

# Analysis and Development of Color Edge Detection Techniques

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**Abstract**—Edge detection is a process to finding meaningful transactions in an image which are the important research task in the field of image processing. Edge detection is to identify area of an image where a large change in intensity occurs. Edge representation reduces the amount of data to be processed, preserving the important information about the shapes of objects. Color images provide more edge information as compared to gray scale images. The number of researchers has proposed various algorithms for color edge detection. The output of color images is different from gray scale images. Results of the edge detection of a color image vary for different color edge detection techniques. The results also differ if the same technique is applied across different color spaces. There are many color spaces like HSV, RGB,  $L^*a^*b^*$ , YIQ, YUV. The focus of this research paper is to analyze the various color edge detection techniques in different color spaces (RGB, HSV,  $L^*a^*b^*$ ) and compare the results.

**Index Terms**—Keyword – Edge Detection, Color spaces (RGB, HSV,  $L^*a^*b^*$ ).

## I. INTRODUCTION

Edge detection is a process of detecting the presence and location of edges. Image edges contain significant amount of information which is useful in image processing, computer vision, pattern recognition, where feature extraction is the main task. Edges are used in various applications like electronic printing, medical imaging, industrial inspection, autonomous guidance in military systems etc. Edge detection highlights the transitions in intensity. The edge detection in gray-level images is a well-established area; edge detection in color images has not received the same attention. In color image processing, vector-valued image functions are treated instead of scalar image functions of gray-scale images. Various algorithms have been introduced for color edge

detection; but the applicability of most of them is limited to some images. The main problems in the area of color edge detection are:

- Gray-scale images contain one component whereas color images contain more components than the gray-scale images.
- Different algorithms used for implementing edge detection behave differently in different color spaces.
- Some of the existing algorithms for color edge detection extend the gray-scale edge detection techniques; some convert the color image into grayscale first. The results thus obtained are not satisfactory.

The objectives of the proposed work are:

1. To implement and analyze the color edge detection techniques in RGB, HSV,  $L^*a^*b^*$  Color Spaces:
  - a. By extending gray scale edge detection to color images.
  - b. Using gradient of a vector function.
2. To compare the results of edge detection using both monochromatic and vector-valued techniques; and vector valued edge detection techniques in different color spaces.

## II. PROPOSED METHODOLOGY

a. Extension of Gray Scale Edge Detection to Color Images Edges in gray-level images can be thought of as pixel locations of abrupt gray-level change. The principal objective is to highlight transitions in intensity. Different derivative operators are used for detecting edges. Fundamentally, the strength of the response of a derivative operator is proportional to the degree of intensity discontinuity of the image at the

point at which the operator is applied.

The edge detection of gray scale can be easily extended to color images. The individual color channels or color vector components are first treated separately and then they are combined together. The gradient operators are applied to each channel of the color image. Then the gradient images obtained from all the channels are combined to form the final edge image. Although, the results are not that satisfactory, all the component results are combined to obtain the final edge map.

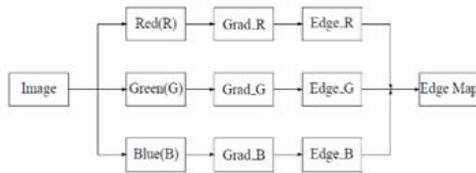


Fig. 1. Monochromatic-based techniques

b. Color Edge Detection Using Gradient of a Vector Function

Vector-valued techniques treat the color information as color vectors in a vector space provided with a vector norm. Vector methods do not have to consider the problem of how to combine the channels to produce a final edge map as all their gradient finding operation is performed in the vector space.

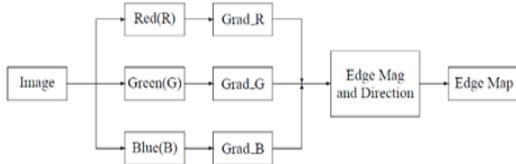


Fig. 2. Vector-valued technique

c. Color Spaces and Conversion of Color Spaces

RGB color space is ideally suited for hardware implementations. There are many kinds of color spaces, such as RGB, HSV, L\*a\*b\*, YUV, YIQ etc. RGB color space describes colors, each pixel of the image is represented in the hardware as binary values for three color components i.e. red, green, and blue.

The RGB color space can be converted into the HSV color space or any desired color space by using the values in some formulation. The HSV color space describes the color in terms of Hue, Saturation, and Value. Following the equation of converting RGB to

HSV components [7]:

$$H = \begin{cases} \theta & \text{if } B \leq G \\ 360 - \theta & \text{if } B > G \end{cases} \quad (1)$$

with

$$\theta = \cos^{-1} \left\{ \frac{\frac{1}{2}[(R-G)+(R-B)]}{\left[ \frac{1}{4}[(R-G)^2 + (R-B)(G-B)] \right]^{1/2}} \right\} \quad (2)$$

$$S = 1 - \frac{3}{(R+G+B)} [\min(R, G, B)] \quad (3)$$

$$V = \frac{1}{3} (R + G + B) \quad (4)$$

In this color spaces Hue represents the color type. The value of Hue is normalized in the range from 0-255. Saturation represents the purity and amount of white light which mixed with a hue. Saturation value ranges from 0-255. Value represents the brightness of color. Its value ranges from 0-255.

The L\*a\*b\* color model (device-independent) was developed with the goal of linearization the representation with respect to human color perception and at the same time creating a more intuitive color system. The dimensions in this color space are the luminosity L\* and the two-color components a\*, b\*, which specify the color hue and saturation along the green-red and blue-yellow axes, respectively. All three components are relative values and refer to the specified reference white point C<sub>ref</sub> = (X<sub>ref</sub>, Y<sub>ref</sub>, Z<sub>ref</sub>).

The conversion of RGB into L\*a\*b\* is as follow:

$$\begin{cases} L^* = 116 \left( \frac{Y}{Y_n} \right)^{1/3} - 16, & \text{for } \frac{Y}{Y_n} > 0.008856 \\ L^* = 903.3 \left( \frac{Y}{Y_n} \right)^{1/3}, & \text{for } \frac{Y}{Y_n} \leq 0.008856 \end{cases} \quad (5)$$

$$a^* = 500 \cdot \left( f \left( \frac{X}{X_n} \right) - f \left( \frac{Y}{Y_n} \right) \right), \quad (6)$$

$$b^* = 200 \cdot \left( f \left( \frac{Y}{Y_n} \right) - f \left( \frac{Z}{Z_n} \right) \right),$$

with

$$f(c) = \begin{cases} c^{1/3} & \text{for } c > 0.008856 \\ 7.787 \cdot c + \frac{16}{116} & \text{for } c \leq 0.008856 \end{cases} \quad (7)$$

were

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} 0.412453 & 0.357580 & 0.180423 \\ 0.212671 & 0.715160 & 0.072169 \\ 0.019334 & 0.119193 & 0.950227 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix} \quad (8)$$

The L\*a\*b\* color space corresponds to brightness. Its value ranges black (0) to white (100). Usually, D65 is specified as the reference white point (X<sub>n</sub>, Y<sub>n</sub>, Z<sub>n</sub>), with (X<sub>n</sub>, Y<sub>n</sub>, Z<sub>n</sub>) = (0.950456, 1.000000, 1.088754).

### III. EXPERIMENTS AND RESULTS

The experiments made in this study aim to analyze the chosen color edge detection techniques in different color spaces. Three color spaces used for implementation and analysis are: RGB, HSV and L\*a\*b\*. In case of HSV and LAB color spaces, R, G, and B components are first converted into the H, S, and V, and L, a, and b, for the HSV and Lab color spaces respectively. For the purpose of analyzing color edge detection, two color edge detectors are used for edge detection of noiseless images in this study. One of these edge detectors is monochromatic-based technique and the other is the vector-valued edge detection technique. Sobel operator is used for computing derivatives in both edge detection techniques. We have implemented the color edge detection techniques first Original color image by extending the grayscale edge detection to color images in RGB color space. All the individual gradients of red, green and blue component images are calculated using Sobel operator, and then results are added to form the final gradient image. Then the vector-valued technique is used for edge detection and the algorithm used is the one proposed by Di Zenzo [1]. For HSV and L\*a\*b\* color spaces, R, and B components in the above algorithm are replaced by L\*, a\* and b\*, and H, S and V, respectively. Sobel operator is used for computing partial derivatives of images.

#### a. Monochromatic-based and Vector-valued Color Edge Detectors:

In this part of experimental results, the aim is to observe the difference between the performances of monochromatic-based edge detectors and vector-valued edge detectors. The results can be viewed in Fig.3. The results illustrate that the edge detail of the vector gradient image is more complete than the detail in monochromatic-based gradient image.

Fig. 3 (b) is the gradient of the image in Fig. 3(a) computed using the vector-valued technique in the RGB color space. Fig. 3 (c) is the gradient image obtained by the monochromatic-based approach. The component gradient images of Fig. 4 are added to obtain the gradient image in Fig.3 (c). The edge detail of the vector gradient image is more complete than the detail of the monochromatic-based gradient image in Fig. 4 (c). The image in Fig.4 (d) shows the difference between the gradient images computed by two different approaches.

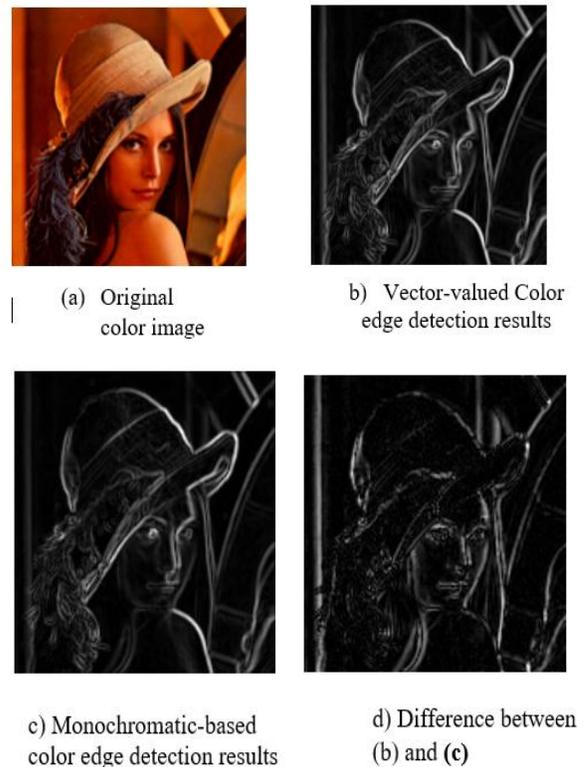


Fig. 3 Monochromatic-based and vector-valued color edge detection results in RGB color space for the image “Lena”

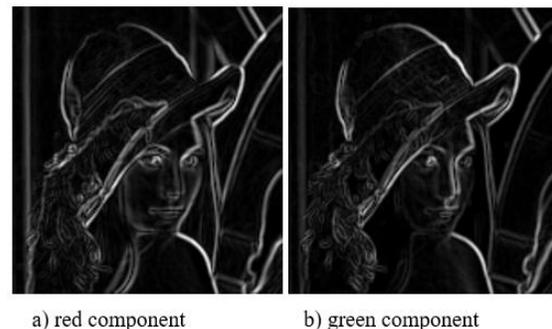




Fig. 4 Component gradient images of the color image Fig. 3 (a).

In monochromatic-based approach, simple Sobel operators are used, whereas vector-valued technique requires complex additional computations. The worth of extra computation required in vector-valued technique can be determined only by the requirements of the problem.

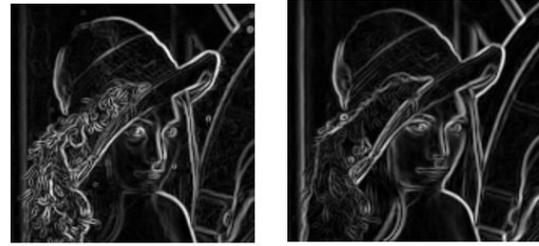
b. Vector-valued Color Edge Detector in different color spaces:

This part of the experimental results examines the results obtained with the vector-valued color edge detector in the three-color spaces: RGB, HSV and L\*a\*b\*. The results can be viewed in Fig. 2.3. The results illustrate that the greater number of edges are detected in HSV color space than the other two-color spaces. Results may vary with noisy images, thresholding and thinning approaches.

In Fig. 5 (a) is the original color image. Fig. 5 (b) contains the image obtained by computing the vector gradient image of the original image in RGB color space. Fig. 5 (c) and Fig. 5 (d) shows the vector gradient image in the HSV and L\*a\*b\* color space, respectively. We can observe by comparing Fig. 5 (b) – (d) with Fig. 5 (a) that the image Fig. 5 (c) (i.e. HSV color space) shows more intensity discontinuities and thus contain more edges in the hair section. Even the edges showing the structure of the lips is more appropriate in Fig. 5 (c). The edge details in Fig. 5 (d) (in HSV color space) are also better in contrast to Fig. 5 (b) i.e. in RGB color space.



a) original color image      b) Color edge detection results in RGB color



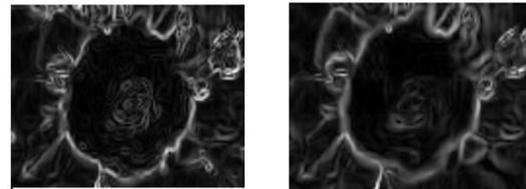
c) Color edge detection results in HSI color space      d) Color edge detection results in L\*a\*b\* color space

Fig. 5. Vector-valued color edge detection results in RGB, HSV and L\*a\*b\* color spaces for the image “Lena”

In Fig. 6, again Fig. 6 (c), the gradient image in HSV color space, contains more edge detail than the results in RGB and L\*a\*b\* color spaces in Fig. 6 (b) and Fig. 6 (d), respectively. And the results obtained in L\*a\*b\* color space in Fig. 6 (d) are better than the results in Fig. 6 (b), i.e. in RGB color space.



a) Original color image      b) Color edge detection results in RGB color space



c) Color edge detection results in HSV color space      d) Color edge detection results in L\*a\*b\* color space

Fig. 6 Vector-valued color edge detection results in RGB, HSV and L\*a\*b\* color spaces for the image “Rose”

In edge detection in HSV and L\*a\*b\* color spaces require conversion from RGB color space to the corresponding color spaces. This additional computation is not required for the RGB color space, since all the images are already in the form of R, G and B components. Although, results obtained in the HSV and L\*a\*b\* color spaces is reasonable, but the worth of extra computation required in these color spaces can be determined only by the requirements of the problem.

## IV. CONCLUSION

In this paper, color edge detection techniques were analyzed and comparisons between different methods, in different color spaces were presented. Firstly, the differences between the monochromatic-based color edge detectors and the vector-valued edge detectors were examined and it was seen that the vector-valued technique presents more edge detail than the monochromatic-based color-edge detector. Then the vector-valued edge detection technique was analyzed in the three, RGB, HSV,  $L^*a^*b^*$ , color spaces. It was observed that more number of edges was detected in the HSV color space than the other color spaces. Implementation of the color edge detection techniques will be extended to include more gradient operators like Prewitt, Roberts etc. and results will be compared in different color spaces (RGB, HSV,  $L^*a^*b^*$ ). The detection will be done for noisy images considering the different smoothing filters. The research will also be extending to include the thresholding and thinning algorithms and the development of some appropriate edge detection technique. The difference between the maximum and minimum gradient will also be studied which may be useful for feature extraction. Considering the three-color spaces, results of different images using different filters and different gradient operators will be obtained and the critical evaluation and analysis of the images will be done stating the merits, demerits and various other issues involved in color edge detection techniques.

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