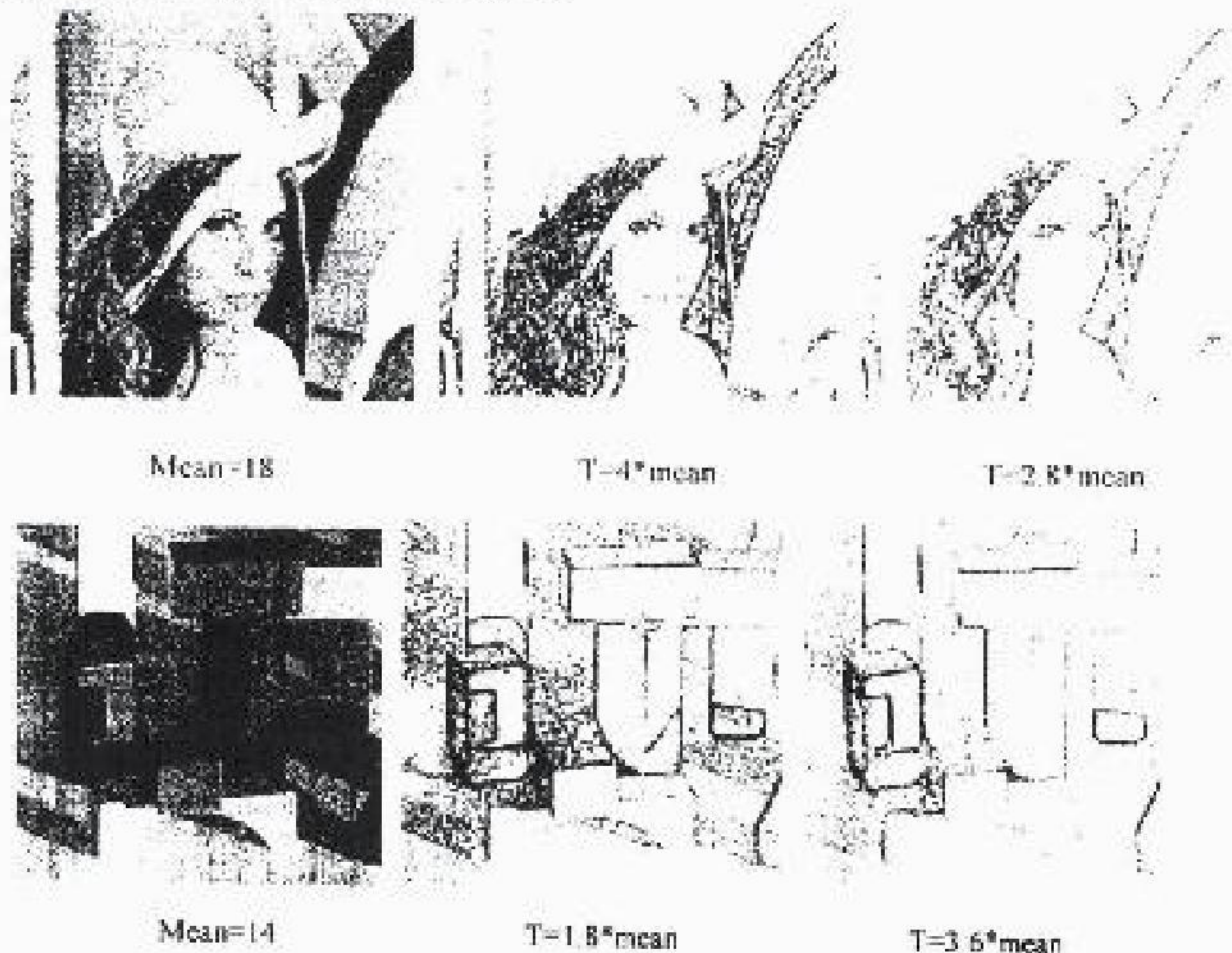


Figure (1.1): The results of Sobel operator applied on VHS colour space using mean thresholding

When partial derivative for each colour channel has been estimated using simple finite differences, edge regions will appear sharper but the effects of image noise are visible and unavoidable.

For RGB colour space, although the outlines of major objects have been detected, the edge is thicker than one pixel wide in many places. When the

threshold is increased the edge will be less thick, but a disconnection in the edges may appear.

When applying it in VHS and LUV colour space the edge thinner and the noise is less, but VHS produce a good results with Lena image, while LUV produce a good results with Geometry blocks image.

Figure (1.2) shows the results obtained by applying Sobel operator with mean thresholding mechanisms.

The implementation of NLLP (Nonlinear Laplace) operator produces a noisy image and there is much discontinuity in the edge. When the threshold increases, the noise becomes less but some edges almost disappear. On the average the edge is not detected well. Figure (1.3) shows the resulting images in RGB and other colour space with mean thresholding technique.

By applying the PNLPP (Proposed Nonlinear Laplace) operator to the two test colour images, it is found that the resultant image is better than the one results obtained from the traditional

nonlinear Laplace especially in the noise existence which are less in the proposed nonlinear Laplace and also the edge are more connect.

Figures (1.4) and (1.5) show the resulted images produced by applying this operator using mean thresholding, and histogram thresholding techniques where, the drawing histogram corresponds to the gradient of an image. Notice that the region in the Lenna image is not detected well as the other regions in this image, but when the threshold increased, the noise decreased. It is better detected with VHS where the edge appear thinner and connected, while in Geometry blocks image a good result obtained with LUV.

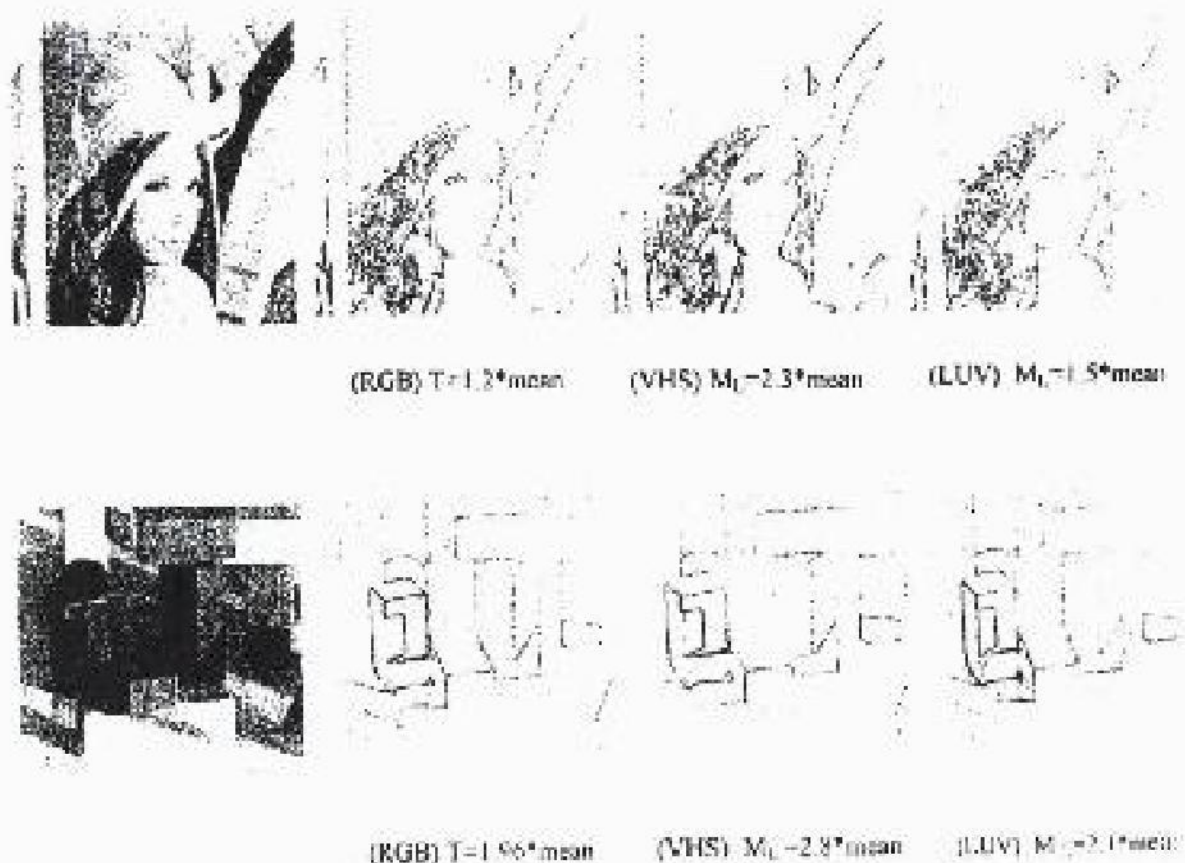


Fig. (1.2): Results of Sobel operator using mean thresholding with different colour spaces

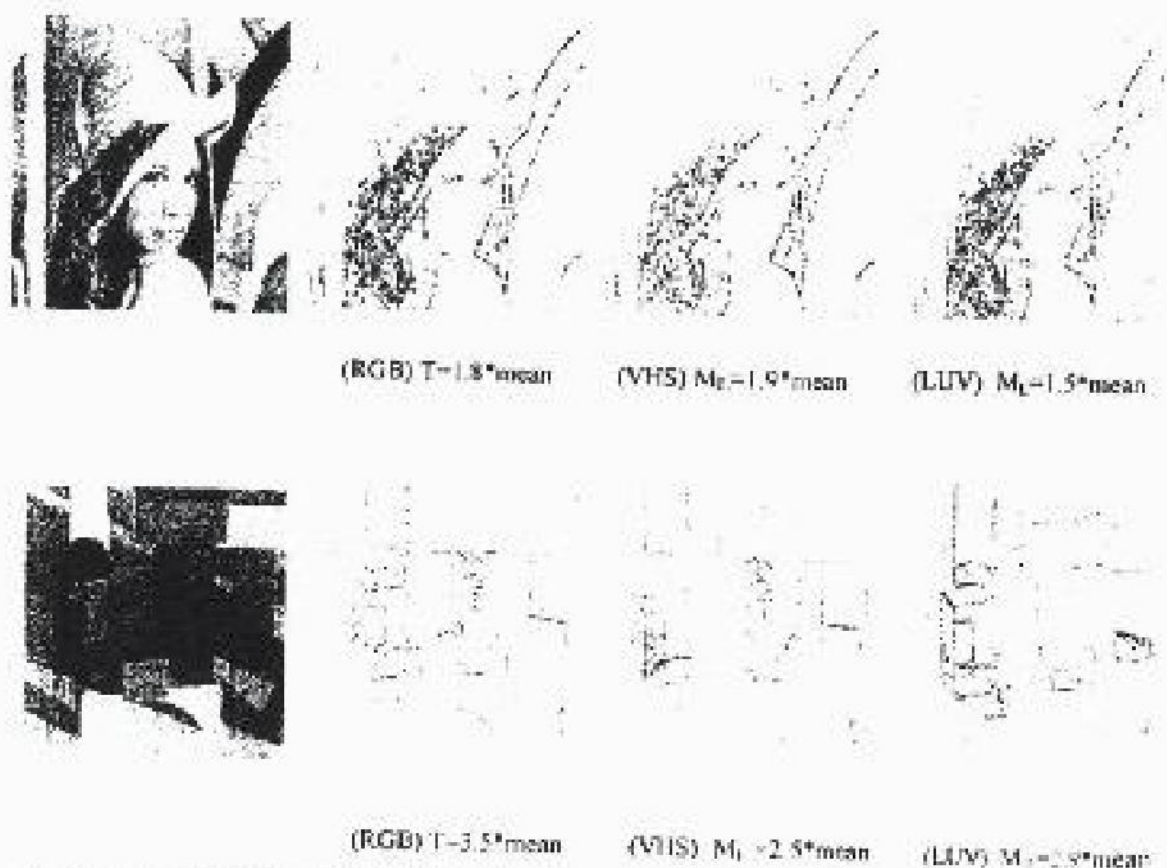


Fig. (1.3): Results of Nonlinear Laplace operator using mean thresholding with different colour spaces

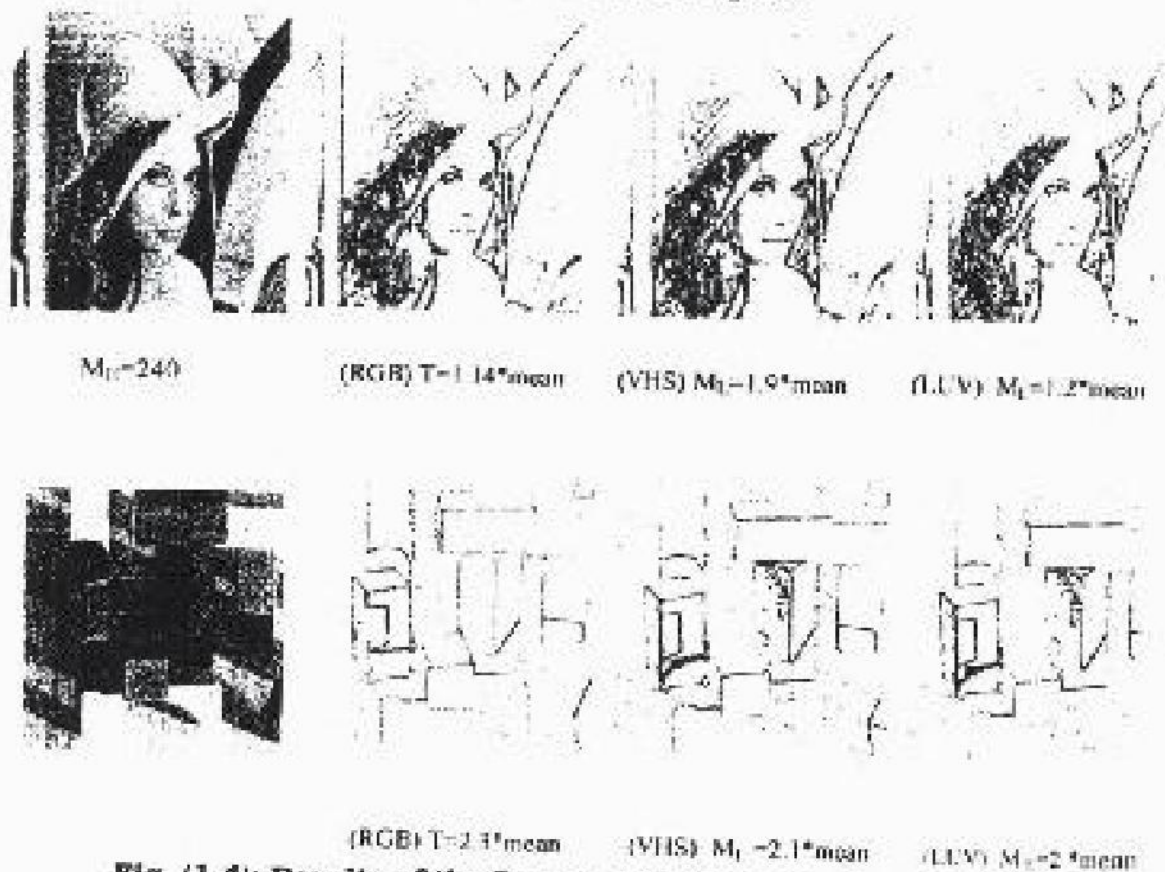


Fig. (1.4): Results of the Proposed Nonlinear Laplace operator using mean thresholding with different colour spaces

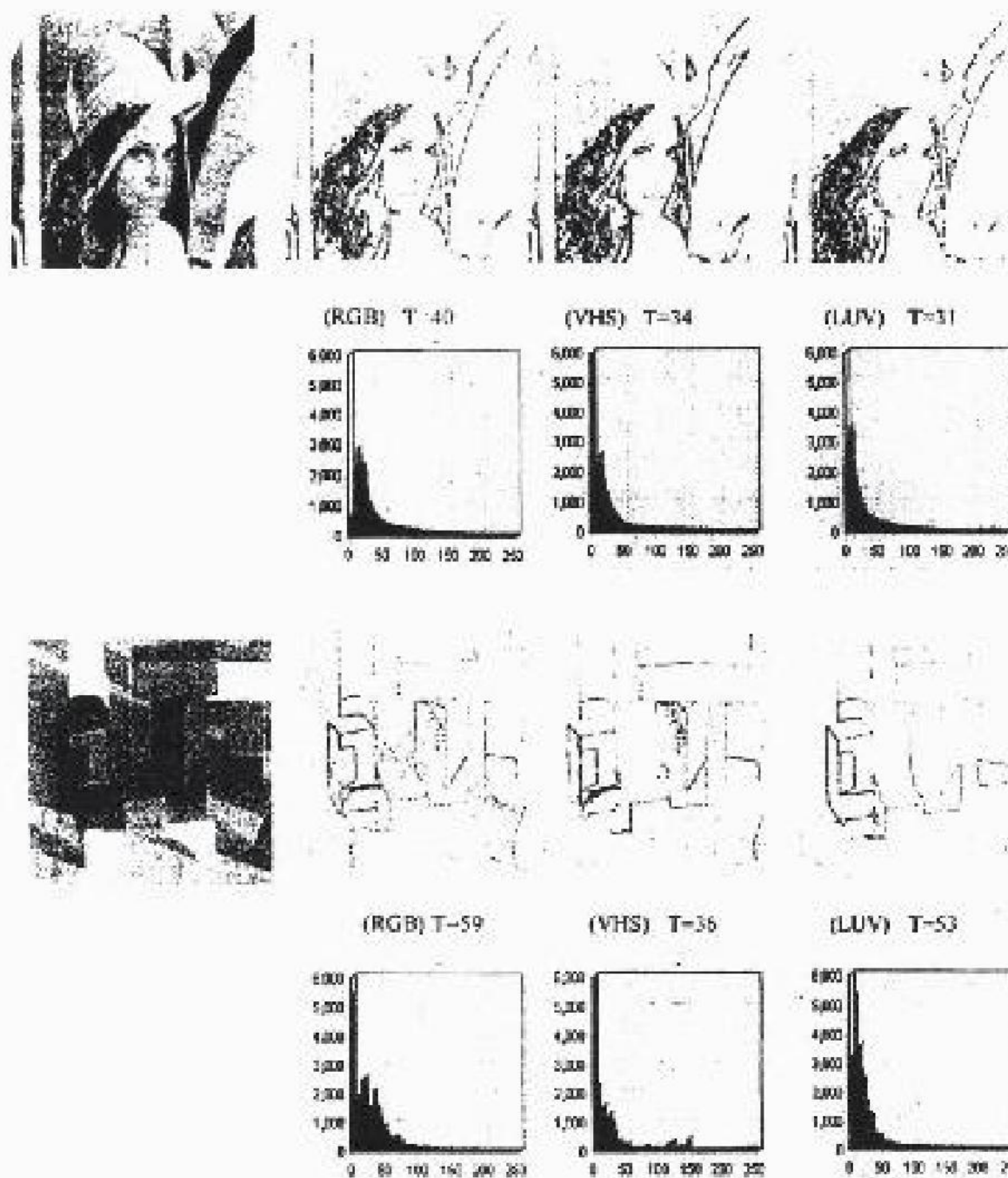


Fig. (1.5): Results of the Proposed Nonlinear Laplace operator using histogram thresholding with different colour spaces

Conclusions

From the analysis of test results, the following conclusions are derived:

1. When applying edge detector to colour spaces other than RGB, we find that using dynamic thresholding with two threshold boundaries (T_1) and (T_2) instead

of fixed threshold value will produce better results, especially in the case of Lenna and Geometry Blocks images, where the dark regions of them are not detected well by using fixed threshold value. So it is necessary to apply low threshold boundary value to test the chromatic

information of regions with high intensity, while the chromatic information (like Hue and Saturation) takes high threshold boundary value if intensity is low.

2. In general, applying edge detectors to some colour space other than RGB makes the image appear smoother and the edges appear thinner.
3. From all the above results, it is obvious that the application of a specific operator to any one of colour spaces differs from one image to another.
4. Two objects in the same image with the same colour are not always detected equally. This may due to the detection dependency upon the neighborhood of specific objects (e. g., in geometry blocks image, the left green block is usually detected better than the right green block).

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