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Color Image Edge Detection using Pseudo-Complement and Matrix Operations

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***Abstract*—**A color image edge detection algorithm is proposed in this paper using Pseudo-complement and matrix rotation operations. First, pseudo-complement method is applied on the image for each channel. Then, matrix operations are applied on the output image of the first stage. Dominant pixels are obtained by image differencing between the pseudo-complement image and the matrix operated image. Median filtering is carried out to smoothen the image thereby removing the isolated pixels. Finally, the dominant or core pixels occurring in at least two channels are selected. On plotting the selected edge pixels, the final edge map of the given color image is obtained. The algorithm is also tested in HSV and YCbCr color spaces. Experimental results on both synthetic and real world images show that the accuracy of the proposed method is comparable to other color edge detectors. All the proposed procedures can be applied to any image domain and runs in polynomial time.

***Keywords*—**Color edge detection, dominant pixels, matrix rotation/shift operations, pseudo-complement.

I. INTRODUCTION

EDGE detection is a vital step in image processing and is one of the most crucial step towards classification and recognition of objects. Color plays a crucial role in image analysis and recognition. A color image will have a vector of three values for every pixel unlike in gray images where a single value representing the intensity of a pixel. Human vision system chooses color rather than shapes and texture as the major discriminant attribute [1-2]. Many algorithms have been proposed in [3-7] for color images. Of all the edge detectors, Sobel is the standard detector and Canny [8] is the modern standard and is used by researchers to compare their results with the results of Canny detector. Novak and Shafer [9] found that 90% of the edges are about the same in gray-level and in color images. It implies that 10% of the edges are left over in gray level images. Since color images give more information than gray-level images, this 10% left over edges may be extracted from color images. In general, to extract edges from the images either gradient based methods [10] or vector based methods [11] are used.

In [12], a pseudo-complement approach has been proposed as a pre-processing step for edge detection. This pseudo-complement acts like a low pass filter and highlights the weak intensity pixels. The nature of the pseudo-complement process is that it reduces the gray intensity distribution to 50% i.e., a gray level image having the intensities in the range 0-255 will be reduced to the intensities of the range 0-128 thereby the weak intensity pixels will be highlighted. In [13], a new method to extract dominant pixels has been introduced. These dominant pixels will represent the core pixels of any image. To achieve this, they used various matrix rotation operations. In the proposed method, we have used the pseudo-complement approach as well as dominant pixel method for extracting the edge pixels of the image. Initially, the algorithm is tested on RGB images, where in each channel is separately processed by the pseudo-complement operation followed by matrix rotation operations. Then, any dominant pixel occurring in at least any two channels are taken and applied median filtering to extract the edge of the given color image. The proposed algorithm is further tested on HSV and YUV color spaces also. In addition, the algorithm is tested on both synthetic and real images and the results are compared with the results of the other methods. All the procedures used in the algorithm runs in polynomial time.

The rest of the paper is organized as follows. In Section II, various color spaces and their inter conversion is introduced. In sections III and IV, Pseudo-complement approach and dominant pixel identification using various matrix rotation operations are discussed respectively. The proposed methodology is presented in Section V and the experimental results are presented in Section VI. Section VII concludes the work.

II. COLOR SPACES

A color space relates to number of actual colors, and is a three dimensional object which contains all realizable color combinations. Color spaces can be either dependent to or independent of a given device. Device-dependent spaces express color relative to some other color space whereas independent color spaces express color in absolute terms. Each dimension in color space represents some aspect of color, such as lightness, saturation or hue, depending on the type of space.

A. RGB Model

An RGB color space is any additive color space based on RGB color model. A particular RGB color space is defined by the three chromaticities of red, green and blue additive

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primaries. RGB is a convenient color model for computer graphics because the human visual system works similar to an RGB color space.

B. HSL and HSV Model

HSL and HSV are two related representations of points in RGB color space which attempt to describe the perceptual color relationships more accurately than RGB. HSL stands for hue saturation lightness and HSV stands for hue saturation value.

C. YUV Model

YUV model defines a color space in one luminance (Y) and two chrominance (UV) components. YUV models human perception of color in a different way from the standard RGB model. Y stands for luminance (brightness) component and UV stands for the chrominance (color) components. The transformation from RGB into YUV is given by

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.3 & 0.59 & 0.11 \\ -0.15 & -0.29 & 0.44 \\ 0.61 & -0.52 & -0.096 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Since the luminance and chrominance components are separate, the YUV space is vigorously used to broadcast video systems and hence it is also used in image and video processing.

III. Pseudo-Complement Approach

The pseudo-complement approach works like a low-pass filter strongly attenuating the lower image frequencies. This method is based on image complement and hence the name, pseudo-complement. The method is inexpensive due to its simple arithmetic operations. The steps involved are as follows.

Step-1: Read the given gray-level image (i).
Step-2: Obtain the complement of the image. (ic).
Step-3: Do image differencing. (i1=i-ic).
Step-4: Perform global / truncated interval thresholding on i1 to get binary image (i2).
Step-5: Obtain the pseudo-complement (i3) of the image by image differencing between i and i2.

The third step in Pseudo-Complement approach is the subtracting the complement of the input image from the given input image of the given image and its complement. Let i be the given image and ic be its complement.

$$i1 = i - ic \tag{1a}$$

Equation (1) can be viewed as

$$i1(x, y) = \begin{cases} 0, \textit{if } i(x, y) \le 127 \\ \ge 0 \end{cases} \tag{1b}$$

This image subtraction makes the background uniform depending on the intensity of the background pixels of the image. For illustration, they categorized the images into three cases based on the background information. The categorization is (i) background → very bright, (ii) background → slightly dark and (iii) background → intermediate range.

In the first case, the background of i1 remains almost since the complement of the bright intensity values when subtracted from its original intensity leads to its nearest (bright) intensity range. In the second case i.e., when the background is slightly dark, the same analogy works as in the case of first case, but nearer to its original range. In the third case, if the difference is a positive value, a similar gray of value is retained otherwise it becomes black.

The fourth step in Pseudo-Complement approach is the binary map formation. This is achieved through either global thresholding or truncated interval thresholding. The binary map of i1 obtained in the previous step is calculated using
(i) global thresholding

$$i2 = g(x, y) = \begin{cases} 0, \textit{if } i1(x, y) = 0 \\ 255, \textit{otherwise} \end{cases} \tag{2}$$

(ii) truncated interval thresholding

$$i2 = g(x, y) = \begin{cases} 255, \textit{if } i1(x, y) > 0 \ \& \ i1(x, y) \le T_1 \\ 0, \textit{if } i1(x, y) > T_1 \ \& \ i1(x, y) \le T_2 \\ 255, \textit{if } i1(x, y) > T_2 \ \& \ i1(x, y) \le 255 \end{cases} \tag{3}$$

Truncated interval thresholding highlights the very high and average range intensity pixels to 255. It also merges the intermediate intensities with background. The values of T_1 and T_2 are fixed by plotting the image histogram and taking the class interval range.

The last step is obtaining the Pseudo-Complement of the input image. Pseudo-Complement is defined as the difference between the original image and the binary map obtained in the previous step. The following equations 4 and 5 represent the pseudo-complement.

$$i3 = i - i2 \tag{4}$$

$$i3 = i2 - i \tag{5}$$

The resultant image (i3) is termed as Pseudo-Complement because it is obtained by the subtraction of two images namely the original input image (i) and the binary map (i2) of the image (i1) obtained by image differencing between the original image (i) and its complement (ic). Equation 5 can be used for the first category of images i.e., for the images for which the background is very bright. In other cases, equation 4 can be used. Depending upon the context, both the equations can be calculated and consider the optimal image.

The suppression of weak pixels is not acceptable in all cases because it leads to loss of information pertaining to the low intensity pixels. The Pseudo-Complement helps in determining such weak intensity pixels. This is due to the fact that the Pseudo-Complement image (i3) ranges between 0 – 127 i.e., the intensity range is reduced to 50% of the original intensity range 0 – 255. Secondly, it passes lower image frequencies but attenuates the higher intensity pixels and hence can be treated as a low pass filter.

IV. Dominant Pixel Identification using Various Matrix Rotation Operations

Literature reveals many edge detectors based on gradients, filters, derivatives etc. A simple method to find dominant pixels has been introduced in [13] based on various matrix rotation operations. The dominant pixels thus obtained represent the core structure or the border of the image. The steps involved in obtaining dominant pixels are as follows.

Step-1: Read the given gray-level image (i).
Step-2: Apply rotation operations.
Step-3: Obtain dominant pixels by image differencing.
Step-4: Dominant pixel enhancement by thresholding.
Step-5: Dominant pixel linking and smoothing.

A. Rotation Operations

The image, represented as a matrix, can be rotated in two ways. (i) On full or entire image and (ii) On blocks of images.

The first case represents the rotation of entire image. In this case, only two parameters are required for rotation namely direction (clock-wise or anti-clockwise) and number of shifts (n). We tried for one circular shift, two circular shift in clockwise, anti-clockwise direction as well as in spiral direction. The circular one shift rotates the intensities of the pixels about the centre pixel of the object concentrically from the border of the image along the rectangular borders towards the interior pixel.

The second case refers to dividing the image into number of blocks of size (2n+1)x(2n+1), where n>=1. In this case, the parameters to be specified are , angle of rotation (θ), and direction (clockwise or anti-clockwise). The value of θ can be 45^0,90^0, 135^0 or 180^0. The rotations are performed keeping the intensity value of the centre pixel unchanged and value of "n". The best results are obtained for n=1 or 2 i.e., dividing the image into blocks of 3x3 and 5x5 each.

This way or rotating the image matrix guarantees the variation of pixels from neighbouring data i.e., the intensity values of an image thereby the sharp variations as well as minute transitions can be captured effectively.

B. Image Differencing

Image differencing is carried out between the given input image and matrix rotated image. The resultant image contains the core pixels of the image representing the boundary or shape of the objects. These pixels are termed as dominant pixels.

C. Edge Enhancement by Thresholding

The dominant pixels obtained are distributed over an intensity range. For better visualization of these dominant pixels, single level thresholding is used. The pixels after thresholding are termed as enhanced dominant pixels. The thresholding is carried out as given in equation below.

$$i(x,y) = \begin{cases} 0, i(x,y) \le T \\ 255, otherwise \end{cases} \quad (5)$$

D. Edge linking and smoothing

Edge linking is carried out based on the chessboard distance of the enhanced dominant pixels. After linking, certain pixels are left isolated. Such isolated pixels are removed using average or median filtering.

V. Proposed Methodology

We combined the pseudo-complement and dominant pixel identification methods proposed by us for extracting edges from color images. The block diagram of the proposed method is given in Fig. 1.

The steps of the proposed method are as follows.
Step-1: Read the given color image (i).
Step-2: Obtain the pseudo-complement for all three channels separately.
Step-3: Apply rotation operations for every pseudo-complement obtained in previous step.
Step-4: Obtain dominant pixels using image differencing.
Step-5: Obtain enhanced dominant pixels.
Step-6: Select the enhanced dominant pixel occurring at least two times. (The resultant image is the edge map of the given color input image).
Step-7: Post-processing of the resultant edge image to get the final output. (smoothing / isolated pixel removal).

VI. Experimental Results

In this section, the results of the proposed method are presented. Both synthetic and real world images are used to show the efficacy of the proposed method. The rotation operations are chosen randomly for all images and it is observed that the results are prevalent irrespective of the operation chosen.

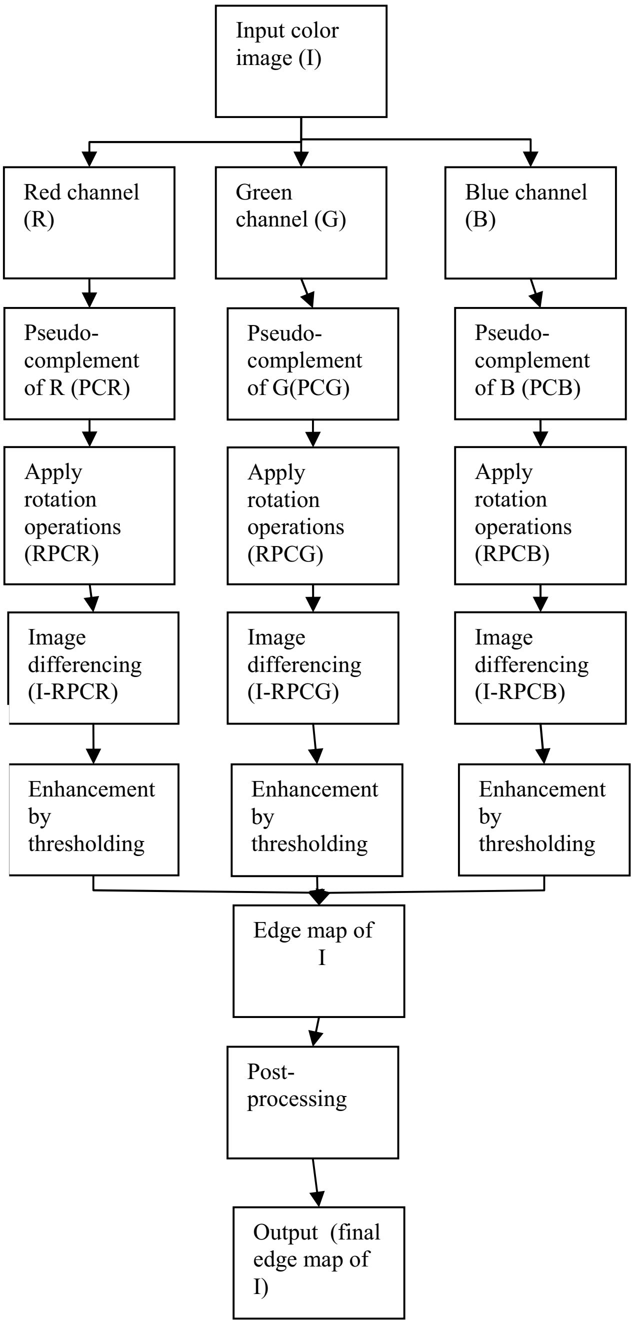

Fig. 1 Schematic representation of the proposed methodology

A. *Experimental Results on Synthetic Images*

The synthetic images are created of size 256x256 with different colors and the corresponding results are displayed. A sample synthetic image used by many researchers and the corresponding results are shown in Fig. 2.

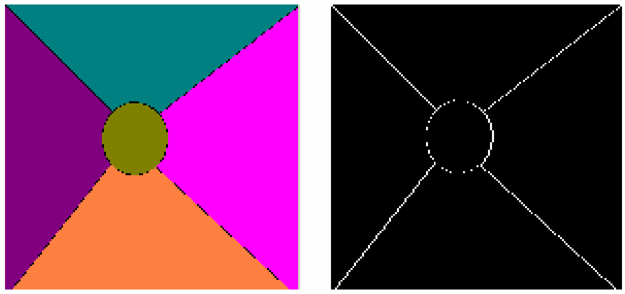

Fig. 2 Synthetic image and its corresponding edge

B. *Experimental Results on Real World Images*

The results of a standard image and also an image from Caltech database are shown in Fig. 3. An aeroplane image and a butterfly image from Caltech database are shown as sample results.

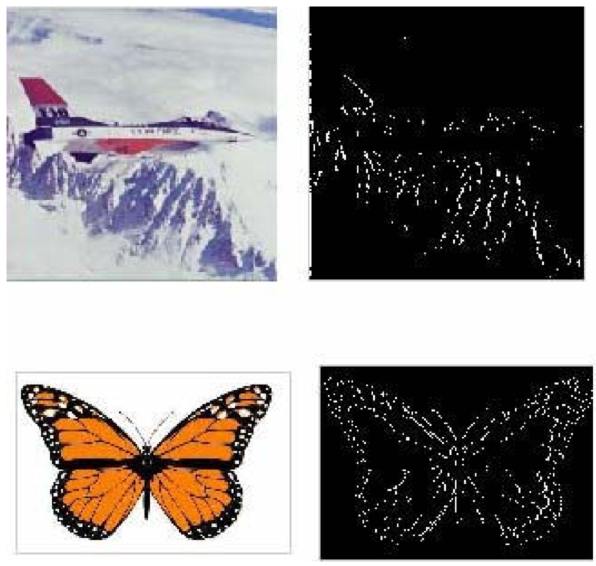

Fig. 3 Two real world images and the corresponding results

The results of some other standard images namely girl, crane and house images are shown in Fig. 4. The images represent the three categories of images discussed in section III. The girl image represents the very bright image, the crane representing the background slightly dark and the house representing the background in intermediate range.

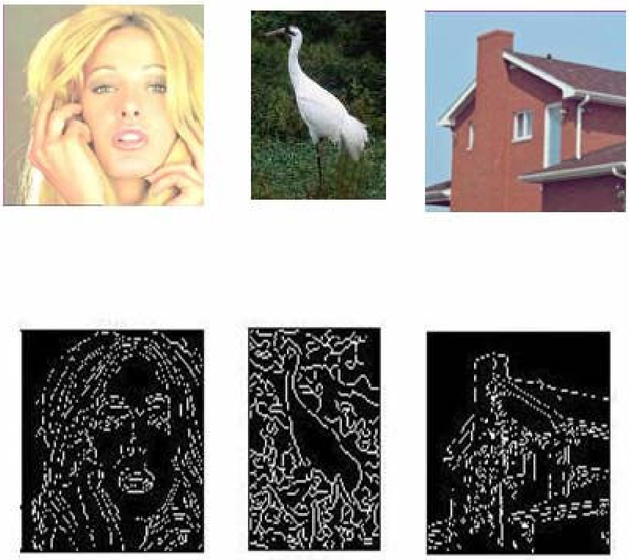

Fig. 4 Results of standard images available in public domain

VII. Conclusion

A new method has been proposed in this paper for extracting edges from color images. The operations involved during the process are simple and depend only on arithmetic operations rather than using gradients and other operations which are computationally expensive. Experimental results indicate that the performance of the proposed method is satisfactory in almost all cases and runs in polynomial time.

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References

[1] J.T.Allen and T. Huntsberger, "Comparing color edge detection and segmentation methods", IEEE SouthEastCon'89, pp.722-728, 1989.

[2] Anil K. Jain, "Fundamentals of digital image processing", Prentice-Hall, Englewood Cliffs, 1989.

[3] T. Carron and P. Lambert, "Color edge detector using jointly hue, saturation and intensity", proceedings of IEEE International Conference on Image Processing, pp.977-981, 1994.

[4] T. Carron and P. Lambert, "Fuzzy color extraction by inference rules – quantitative study and evaluation performances", proceedings of IEEE International Conference on Image Processing, pp.181-184, 1995.

[5] R. Nevatia, "A color edge detector and its use in scene segmentation", IEEE Transactions on Systems, Man Cybernetics, Vol. 7, pp.820-826, 1977.

[6] M.A. Abidi, R.A. Salinas, C. Richardson and R.C. Gonzalez, "Data fusion: color edge detection and surface reconstruction through regularization", IEEE Transactions on Ind. Electron.,43(3), pp.355-363, 1996.

[7] P.E. Trahanias and A. N. Venetsanopoulos, "Vector order statistics operators as color edge detectors", IEEE Transactions on Systems, Man, Cybernetics, 26(1), pp.135-143, 1996.

[8] J. Canny, "A computational approach to edge detection", IEEE Transactions on Pattern Analysis and Machine Intelligence, 8(6), pp.679-698, 1986.

[9] C.L. Novak and S.A. Shafer, Color edge detection", Proceedings of DARPA Image Understanding workshop, Los Angeles, CA, USA, vol.1, pp.35-37, 1987.

[10] A. Koschan, "A comparative study on color edge detection", Proceedings of 2nd Asian Conference on Computer Vision, ACCV 95, vol.3, pp. 574-578, 1995.

[11] R. Machuca and K. Philips, "Applications of vector fields to image processing", IEEE Transactions on Pattern Analysis and Machine Intelligence, 5(3), pp316-329, 1983.

[12] T.N. Janakiraman and P.V.S.S.R. Chandra Mouli, "A Robust Pre-processing step for efficient edge detection", Proceedings of IEEE sponsored Intl. Conference ACVIT-07,Aurangabad, pp.810-815, 2007.

[13] T.N. Janakiraman and P.V.S.S.R. Chandra Mouli, "Dominant Pixel Identification from Gray-level Image using various matrix rotation operations – An application to Edge Detection", Proceedings of IEEE sponsored Int. Conference ICSCN-08, Chennai, pp.510-513, 2008.