Detection of Edges in Color Images

Ganbold Ganchimeg[1] and Renchin Turbat[2]

[1] School of Applied Sciences / The Mongolian University of Science and Technology / Ulaanbaatar, Mongolia, ganaa@must.edu.mn
[2] School of E-Open / The Mongolian University of Science and Technology / Ulaanbaatar, Mongolia rturbat@must.edu.mn

***** Corresponding Author:

Received February 20, 2014; Revised April 20, 2014; Accepted August 28, 2014; Published December 31, 2014

** Short Paper*

Abstract: Edge detection considers the important technical details of digital image processing. Many edge detection operators already perform edge detection in digital color imaging. In this study, the edge of many real color images that represent the type of digital image was detected using a new operator in the least square approximation method, which is a type of numerical method. The Linear Fitting algorithm is computationally more expensive compared to the Canny, LoG, Sobel, Prewitt, HIS, Fuzzy, Parametric, Synthetic and Vector methods, and Robert' operators. The results showed that the new method can detect an edge in a digital color image with high efficiency compared to standard methods used for edge detection. In addition, the suggested operator is very useful for detecting the edge in a digital color image.

Keywords: Color image processing, Color edge detection, Fuzzy, Synthetic, Vector and HIS methods

1. Introduction

Edge detection in color images is an important process in low-level image processing [1]. The purpose of a general image understanding system is to recognize objects in a complex scene or document. Edge detection is one of the first steps in such a system [2, 3]. A color image provides more information than a grayscale image, because detailed edge information from color edge detection is expected [4]. Edge detection algorithms normally detect the sharp transitions of intensity and color within an image. These transitions are characteristic of object edges. Once the edges of an object are detected, other processes, such as region segmentation, text finding and object recognition can take place [3].

2. Color Edge Detection

The human visual system can distinguish hundreds of thousands of different color shades and intensities, but only approximately 100 shades of gray [2]. Therefore, a color image may contain a great deal of extra information, which can then be used to simplify image analysis, e.g. object identification and extraction based on color. Three independent quantities are used to describe any particular color [2-5]. The hue is determined by the dominant wavelength. The relationship between the RGB and CMY models is given by the following equation [6, 7]:

$$\begin{pmatrix} C \\ M \\ Y \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

The CMY model is used by printing devices and filters.

For color images, the notion of an edge is much more complex than in grayscale images. In color images, the intensity and saturation of a color all play a role in determining the object boundaries [2, 8]. The physical boundary produces an edge that needs to be captured using a measure that combines the different color characteristics. The use of color in edge detection increases the amount of information required for processing, which complicates the definition of the problem. In color an image, a distance measure needs to be used to define the color gradient, i.e., it is very easy to extend the Robert, Prewitt, Log, Canny and Sobel operators [9, 10]. Most edge detection schemes are based on finding the maxima in the first derivative of the image function. The difficulty in extending derivative approaches to color images can be attributed to the image function being vector-valued. Whenever the gradients of the image components are computed, the problem is how to combine them into a single result.

Three tristimulus values, T1, T2, and T3 can be used to quantify the amount of RGB colors at each pixel of a color image.

Several different definitions of color edge detection have been proposed. A definition states that detection depends on the vector sum gradient of the three tristimulus values [11-13]:

$$G(j,k)=\{[G_1(j,k)]^2+[G_2(j,k)]^2+[G_3(j,k)]^2\}^{\frac{1}{2}}$$

Each gradient represents the three tristimulus component values. A color edge is detected if the gradient exceeds the defined threshold.

3. Stander Detector Operators

The standard edge detector operators have been used by many researchers. In detector operators, the image process based on the gradient processes [9, 13]. The fundamental types of gradient operators used are Robert, Prewitt, Log, Canny and Sobel operators. Robert's operator determines only the edge points without information on the edge orientations [14]. The Sobel operator is the classical standard edge detector [15], which is described in Fig. 1. The reason for using Sobel operator is that it is insensitive to noise and it has relatively small mask in images. The convolution kernel, one kernel is simply the other rotated by 90 degrees. These kernels are designed to respond to edges running vertically and horizontally relative to the pixel grid, one kernel for each of the two perpendicular orientations.

The gradient of a continues function $f(x,y)$ at (x,y) can be defined as [2, 13]:

$$G[f(x,y)]=\left[\frac{\partial f}{\partial x},\frac{\partial f}{\partial y}\right] \qquad (1)$$

These points toward the direction of the largest increase in the function. Any Cartesian x-y coordinate system can be chosen because it is easy to verify the gradient [2].

$$Mag\,G=\left[\left(\frac{\partial f}{\partial x}\right)^2+\left(\frac{\partial f}{\partial y}\right)^2\right]^{\frac{1}{2}} \qquad (2)$$

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

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

Fig. 1. Sobel operator 3x3 masks.

Because a digital image can be described as a discrete function, the differences have been used instead of the differential. Therefore, the equation can be approximated as follows:

$$G[f(x,y)]=[[f(x,y)-f(x+1,y)]^2+ \\ +[f(x,y)-f(x,y-1)]^2]^{\frac{1}{2}} \qquad (3)$$

To obtain the gradient image $g(x,y)$, we use the following relation is used:

$$g(x,y)=G[f(x,y)] \qquad (4)$$

The solution of this problem can be obtained using the following threshold condition:

$$g(x,y)=\begin{cases}G[f(x,y)], & if\ G[f(x\ y)]>T \\ 0 & otherwise\end{cases} \qquad (5)$$

where T is a nonnegative threshold.

4. Parametric Edge Models

Parametric models are based on the idea that the discrete image intensity function can be considered a sampled and noisy approximation of the underlying continuous or piecewise continuous image intensity function. Therefore, an attempt was made to model the image as a simple piecewise analytical function. The task now becomes the reconstruction of the individual piecewise function. The next step is to find simple functions that best approximate the intensity values only in the local neighborhood of each pixel. This approximation is called the facet model (Haralick and Shapiro, 92). These functions, and not the pixel values, are used to locate the edges in the image. To provide an edge detection example, consider the bi-cubic polynomial facet model:

$$f(x,y)=k_1+k_2x+k_3y+k_4x^2+k_5xy+k_6y^2+ \\ k_7x^3+k_8x^2y+k_9xy^2+k_{10}y^3$$

The first derivative in the direction α- is given by

$$f_\alpha{}'(x,y)=\frac{\partial f}{\partial x}\cos\alpha+\frac{\partial f}{\partial y}\sin\alpha \qquad (6)$$

The second directional derivative in the direction α is given by

$$f_\alpha{}''(x,y)=\frac{\partial^2 f}{\partial x^2}\cos^2\alpha+2\frac{\partial^2 f}{\partial x\partial y}\cos\alpha\sin\alpha+\frac{\partial^2 f}{\partial y^2}\sin^2\alpha \qquad (7)$$

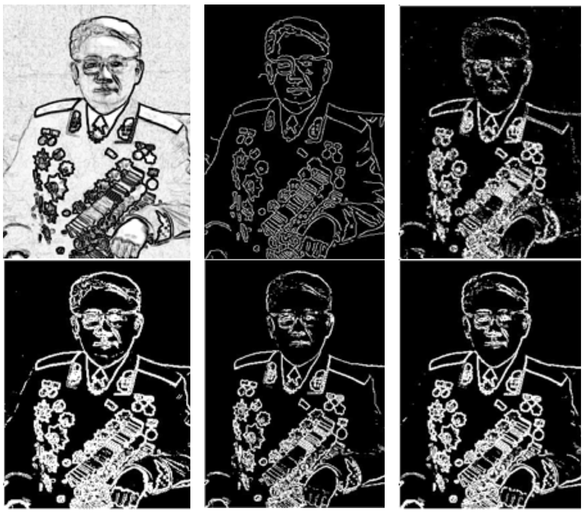


Fig. 2. This result shown in edge detection.

$$\sin\alpha = \frac{k_2}{\sqrt{k_2^2 + k_3^2}}, \qquad \cos\alpha = \frac{k_3}{\sqrt{k_2^2 + k_3^2}} \tag{8}$$

This study considers only the points on the line in the direction α, $x_0 = \rho\cos\alpha$ and $y_0 = \rho\sin\alpha$.

$$f_\alpha^{''} = 6(k_7\sin^3\alpha + k_8\sin^2\alpha\cos\alpha + k_9\sin\alpha\cos^2\alpha + k_{10}\cos^3\alpha)\rho +$$
$$+2(k_4\sin^2\alpha + k_5\sin\alpha\cos\alpha + k_6\cos^2\alpha) = 6A\rho + 2B$$

The following possibilities exist:

$A = 0, \quad f^{'} = 2B\rho + C, \quad f^{''} = 2B,$

$\rho = -C/B, \quad \rho = 0$

1. if $B > 0$ and $f^{''} > 0$ (valley)
2. if $B < 0$ and $f^{''} < 0$ (ridge)
3. if $B = 0$ and $f^{'''} = 0$ (plane)

5. Classified the color edge detection methods

Edge detection in color images is different from that in gray scale images due to a fundamental difference in their nature. In contrast to a scalar value used to represent a pixel in a gray scale image, a pixel in a color image is represented by a color vector. Thus, in color edge detection a vector-valued image function is processed instead of a scalar image function. On the basis of the principle used for this processing, Koschan and Abidi [16] and Chen and Chen [17] classified the color edge detection methods into two categories:

1. *Synthetic methods or monochromatic-based methods:* These methods decompose the color vectors into different components, process each component separately and combine together the individually gained results (image recombination). According to the nature of recombination,

P1	P2
P3	P4

Fig. 3. 2*2 mask used for finding edges.

Ruzon and Tomasi [18] classified the synthetic methods as: output fusion methods [17, 19] and multidimensional gradient methods [20].

2. *Vector methods:* These methods preserve the vector nature of color throughout the computation and use various features of three-dimensional vector space to detect edges in a color image.

6. The edge detection of color image based on HIS color model

HIS color model better reflects the human visual experience on color, and for some images, the use of HIS color model can reduces the complexity of color image processing. Since the effects can be well changed as long as fine adjustment saturation component and brightness [20], therefore, in HIS color space, can greatly reduces the workload of edge detection of color image and meets the visual requirement [21, 22]. In order to make further optimization in the detection effect, the improved HIS model can be got in the process of coordinate transformation from RGB space to HIS space and under the condition of invariable tone, that is, no color displacement, improving the two components-saturation and brightness based on the practical application, the formula is as follows:

$$H = \begin{cases} \alpha, B \le G \\ 2\pi - \alpha, B > G \end{cases} \tag{10}$$

$$I^* = \frac{16R + 3G + B}{20} \tag{11}$$

$$S^* = 1 - \frac{2[\min(R,G,B)]}{5[\max(R,G,B)]} \tag{12}$$

Here,

$$\alpha = \arccos\left\{\frac{(R-G)+(R-B)}{2[(R-G)^2 + (R-B)(G-B)]^{1/2}}\right\} \tag{13}$$

7. Fuzzy logic based edge detection

Fuzzy logic is used to perform the edge detection on an image. The algorithm is based on the selection of a set of four pixels of the image [23]. The 2x2 window of an image is used to set of fuzzy conditions to highlight all the edges that are associated with an image. The image is said to have an edge if there is large variation in intensity between the adjacent pixels [24]. This task of edge detection is accomplished with the help of sixteen fuzzy inference rules.

The mask used for scanning image is shown below in

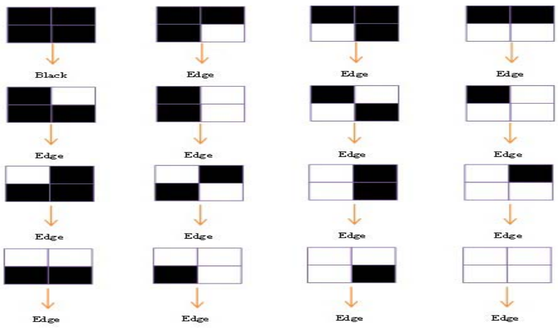


Fig. 4. Rules of Fuzzy Inference System.

Fig. 3 which uses four pixels P1, P2, P3 and P4. The input to these pixels can be black or white, and the output can be black or edge [25].

Each of the mapped values is partition into three fuzzy regions low, medium, and high. The fuzzy inference rules are defined in such a way that the FIS can detect edges of the image and reject the non-edge pixels [26]. For example, the first rule is for pixels that are not part of edge, i.e. for black output and the rest of the rules are in edge pixels.

8. Linear Fitting Algorithm

In this study, a linear regression method was used to detect the image edges [27] to expand it with a color image, where this algorithm was used previously to introduce an adaptive digital smoothing filter for reduce the noise from the images [28]. A sliding mask and some steps were taken to detect an edge point in this mask. In the first step, the pixels of this mask were rearranged in a pair $\left[x, y\left(x\right)\right]$, where $\left(x\right)$ represents the location of the color levels values ly(x)3,$\{x = \ldots n\}$ n is the total number of pixels in the mask. The relation is then modified in the form of a straight-line equation given in the equation [28, 29].

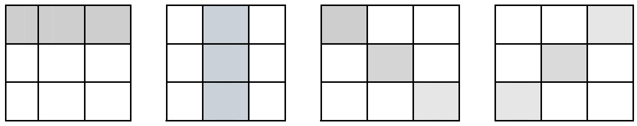
$$Y\left(x\right) = a + bx \tag{14}$$

where a, b are constant can be obtained in the following: *Compute the summation*

$$\sum_{n=1}^{n} x, \quad \sum_{x=1}^{n} y\left(x\right)$$
$$\sum_{x=1}^{n} x^2, \quad \sum_{x=1}^{n} x, y\left(x\right) \tag{15}$$

From the least square approximation method, a and b *are* calculated as follows:

$$b = \frac{n\sum_{x=1}^{n} xy - \sum_{x=1}^{n} x \sum_{x=1}^{n} y\left(x\right)}{n\sum_{x=1}^{n} x - \left[\sum_{x=1}^{n} x\right]^2} \tag{16}$$



(a) (b) (c) (d)

Fig. 5. Four direction of mask (3x3)where (a) and (b) represents the horizontal and vertical directions, respectively, (c) and (d) are the two diagonal directions.

$$a = \frac{\sum_{x=1}^{n} y\left(x\right) - b\sum_{x=1}^{n} x}{n} \tag{17}$$

The best of the derived data can be obtained from Eq. (14) depending on the values of $\left(a\right)$ and $\left(b\right)$. The algorithm used in this study depends on a local scan of the image in four major directions. For a digital image of (3x3), the image function can be written as

$$f(x, y) = \begin{bmatrix} (x-1, y-1) & (x-1, y) & (x-1, y+1) \\ (x, y-1) & (x, y) & (x, y+1) \\ (x+1, y-1) & (x+1, y) & (x+1, y+1) \end{bmatrix} \tag{18}$$

The four major directions of the matrix can be represented in Fig. 5.

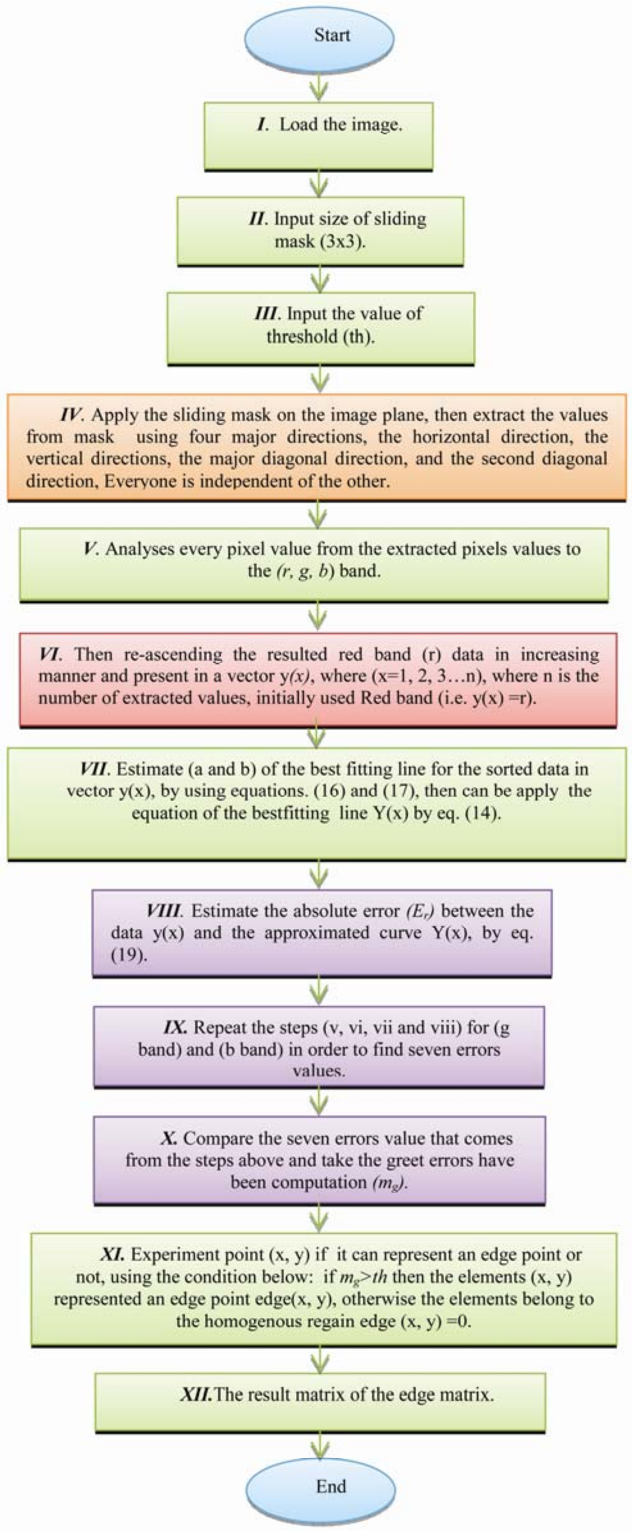
The pixel at $\left(x, y\right)$ has a neighbor in the horizontal direction, as $\left(x,\ y-1\right), \left(x,\ y+1\right)$, and in the vertical direction, as $(x-1,\ y), (x+1,\ y)$, and the neighbors in the major diagonal direction, as $\left(x-1,\ y-\ \right)\ \left(x+\ \ \ y+\ \right)$ while where as in the second diagonal direction, $\left(x+1,\ y-1\right)$.

From the above step, the pixels of all directions of the image are determined.

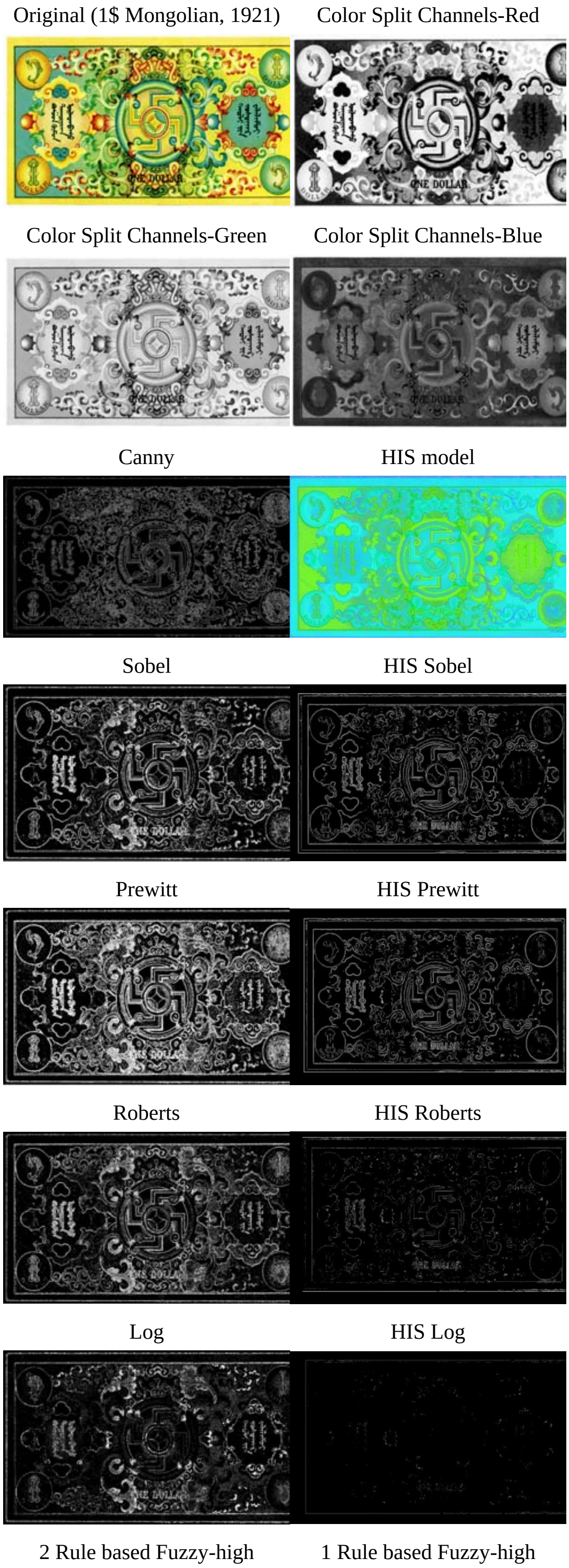
Assume that the $x-$ axis represents the local and $y-$ axis represents the color levels $Y\left(x\right)$, where $\left(x = 1,\ \ \ldots\ n\right)$ *and* $\left(n\right)$ is the total number of points in this direction. From the pair $\left[x, y\left(x\right)\right]$, can calculate the values of $\left(a, b\right)$ can be calculated from Eqs. (16) and (17). The equation of the best line of data for the image $y\left(x\right)$ due to Eq. (14) can then be found. In the next step, the error between $y\left(x\right)$ and $Y\left(x\right)$ using is calculated using the equation:

$$Er = \frac{1}{n}\sum_{x=1}^{n} \left|y(x) - Y(x)\right| \tag{19}$$

If the error calculated in Eq. (19) is small, it means the determining region in this direction is a homogenous region.



Algorithm (1) shows the linear fitting algorithm to detect edges for the color image by using four major directions sliding mask on the image plane.



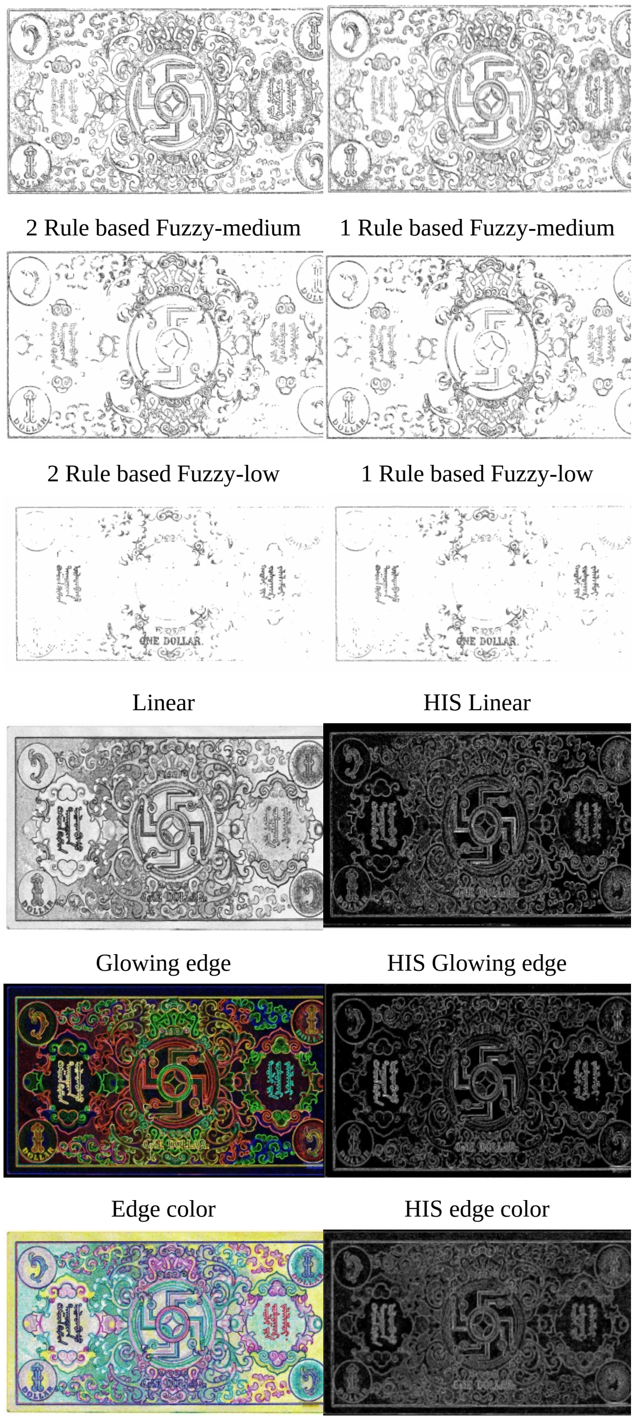


Fig. 6. Result shown in the comparison of the edge detection algorithms.

9. Conclusion

Because edge detection is the initial step in object recognition, it is important to know the differences between the various edge detection techniques. A range of edge detection algorithms and detector design methods were described and discussed. Edge detection methods are fundamental to computer vision, because edge detection is often the first stage of a lengthy image interpretation process. The goal of edge detection is to locate the pixels corresponding to the edges of the objects observed in an image. The real color image is used to evaluate the implementation efficiency ofthe suggested algorithm. This image (original) has spatial resolution (1744x927) pixels, and true color resolution 32 bits/pixel. To determine the power of the introduced edge detector, the results were compared with those from the Sobel, Canny, Prewitt, Log, Robert, Fuzzy, HIS, Linear fitting, Parametric, synthetic and vector methods edge detectors. From the results shown in figures (2 and 6), the present Linear Fitting algorithm edge detector produced the best results, compared to the assessed.

While detecting edges, it is very important to compromise. Certain algorithms, such as Canny, will pick out many details and work quite well. On the other hand, when the image is noisy, this edge detector picks up many edges that are not in the image. Although the Sobel and Prewitt detectors did not find edges as well as the Canny did, they performed much better for noisy images. Roberts and LoG were good for simple images with easy to spot objects.

Accordingly, it can be said that the color image regions in RGB band values can be modeled locally as a linear function in the homogeneous region. Any contrasts with this model, means that the band region represents an edge region or non-homogenous region, and the physical meaning of the color edges is that they are produced by discontinuities in the color values (R, G, and B).

The synthetic methods for color edge detection are simple and easy to implement, but their output quality is not comparable with that of vector methods. How-ever, all the vector methods have a shortcoming. The quality of their output is dependent upon the neighborhood window size and the threshold value used.

HIS model is derived from the RGB model by nonlinear changes, the HIS model is relatively more consistent to perception; it is also helpful to reduce the complexity of edge detection. Meanwhile, the paper in the original model based on the HIS brightness and saturation components of the fine-tuning and further optimized by the new HIS-color model. Tests show that the improved one based on edge detection image effects model is relatively good, it removed a lot of false edges, further reducing the workload, while the edge effect is clearer. A bad thing is that detection of the defects is prone to break; making some of the edge is not continuous, causing the loss of the edge.

We use at least square method with HIS method in experimental data. Then result was good a color image edge detection. Therefore we would like to use this type of method.

Fuzzy image processing is a powerful tool as the fuzzy sets provide a framework for incorporating human knowledge in the solution of problems whose formulation is based on imprecise concepts. In this paper, using the fuzzy logic a very simple and very efficient edge detection method is developed. The algorithm uses a 2x2 window mask, which is of smallest size, thus it minimizes the computation. Besides this no threshold value need to be determined in this algorithm. The algorithm is able to detect edges of various images and produces comparatively better results than some standard edge detection algorithms.

In conclusion, finding edges depends strongly on the quality of the image used. Therefore, the best edge detector change depending on the noise. Also experimental results show that the proposed method effectively improves the accuracy of edge detection.

References

[1] Ando, S.,*"Consistent Gradient Operators"*, Pattern Analysis and Machine Intelligence, IEEE Transactions on Vol.22, pp 252-265, 2000. Article (CrossRef Link)

[2] R.Gonzalez and R.Woods,*"Digital Image Processing, Addison Wesley"*, 1992, pp 416-458. Article (CrossRef Link)

[3] Slaw Wesoikowski and Ed Jemigan,*"Color Edge detection in RGB Using Jointly Euclidean Distance and Vector Angle"*, Trois - Rivieres, Vision interface, Canada, 1999. Article (CrossRef Link)

[4] Andréa's Koschan, *"A comparative study on color Edge Detection "*, Accv, Singapore, Vol. III, pp 574-578, 1995. Article (CrossRef Link)

[5] J.D. Foley, A. Van Dam, S.K. Feiner and J.F. Hughes, *"Computer Graphics"*, 3th Edition, Principles and Practice, Addison-Wesley, Reading, 2013. Article (CrossRef Link)

[6] I. Newton, *"Opticks"*, 4th Edition, Dover, New York, 1704/1952. Article (CrossRef Link)

[7] E.B. Goldstein, *"Sensation and Perception"*, Ninth Edition, Bruce Goldstein, 2014, 2010. Article (CrossRef Link)

[8] Slawomir B. Wesolkowski, *"Color Image Edge Detection and Segmentation"*, PhD Theses, Waterloo, Ontario, Canada, 1999. Article (CrossRef Link)

[9] Umbough S. E., *"Computer Vision and Image Processing a practical Approach Using CVIP Tools"*. Prentice-Hall, 1998. Article (CrossRef Link)

[10] Canny, John, "A Computational Approach to Edge Detection," *IEEE Transactions on Pattern Analysis and Machine Intelligence*,Vol. PAMI-8, No. 6, 1986, pp 679-698. Article (CrossRef Link)

[11] Lim, Jae S., *"Two-Dimensional Signal and Image Processing"*, Englewood Cliffs, NJ, Prentice Hall, 1990, pp 476-498. Article (CrossRef Link)

[12] J. R. Parker, *"Algorithms for Image Processing and Computer Vision"*, 2nd edition, John Wiley & Sons, Inc., 2011, pp 23-29. Article (CrossRef Link)

[13] Tzu-Heng Henry Lee,*"Edge Detection Analysis"*, Tzu-Heng Henry Lee Graduate Institute of Communication Engineering, National Taiwan University, Taipei, Taiwan, ROC, pp1-25. Article (CrossRef Link)

[14] Janakiraman T. N., and Chandra Mouli P. V. S. S. R., *"Color Image Edge Detection using Pseudo-Complement and Matrix Operations"*, Proceedings of World Academy of Science, Engineering and Technology Volume 32, ISSN 2070-3740, 2008. Article (CrossRef Link)

[15] Van de Weijer J.; Gevers Th. And Geusebroek J.M., *"Color Edge Detection by Photometric Quasi-Invariants"*, Proceedings of the Ninth IEEE International Conference on Computer Vision (ICCV 2003) 2-Volume Set, 2003. Article (CrossRef Link)

[16] Koschan, A.,Abidi, M.: *"Detection and classification of edges in color images: A review of vector valued techniques"*, IEEE Signal Processing Magazine, pp64-73 Jan (2005). Article (CrossRef Link)

[17] Chen, X., Chen, H.: *"A novel color edge detection algorithm in RGB color space"*, Proc. of IEEE 10th International conference on signal processing, pp 793-796 (2010). Article (CrossRef Link)

[18] Ruzon, M.A., Tomasi, C.: *"Edge, Junction, and Corner Detection using Color distributions"*, IEEE Transactions on Pattern Analysis and Machine Intelligence, 23, no. 11 Nov (2001). Article (CrossRef Link)

[19] Nevatia, R.: *"A Color edge detector and its use in scene segmentation"*, IEEE Transactions on Systems, Man and Cybernetics, SMC-7, no. 11 Nov (1977). Article (CrossRef Link)

[20] Ajay Mittal, Sanjeev Sofat, Edwin Hancock, *"Detection of edges in Color Images: A review and evaluative comparison of state of the art techniques"*,

[21] AIS 2012, LNCS 7326, pp 250-259, 2012 ©Springer-Verlag Berlin Heidelberg 2012. Article (CrossRef Link)

[22] Y.G.Tang, "The realize of the transformation between the GRB model and the Color image in VB", *Technical information*, Vol.11, pp 457-458, Dec 2009. Article (CrossRef Link)

[23] J.S.Zhao, and L.Yang, "Automatic adjustment method for color image based on HIS color model", *Technical information*, Vol.10, pp 102-104, May 2008. Article (CrossRef Link)

[24] Linhua Zhang, Xiuli Mao, Chuan bin Zhou and Ping Yu, *"Improved HIS Model with Application to Edge Detection for Color Image"*, Journal of Computers, pp 1400-1405, Vol. 7, No. 6, June 2012. Article (CrossRef Link)

[25] L.A. Zadeh, "Fuzzy sets", Information and Control, 8: pp 338-353, 1965. Article (CrossRef Link)

[26] A. Kaufmann, "Introduction to the Theory of Fuzzy Subsets Fundamentals Theoretical Elements", Vol. 1. Academic Press, New York, 1975.

[27] L.C. Bezdek, *"Pattern Recognition with fuzzy Objective Function Algorithms"*, 1981. Article (CrossRef Link)

[28] K. Cheung and W. Chan, *"Fuzzy One Mean Algorithm for Edge Detection"*, IEEE International Joint Conference, Fuzzy Systems, pp 2039-2044, vol.4, 1995. Article (CrossRef Link)

[29] Y. Kuo, C. Lee and C. Liu, *"A New Fuzzy Edge Detection Method for image Enhancement"*, IEEE International Conference on Fuzzy Systems, pp 1069-1074, 1997. Article (CrossRef Link)

[30] S. Baker, S. K. Nayar and H. Murase, *"Parametric Feature Detection"*, International Journal of Computer Vision, Vol.27, No.1, pp 27-50, Mar, 1998. Article (CrossRef Link)

Ganbold Ganchimeg received her B.S. and M.S. degrees in mathematics and software engineering from Mongolian University of Science and Technology, Mongolia, in 2002 and 2004. She is currently studying for a PhD degree in information technology engineering from MUST, Mongolia. Her research interests include image processing, pattern recognition, multimedia and computer vision.

Renchin Turbat, Head professor of Virtual and Information Technology of Mongolian University Science and Technology (MUST), received the B.S. degree and M.S degree in system and software engineering from Computer Science and Management School (CSMS) of MUST, Mongolia and the Ph.D. degree Comparative study of Image processing some methods in Medicine image from the Department of Computer Science, MUST in 2008. He worked as a Staff Researcher, system administrator and Director with Information technology center of MUST, and was a Director of e-Open School, in MUST. He is Professor of Virtual and Information Technology Department of MUST. His current research interests include information technology, computer graphics and image processing, software technology and pattern recognition, network and security.