Sobel-Freichen Hybrid Filters to Improve Edge Detection Performance

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***Abstract*—Edge detection is one of the most critical tasks in the image processing, computer vision and pattern recognition. Edge is a line between two corners or surface which also significant transitions in an image. It also can be defined as an abrupt change in intensity of pixels and discontinuity in image brightness. This research paper provides visual analysis of edge detection using Sobel and Freichen operator. Furthermore, a new hybrid technique proposed which is the combination of Sobel and Freichen filters to overcome some drawbacks of the classical operator. Based on the frequency distribution, the proposed hybrid method is producing a better edge profile than the traditional filters Sobel and Freichen**

***Index Terms*—Kernels; Hybrid; Sobel; Freichen; Edge Detection.**

I. INTRODUCTION

An image which means a visual form of an object can be digitised to store in any form of storage media. Once the image has been digitised, it can be operated upon by using various image processing operations. An edge in an image is a significant local change in the image intensity, usually associated with a discontinuity in either the image intensity or the first derivative of the image intensity which is stated by [1]. Edge detection is one of the most important tasks in the image processing, computer vision and pattern recognition. The primary goal of edge detection methods is to extract the edge features and essential information in an image. The edges occur on the boundaries between two different regions which are significant local changes in the intensity of an image. The conventional methods to detect edge features usually involve convolving an image with 2-D (filter) or operator to be sensitive to large gradients in the digital images. There are various ways to detect edges in digital images however the majority of methods are grouped into two main groups namely the Gradient and Laplacian techniques. The primary goal of this study is to analyse the visual comparison in term of good localisation and to make a quantitative comparison of the hybrid algorithm and finally to evaluate using edge detection index for obtaining ideal edge detection filters. The purpose of this study is to improve the edge detection process to get better results in term of proper detection and good localisation. This will be done by employing two or more filters that will be used together to perform the edge detection and to evaluate using edge detection index. Hybrid edge detection combines more than one filter. By combining more than one filter, the advantages of every filter also combine to work together. Combination of operators not only increases the number of the pixel but also precisely find the clear boundaries of an image. In the real world of recognition and interpretation of a system, issues such as noise and variable scene illumination make the edges difficult to be identified. Effective edge detection technique is required for many important areas and widely used in medical imaging. There is the absence of edge detectors that work under all condition. Traditional edge detectors commonly extract edges by adopting specific template. However conventional edge detectors often result in some drawbacks such as broken edges, false edges or thick edges. Other than that, tools to evaluate the edge detection also play a vital role to justify a filter. Therefore, evaluation should be done in multiple ways to test the effectiveness of an edge detector. Edge detection continues to be an active research area. Thus, there is a substantial need to conduct such a study to find a method to define and improve the detection method of edge features in digital images to efficiently use in any application. Thus, a hybrid technique is used in order to overcome some drawbacks of the classical operator.

II. BACKGROUND STUDY

Edge detection is an essential operation in the field of image processing that includes a mathematical method to identify the sharp points of an image. Fundamental tool, edge detection process in image processing and various techniques that have been used to enhance the edges will be discussed. The scope of this background study is limited to the studies related to the edge detection features in image processing and application of the hybrid technique to retain required information from an image.

A. Definition of Edge

Edge is a line between two corners or surface which also significant transitions in an image. It also can be defined as an abrupt change in intensity of pixels and discontinuity in image brightness. Generally there are three types of edges which are horizontal edges, vertical edges and diagonal edges. A vital edge feature of an image involves corners, lines as well as curves.

B. Definition of Noise

Noise is unwanted electrical energy that degrades the quality of a signals and data. In image processing noise is said to be a distortion in an image as in the figure below. The typical salt- pepper noise, Gaussian noise, Poisson noise and speckle noise are the type of noises that caused by an error in data transmission as shown in Figure 1 according to [2].


Original image


Poisson Noise


Salt-pepper noise

Figure 1: Different type of image noise

III. Concept of Gradient

Edge detection is an important process to identify a significant characteristic of an image. The process involves, identifying sharp discontinuities in digital images where it can be done in vertical, horizontal and diagonal edges. In edge detection, there are two types of operators namely gradient-based edge detection and Laplacian-based edge detection. The gradient method is the first order approach which is a generalisation of the usual concept of the derivative of a function in one dimension to a function in several dimensions that done through the close observation of the minimum and maximum first derivatives of a particular image. Laplacian and Gaussian are two examples of the Laplacian edge detection methods which are the second order approach. This operator is considered a 2-D isotropic measure of the 2nd spatial derivatives for any image in which the regions of rapid intensity change are highlighted. According to [3], the gradient-based operator is simple and easy to execute. The following operators come under Gradient Based Edge Detection like Robert Operator, Sobel Operator, Prewitt Operator and Freichen Operator. This paper focuses on Sobel and Freichen operator.

A. Sobel Operator

The Sobel operator performs gradient measurement on an image, and this filter is used in image processing and computer vision field. The operator uses two 3×3 kernels which are convolved with the original image to respond to edges, for horizontal changes, and for vertical changes as shown in Equation (1). The gradient approximation that it produces is relatively crude, in particular for high-frequency variations in the image. The magnitude calculation is as Equation (2).

$$Gx = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad Gy = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \tag{1}$$

$$|G| = \sqrt{Gx^2 + Gy^2} = |Gx| + |Gy| \tag{2}$$

B. Freichen Operator

These operators are similar to all the other operators as they can be used to detect horizontal or vertical edges in images Thus, this operator also uses two 3×3 kernels, where G_x for horizontal changes, and G_y for vertical as shown in Equation (3) and the magnitude calculation is as shown as Equation (2).

$$Gx = \frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & \sqrt{2} & 1 \\ 0 & 0 & 0 \\ -1 & -\sqrt{2} & -1 \end{bmatrix} \quad Gy = \frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 0 & -1 \\ \sqrt{2} & 0 & -\sqrt{2} \\ 1 & 0 & -1 \end{bmatrix} \tag{3}$$

IV. Hybrid Approach Edge Detection

Hybrid refers to the fusion of two or more operators to form a new edge detection technique which keeps their respective advantages according to [4]. In this study combination of any two operators from Robert, Sobel, Prewitt and Freichen operator will be applied to the input image. Edge detection index used to evaluate the combinations to choose the ideal edge detector that detected the edge close to true edges.

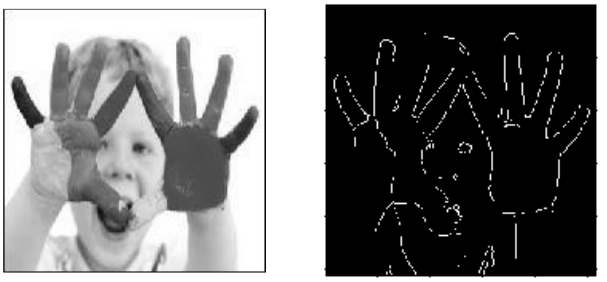
A. Advantages of Hybrid Edge Detection

Compared to the performance of an individual operator, the hybrid method has high possibilities to improve the process of the edge which can be summarised in the following points, Edge detection using hybrid filters involves simple steps and gives considerably better output. It gives smooth and thin edges without distorting the shape of images. According to [1], features like lines, circles, triangle, edges and boundaries are easier to be located with same accuracy and efficiency.

B. Summary of Previous work

This section addresses the previous literature related to the detection of edge features in digital image processing. A new algorithm is proposed as well as a hybrid approach using Sobel, canny and log filters [5]. The goal of this study is to prove that hybrid technique improves accuracy with a final image that consists relatively complete edge profile. It was confirmed that the output of the proposed new algorithm clearly shows that it automatically obtains a relatively comprehensive edge profile as compared to the traditional methods like Sobel, Prewitt, Roberts and Canny.

Quantitative performance analysis of edge detectors using hybrid edge detection approach [6]. In their study paper, a quantitative analysis done for edge detection operator using Canny, Prewitt, Sobel, Laplacian of Gaussian, fuzzy concept edge detection, wavelet-based edge detector with hybrid edge detection technique that proposed based on the correspondence between their outcomes. The hybridisation process implemented the multi-scale edge tracking behaviour of wavelet transform and removes its inherent limitation i.e., insensitive to edge direction by using the fuzzy theory. Quantitative analysis represented by the comparison of the percentage of correct detection (Pcod) and percentage of pixels that were not detected (Pnod) respectively. Percentage of false alarm Pfal (percentage of pixels that are erroneously detected as edge pixels) for different edge detectors. The experimental results confirmed that compared to other techniques the hybrid edge detection technique outperforms regarding edge detection accuracy which is shown in Figure 2 exclusively when noises corrupt the images.



a) Original image b) Prewitt

c) Wavelet d) Hybrid

Figure 2: Hybridization results

V. METHODOLOGY

A. Pre-processing

Pre-processing is the beginning stage where the aim is to improve the image data that suppresses unwanted distortions or enhances the image features for further processing. Basic filters such as linear filter and non-linear filter can be used in this stage to improve the image quality, improve specific image features and to reduce noise signals in two areas, namely the resolution and brightness. Median filters are simply non-linear filters that are utilised in image processing to reduce noise. The main advantages of median filtering are given below:

i. The median filters provide better robustness over the mean filters
ii. Provide better preservation of sharp edges over the mean filters.
iii. Very efficient in reducing the impulse noise.

B. Proposed Hybrid Technique

Hybrid refers to the fusion of two or more operators to form a new edge detection technique which keeps their respective advantages. The proposed hybrid technique described as follows:

i. Apply mask, 3x3 matrix form as in Figure 3 by multiplying each matrix pixel from two different operators with the corresponding image pixel. Mask of Sobel filter is convolved with a mask of Freichen filters to design hybrid filters.
ii. Apply the proposed algorithm to the input image to get the edges detected
iii. Make the double gradient of the image in x and y directions
iv. Threshold chosen, to separate the background and foreground objects.
v. Take the average, or maximum or minimum of the proposed algorithm as shown by Equation (4) to Equation (6).

$$Gx_1 = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad Gy_1 = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}$$

Sobel

$$Gx_2 = \frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & \sqrt{2} & 1 \\ 0 & 0 & 0 \\ -1 & -\sqrt{2} & -1 \end{bmatrix} \quad Gy_2 = \frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 0 & -1 \\ \sqrt{2} & 0 & -\sqrt{2} \\ 1 & 0 & -1 \end{bmatrix}$$

Freichen

Figure 3: Kernels of filters that used in this study

$$|G| = \sqrt{ave\ (Gx_1^2 + Gx_2^2) + ave\ (Gy_1^2 + Gy_1^2)} = |Gx| + |Gy| \quad (4)$$

$$|G| = \sqrt{\max\ (Gx_1^2 + Gx_2^2) + \max\ (Gy_1^2 + Gy_2^2)} = |Gx| + |Gy| \quad (5)$$

$$|G| = \sqrt{\min\ (Gx_1^2 + Gx_2^2) + \min\ (Gy_1^2 + Gy_2^2)} = |Gx| + |Gy| \quad (6)$$

VI. RESULTS AND DISCUSSION

In this section, results of classical and proposed hybrid techniques presented to compare visually which is shown in Figure 4. Sobel and Freichen edge detection techniques are applied to the resulting grey images and followed by the proposed hybrid technique which in turns gives the edges of image and Table 1-3 shows the relative frequencies of the occurrence of edge pixels in the filters. The maximum frequency occurrence and the ratio of edge pixels concerning each other provide comparative statistics of edge to determine which filter detected higher edge pixels.

(a) Typical original image of Lena

(b) Sobel Operator that has many missing lines

(c) Freichen Operator that has broken edges

(d) Proposed Hybrid Sobel-Freichen

Figure 4: Visual comparisons of filters

Table 1
Frequency Distribution of Sobel, Freichen and Maximum of SobelFreichen with Threshold Value =100

	Sobel	Freichen	Sobel-Freichen Maximum	SobelFreichen Average
Sobel	1	0.79	1.11	0.65
Freichen	1.25	1	1.40	0.81
SobelFreichen maximum	0.90	0.72	1	0.58
SobelFreichen Average	1.54	1.23	1.72	1

Table 2
Frequency Distribution of Sobel, Freichen and Maximum of SobelFreichen with Threshold Value =150

	Sobel	Freichen	Sobel-Freichen maximum	SobelFreichen Average
Sobel	1	0.79	1.03	0.61
Freichen	1.37	1	1.37	0.83
SobelFreichen maximum	0.97	0.77	1	0.68
SobelFreichen Average	1.64	1.20	1.64	1

Table 3
Frequency Distribution of Sobel, Freichen and Maximum of SobelFreichen with Threshold Value =200

	Sobel	Freichen	Sobel-Freichen maximum	SobelFreichen Average
Sobel	1	0.77	1.02	0.61
Freichen	1.26	1	1.30	0.90
SobelFreichen maximum	0.96	0.73	1	0.61
SobelFreichen Average	1.42	1.13	1.47	1

As shown in the visual comparison, the proposed hybrid method enlightens those edges and gives better edge profile compared to the traditional edge filter Sobel and Freichen. Table 1 to Table 3 shows the relative frequencies of detected edge pixels. The ratio of edge pixels with respect to each other provides a definitive comparative for the occurrence of edges. In term of frequency distribution, the active pixels hybrid of SobelFrecihen more than Sobel filter. While Sobel filter's active pixels more than Freichen filter. Thresholding is a technique that used to reduce the number of false edge fragments.The lower the threshold, the more edges will be detected, and the result will be increasingly susceptible to noise and edges of irrelevant features in an image. Conversely, a high threshold may miss subtle edges, or result in fragmented edges. Therefore, from the table, the hybrids filter of SobelFreichenmaximum reports the higher detected edge pixels.

VII. CONCLUSION

This paper provided a comparison of different thresholding value with classical and hybrid edge detection. Edge detection using hybrid filters involves simple steps and gives a considerably better output when compared to classical filters, Sobel, and Freichen. Visual comparison results show that hybrid technique combines the advantages of different classical technique in order to obtain better results by enlightening portions of the final fused edge detected image. From the relative frequencies, also the hybrid filter of SobelFreichen reports the higher detected edge pixels. It also leaves some of true edges as dim which should have been highlighted. The future scope will be to study the reason for the missing edges and improve this hybrid technique in a broader scope.

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