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Performance Evaluation of Color Based Edge Detectors

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Abstract— This paper evaluates the performance of the color based edge detection techniques. As known in prior the color images provides more information than the gray scale images, 90% of the edges are same in both type of images but 10% edges cannot be detected in gray images. Therefore color edge detection may improve the edge clarity further and also avoids false edges. The overall purpose of this paper is to design and implement color edge detectors variations using canny edge detector. This paper ends up with the comparison of Hue, PCA, Fusion of them, Color fuzzy and Fusion based Fuzzy color edge detection algorithms. The overall performance analysis has proven that the fuzzy based color edge detection outperforms over available techniques. But there exists tradeoff between fuzzy and fusion based fuzzy with respect to Pratt's figure of merit.

Keywords—Edge detection, PCA, Hue, Edge fusion, Fusion Based Fuzzy.

I. INTRODUCTION

Edges can be defined as the boundaries between regions in an image that helps with segmentation and object recognition. Edge detection is an important area in the field of Computer Vision [2].Edge detection [9] is the method of identifying and locating sharp discontinuities within an image. The discontinuities are abrupt variations in pixel intensity which describe boundaries of objects in a scene [3]. As contrast to the grey-scale images, the color and multispectral images enclose extra information. The benefit of color edge detection schemes over grey-scale approaches is that those edges that exist at the boundary between regions of different colors cannot be detected in grey-scale images if there is no variation in intensity [12].

Classical techniques [18] of edge detection involve convolving the image through an operator (a 2-D filter), which is made to be sensitive to huge gradients in the image whereas returning values of zero in uniform regions. There are an extremely huge number of edge detection operators existing, each created to be sensitive to certain types of edges. Variables involved in the choice of an edge detection operator encompass orientation of edge, Noise surroundings and structure of edge. The geometry of the operator chooses a characteristic direction in which it is most responsive to edges. Operators can be optimized to discover for edges in horizontal, vertical and diagonal direction. Edge detection is tough in noisy images, as both the noise and the edges have high frequency content. Efforts to minimize the noise result in blurred and distorted edges. This results in less precise localization of the found edges. Not all edges involve a step deviation in intensity. Effects like refraction or poor focus can results in objects with boundaries explained by a gradual deviation in intensity. The operator needs to be selected to be sensitive to such a gradual change in those cases. So, there are problems of 1) fake edge detection, 2) missing true edges, 3) edge localization,4) high computational time and problems because of noise etc.

There are numerous ways [2] to perform edge detection. Although, the majority of these may be divided into two categories first is Gradient based Edge Detection and second id Laplacian based edge detection [18]. The gradient technique detects the edges through seeking the maximum and minimum in the first derivative of the image. A pixel location is stated an edge location if the value of the gradient goes beyond some threshold. Edges will have more pixel intensity values than those surrounding it. Hence once a threshold is set, you can contrast the gradient value to the threshold value and detect an edge each time the threshold is exceeded. Moreover, when the first derivative is at a maximum, the second derivative is nil. As a result, another option to finding the location of an edge is to find the zeros in the second derivative. This technique is known as the Laplacian and the second derivative of the signal.

Fig. 1.Edge detection [16]

Sobel, Robert's, Prewitt's comes under gradient approach. Sobel detects edges running vertically and horizontally, Robert's react maximum to edges running at 45° to the pixel grid and Prewitt's is alike to the Sobel operator and is utilised for locating vertical and horizontal edges inside images[2].

II. RELATED WORK

J. Ren et al.[4] proposed an technique on color edge detection in which utilize of inter-component difference information for proficient color edge detection. Input image C, a grey image D is defined as the accumulative differences among every two color components of it, and another grey image R is obtained by weighting of image D and the grey intensity image G. The final edges attained by blend of edges detected from image R and G. Its performance is better than traditional color spaces as RGB and HSV in terms of effectiveness and robustness even with attached Gaussian noise. But it was very complex. **Chreyl Lau** et al.[6] proposed a cluster-based approach for optimizing the transformation by preserving as much as possible information from the source space for individual images and as possible whilst staying as loyal as possible to the natural mapping. This method groups the pixels into clusters according to their spectral and spatial similarity, improves contrast among clusters by translating the clusters to optimal colors in the target space, and moves those translations reverse to the pixels. It can be used to color transformation problems including color to gray, gamut mapping etc. **Xinghui Zhang** et al. [7] proposed an adaptive algorithm based on multiple structure and multi-scale elements in HSI space. Initially, morphological edge detection is performed using different structure and scale elements to hue, saturation and intensity. After that, according to the weight obtained from information entropy, the color edge information is acquired by combining component's edge information. It can further enhance the accuracy of segmentation and efficiently removes the over-segmentation. **Geng** et al [8] proposed improved Canny algorithm which is comprised of five steps in first quaternion weighted average filter then vector Sobel gradient computation after that non-maxima suppression based on interpolation, edge detection and connection. It is used for outline detection and fake edges removal. It can be applied to images of transmission line icing. **Hui** et al [10] proposed a method in which initially, multi-structure elements are devised to construct morphological gradient operators. Subsequently, the color image is converted from RGB to HSV color space .Finally, morphological edge detection operators applied. The method can effectively preserve edge in noise emergence. **Lei** et al [11] proposed technique based on vector morphological operators. A new vector ordering in RGB color space is designed then by analysing the features of the noise infected image, vector morphological operators are proposed and these operators are applied in color edge detection. It has better noise suppressing and edge detection. **Hongli** et al [12] proposed new algorithm for color road image edge detection. The RGB color model were converted to Lab color model, and the difference information among the gray image from L channel and red-green image was got by difference image technique, and the threshold was obtained by difference information with optimal threshold value algorithm, then the edge detection was executed. It provides more noise resistance and preserves better edges for color road image. **Feng** et al [5] proposed a multi-scale edge detection algorithm that used soft threshold technique to implement detail enhancement and noise reduction of the true color image. Initially, getting the true color images at diverse scales by wavelet multi-scale edge detection algorithm, then utilizing improved soft threshold filter function, choosing suitable threshold of the attained image edges to execute noise reduction while improve the edge details of the reservation; and finally, executing the weighted 2-norm fusion of edges of different-scale-image. It effectively suppresses noise, enhance the image edge details. It has better robustness, thus more conducive to the image analysis and processing.

III. HUE

HSV color space [1] is a cone. Seen from the circular side of the cone, the hues are shown by the angle of each color in the cone relative to the 0° line, which is conventionally allocated to be red. The saturation is shown as the distance from the middle of the circle. Highly saturated colors are on the external edge of the cone, while gray tones (which have nil saturation) are at the very centre. The brightness is computed by the colors vertical position in the cone. At the sharp end of the cone, there is no brightness, therefore all colors are black. At the fat end of the cone are the brightest colors. The *hue* (H) of a color refers to which pure color it looks like; every tints, tones and shades of blue have the same hue.The *saturation* (S) of a color illustrate how white the color is, A pure blue is completely saturated, with a saturation of 1; tints of blue have saturations less than 1;and white has a saturation of 0.The *value* (V) of a color, also known as its *lightness or brightness*, demonstrates how dark the color is, A value of 0 is black, with growing *brightness* going away from black. Therefore in fusion technique RGB space is transferred into HSV color space. The gradient of hue component is compute using following formula[14]:-

$$G^h = \sqrt{(G_x^h)^2 + (G_y^h)^2} \tag{1}$$

$$\theta^h = actan\frac{G_x^h}{G_y^h} + k\pi \tag{2}$$

$$G_x^h = \left(h_{i+1,j-1} + 2h_{i+1,j} + h_{i+1,j+1}\right) \div \left(h_{i-1,j-1} + 2h_{i-1,j} + h_{i-1,j+1}\right) \tag{3}$$

$$G_x^h = \left(h_{i+1,j-1} \div h_{i-1,j-1}\right) + 2\left(h_{i+1,j} \div h_{i-1,j}\right)\left(h_{i+1,j+1} \div h_{i-1,j+1}\right) \tag{4}$$

$$G_y^h = \left(h_{i-1,j+1} + 2h_{i,j+1} + h_{i+1,j+1}\right) \div \left(h_{i-1,j-1} + 2h_{i,j-1} + h_{i+1,j-1}\right) \quad (5)$$

$$G_y^h = \left(h_{i-1,j+1} \div h_{i-1,j-1}\right) + 2\left(h_{i,j+1} \div h_{i,j-1}\right) + \left(h_{i+1,j+1} \div h_{i+1,j-1}\right) \quad (6)$$

IV. PRINCIPAL COMPONENT ANALYSING

PCA [13] is a statistical tool which converts a number of correlated variables into a number of uncorrelated variables. The PCA is used broadly in image classification and image compression. The PCA involves a statistical formula that converts a number of correlated variables into a number of uncorrelated variables called principal components. It determines a compact and optimal description of the data set. The first principal component explains as much of the variation in the data as possible and each subsequent component explains as much of the left over variation as possible. First principal component is taken to be along the orientation with the maximum variance. The second principal component is limited to lie in the subspace perpendicular of the first. In this Subspace, this component indicates the direction of highest variance. The third principal component is taken in the highest variance direction in the subspace perpendicular to the initial two and so on [15].

V. FUSION OF HUE AND PCA

The existing techniques of edge detection generally lose some edges caused by hue variations. So to overcome this problem, the popular techniques merge with the Gradient of hue difference to form novel techniques in order to get more complete object edges. Here, it is essential to maintain balance among the effectiveness and real-time. In other words, this technique has to meet good edge detection outcomes with minor computational complexity. CE-PCA [19] carry outs the best real-time between the existing techniques, and it is selected to combine with GOHD to obtain the edge detection of colour images [14].

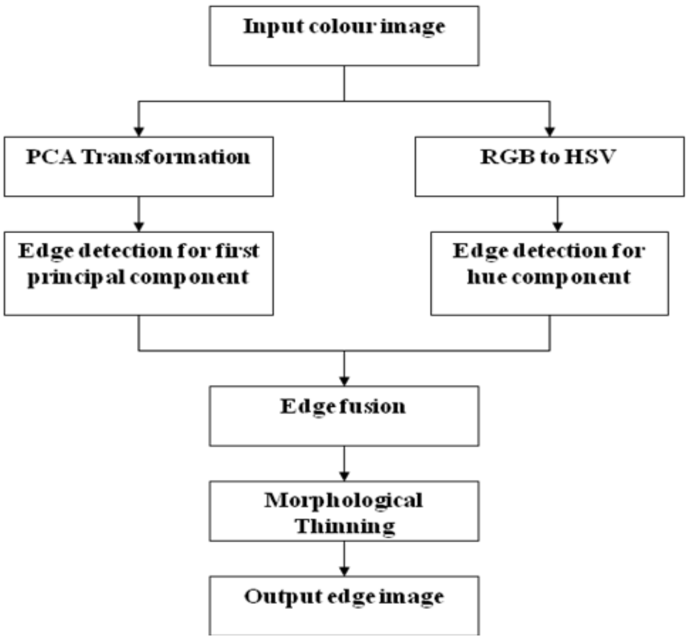

Fig.2. Color edge detection based on the proposed method PCA-GOHD
(fusion of edges obtained by CE-PCA and GOHD)

Fig.2 demonstrates the exact implementation process of proposed PCA-GOHD [14] (fusion of edges acquired by PCA and hue component), and Canny operator is selected as the edge detector because GOHD [14] is universal to different edge detectors like Canny, Sobel, Roberts and Prewitt [18]. This technique has following key benefits.

- This technique acquires accurate edges for hue component. This method GOHD is also used, as gradient magnitude attained by GOHD Gradient operator based on hue difference (GOHD) is reliable with human vision perception. Therefore, the proposed PCA-GOHD can get more complete object edges compared with other techniques under the state of poorer illumination.
- Absolute object edges can be acquired with low-computational complexity as CE-PCA[19] utilizing PCA conversion detects edges for first principle component
- Proposed technique is effective and simple to implement [14].

VI. IMPROVED COLOR EDGE DETECTOR USING FUZZY SET THEORY

Recently, approaches based on artificial intelligence techniques are applied for developing edge detection algorithms. Fuzzy image processing is a prevailing tool as the fuzzy sets offer a support for integrating human knowledge in the answer of problems whose formulation is based on vague notions. Fuzzy logic is a broadly utilised tool in image

processing because it gives extremely efficient result. Fuzzy logic approach is found to be suitable for image processing applications due its capability in representing distinct, inexact, and inaccurate information by decision making or subjective evaluation.
There are dissimilar opportunities for development of fuzzy edge detectors [20]:

1. Designation of suitable membership functions
The generalized fuzzy set on region U is stated as
$A = \{(\mu_A(x), x \in U)\}$ and $\mu_A(x) \in [-1, 1]$ is known as the generalized membership function. Clearly, the generalized fuzzy set broadens the normal fuzzy set. That is to declare, the membership function $\mu_A(x) \in [-1, 1]$ of the normal fuzzy set is broadened to the one of the generalized fuzzy set.
This is the easiest method. One can describe a membership function representing the degree of edginess in every neighbourhood. This technique can only be considered as a true fuzzy technique if fuzzy concepts are in addition used to modify the membership values. The membership function is concluded heuristically. It is speedy but the performance is less.

$$\mu_{Edge}\left(g(x,y)\right) = 1 - \frac{1}{1 + \frac{\sum_H |g(x,y) - g(i,j)|}{\Delta}} \quad (7)$$

μ_{Edge} is the membership function for image g(x,y)

2. Rule-based fuzzy edge detection
Using appropriate fuzzy if-then rules, individual can create general or specific edge detectors in pre-defined neighbourhoods.

VII. GAPS IN EARLIER WORK

With survey various limitations has been found from existing research. Which are shown as follows:-

1. The most of the existing researchers has not considered haze and low intensity images.
2. The use of the Gradient based minimization has also been neglected by various researchers which has the ability to smooth the image in such a way that the redundant edges i.e. pseudo edge can be effortlessly minimized.
3. Most of the existing researchers have not much concentrated on the texture images; which are becoming more useful in vision applications.

VIII. EXPERIMENTAL SETUP AND RESULT

The hue, PCA, integrated PCA and hue edge detectors has been designed and implemented with MATLAB. Sixteen different images are taken for experiment and the results have shown that the fusion based edge detectors have more efficient and effective results over the existing techniques. Following section encloses the result of designed and implemented algorithms.

Fig.3. Input image [17]

Fig.3 has shown the input image. The image has not been effected by any issue as noise, poor atmosphere etc.

Fig.4. Hue image

Fig.4 shows the Hue image of the input image shown in the Fig. 3.

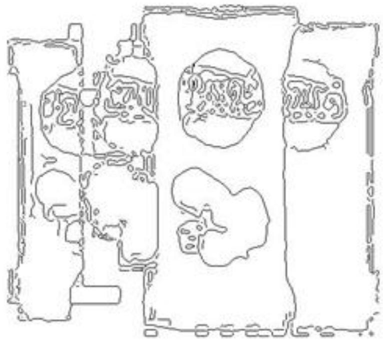

Fig.5. Hue edge detected image

Fig.5 shows the Hue edge detected image of the hue image shown in the Fig.4.

Fig.6. PCA image

Fig.6 shows the PCA image of the input image shown in the Fig. 5.

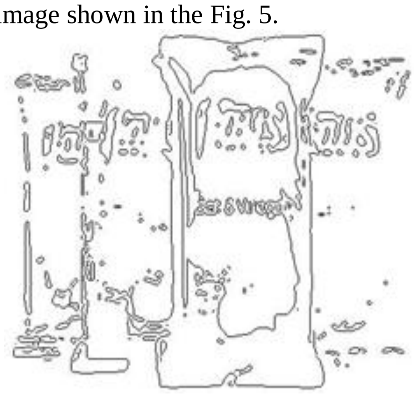

Fig.7. PCA edge detected image

Fig.7 shows the PCA edge detected image of the PCA image shown in the Fig. 6.

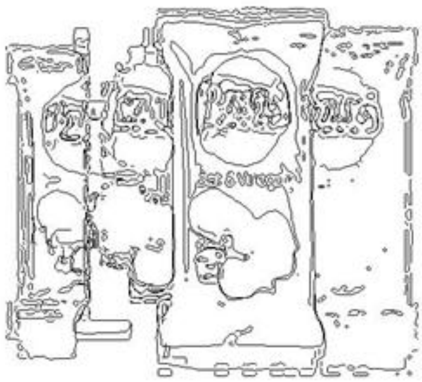

Fig.8. Fusion based edge detected image

Fig.8 shows the Fusion based edge detected image of the input image shown in the Fig. 3.

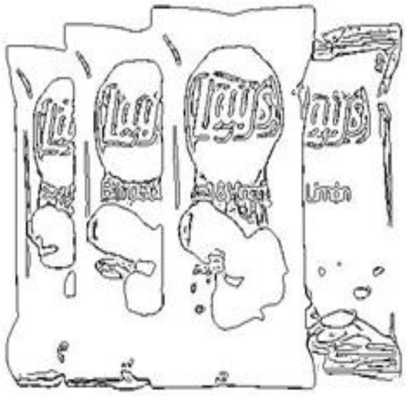

Fig 9.Color Fuzzy edge detected image

Fig.9 shows the Color Fuzzy based edge detected image of the input image shown in the Fig. 3.

Fig 10.Hybrid edge detected image

Fig.10 shows Hybrid based edge detected image of the input image shown in the Fig. 3.
The results have shown that Hybrid technique is more effective than other techniques because of having maximum edges. The results has exposed that the each methods has pretty effective results above each other but the result of integrated hue and PCA based edge detectors are pretty more effective because of having highest edges. But the outcome of the fuzzy based edge detectors are much more informative and clear than other methods.

IX. PERFORMANCE EVALUATION

Numeral researchers have considered the problem of measuring the performance of edge detector. In fact, it is difficult as we don't really know what the underlying features are that we desire to detect. However, if we suppose that there are step edges corrupted with Gaussian noise, then some criteria can be set for calculating performance. Such criteria are generally the following:

- The probability of false edges and missing edges.
- An error to approximate the edge angle.
- Edge' mean square distance is estimated from the true edge.
- Algorithm's tolerance to deformed edges and additional features similar to corners and junctions.

The first criterion relate to edge detection, the subsequently two to edge localization, also the very last to tolerance to exits from the ideal edge model. Pratt created function FOM for computed quantitatively the performance of distinct edge detectors. The measure is

$$FOM = \frac{1}{max\ (I_d, I_I)} \sum_{i=1}^{I_d} \frac{1}{1+\beta(d_i)^2} \quad (8)$$

where I_d, I_I, and d_i are respectively the detected edges, the ideal edges, the edge variation from ith detected edge pixel and $\beta > 0$ is a design constant which used to penalise displaced edges. The value of FOM lie among 0 and 1 i.e. 0<FOM≤ 1, value 1 illustrates the ideal match among detected and ideal edge points [14].

TABLE 1. PFOM COMPARITIVE ANALYSIS

Image No.	Hue	PCA	Fusion	CF	Hybrid
1	0.0738	0.0725	0.5139	0.6745	0.6873
2	0.0909	0.0886	0.5585	0.6835	0.6938

3	0.1005	0.0982	0.4201	0.7252	0.7327
4	0.0760	0.0752	0.4210	0.5757	0.6236
5	0.0709	0.0701	0.6608	0.8274	0.8362
6	0.0694	0.0678	0.6763	0.7871	0.8357
7	0.0575	0.0553	0.6330	0.5387	0.9798
8	0.0726	0.0699	0.4495	0.7349	0.7261
9	0.0899	0.0886	0.4367	0.6238	0.6280
10	0.0604	0.0611	0.4627	0.7048	0.7248
11	0.1054	0.1005	0.6672	0.4947	0.8599
12	0.0735	0.0709	0.4371	0.5984	0.6118
13	0.0722	0.0712	0.4453	0.5388	0.5996
14	0.0698	0.0690	0.5498	0.4284	0.5608
15	0.0897	0.0890	0.4353	0.5265	0.6068
16	0.0939	0.0930	0.2996	0.4821	0.6360

Table 1 has shown the outcome of PFOM of the hue only, PCA only, Fusion (Hue and PCA), CF (Color Fuzzy) technique and Hybrid technique (combination of Hue, PCA and Color Fuzzy). It has been clearly shown that the PFOM of the Hybrid technique is better in every case. Therefore the proposed algorithm has shown important improvement over the available techniques.

Fig.11 shows the result of PFOM of the Hue only, PCA only and Fusion (Hue and PCA), CF (Color Fuzzy) technique and Hybrid technique (combination of Hue, PCA and Color Fuzzy). It shows that the PFOM of the Hybrid technique is improved in every case. Therefore the Hybrid algorithm shows significant improvement over the existing techniques.

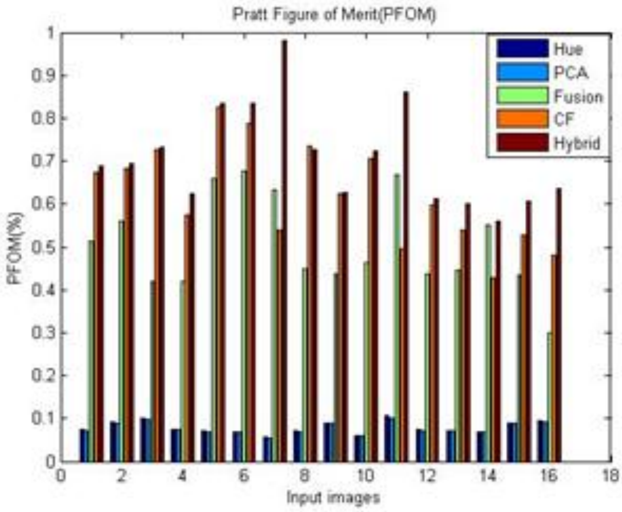

Fig.11. PFOM comparative analysis

X. CONCLUSION

This paper has evaluated the performance of PCA, HUE, Fusion of PCA and HUE and Fuzzy based color edge detection methods. In this paper it has been shown that the most of the existing techniques has neglected the use of colors while detecting the edges but in many applications a region can be categorized based upon the color. This paper has shown the result of different color based edge detectors i.e. Hue, PCA, Fused Hue and PCA, Color Fuzzy, Fusion based Fuzzy methods. The outcomes of fuzzy based edge detectors have shown the effectiveness of the fuzzy based edge detection. The fuzzy based edge detector outperforms over the available techniques. In this work only PFOM is considered for experimental purpose in near future some more performance parameters will also be considered to verify the proposed algorithm.

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