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Histogram Features Extraction for Edge Detection Approach

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***Abstract*— An edge is where an image's intensity values rapidly change from low to high-intensity values or vice versa. The edge itself is at the midpoint of this change. Edge detection remains a challenge in computer vision despite recent advances. It cannot be applied to an image with excessive brightness and contrast. This paper produces a new method based on the standard deviation histogram feature to reduce the onerousness. The proposed method aims to prepare the input image for the edge detection approaches by performing a histogram feature extraction. The main characteristics of the proposed approach are simplicity and functionality. The authors utilize twenty MATLAB standard images as well as ADNI brain images. The authors use the Canny edge detection method to defect edges from the proposed method. The authors use edge detection evaluation metrics such as Figure of Merit (FOM), Structural Similarity Index Metric (SSIM), Peak Signal to Noise Ratio (PSNR), and Mean Square Error (MSE) measures for evaluating and justifying edge quality. The experimental results show that the proposed method performs better in visual and statistical edge quality than both classical and fractional-order edge detection methods.**

Keywords*— Histogram feature extraction, edge detection, feature extraction, Histogram.

I. Introduction

Edge detection is a technique for locating and identifying the surrounding elements of an image object. It works by detecting the rapid variation in the intensities of the image's pixels. It is used for image registration, segmentation, and feature extraction [1, 2] in machine vision, computer vision [3], and image processing. Also, edge detection is applied to iris segmentation [4, 5] and leukemic cell [6] detection [7]. Many edge detection operators include Canny, Sobel, Prewitt, Robinson, and compass operators. Some operators have two masks, while others (compass operators) have eight masks. A highly efficient edge detector preserves important image features while reducing a large amount of data [8, 9].

The main approaches to implementing feature extraction for edge detection using histogram, local turnery pattern [10], local binary pattern [11], gray level co-occurrence matrix [12, 13], and texture feature coding method [14]. Recent approaches combine two or three standard algorithms [15] or use deep learning [16]. One of the most straightforward feature extractions approaches is histogram features. For a given image, calculating the histogram is simple. The shape of the histogram reveals a lot about the image's attitude. A narrowly distributed histogram, for example, indicated a low-contrast image. A bimodal histogram typically indicates that the image contains an object with a narrow intensity range set against a background with varying intensities. In addition, the histogram can be used to calculate various functional parameters (image features) that can quantitatively describe the image's first-order properties—the so-called central moments [17].

The rest of this paper is divided into five sections in addition to the introductory section. Section two will illustrate the literature. Section three will lay our proposed method's architecture, flowchart, and algorithm. Next, section four will state the proposed approach's results and discussion. Finally, section five will conclude this paper.

II. Literature Review

Many edge detection approaches have been proposed in the literature. For example, a new algorithm was proposed to determine an optimal edge detection method using the Genetic Algorithm (GA) [18]. The Singular Value Decomposition and Gradient Operator (SVD-GO) algorithm are presented to detect an image's edge [19]. In [20], the authors built an Artificial Neuron Structure (ANS) that utilized drift and diffusion memristor models. Another edge detection approach was proposed using the Neutrosophic Logic Set (NLS) [21]. In [22], the ant colony algorithm was used to detect the edge of an image. The proposed method utilized the Fuzzy Triangular Membership Function (FTMF) to obtain an improved image edge. Artificial Neural Network and Kalman Filter (KF-ANN) [23] method were used to produce a projected filter. Finally, to improve the image edges, the Canny edge detector, the Discrete Wavelet Transform (DWT), and two other techniques are applied [24, 25].

III. Methodology

Our proposed method contains three stages. In stage 1, extracts feature based on the histogram feature extraction method. At first, the authors use a 3X3 filter to count the bins of a histogram. Next, the authors calculate the probability of pixels inside the filter; then, the authors calculate the mean; Finally, the authors calculate the standard deviation (STD) using Eq 1, 2, and 3, respectively. The last step produces an image. This image will be used in the second stage of the proposed method. In stage 2, the authors utilized a well-known edge detection method called the Canny approach. In stage 3, the authors use four measures mentioned in the introductory section (FOM, SSIM, PSNR, and MSE) to evaluate the detected edges. The evaluation phase was conducted two times. Once to test the original image with its detected edges, and again for the proposed method with its detected edges. Fig. 1 shows the structure of the proposed method. Finally, the authors implemented the algorithm with MATLAB R2020a and run it on a PC with an Intel Core i7 CPU and 4GB of RAM.

A. Histogram Feature Extraction

Convolving a 3X3 mask can calculate the first-order histogram probability of the original image. Then, we compute the probability by dividing the number of occurrences of the pixel value over the number of all pixels in the mask (which is 9 in the case of 3X3) using Eq 1.

$$Prob(g) = \frac{GP(g)}{IP} \quad (1)$$

Where GP(g) represents the number of occurrences of the pixel value at the gray level g, and IP represents the number of all pixels in the mask. First-order features are calculated as follows [26]:

Mean

$$\mu(g) = \sum_{g=0}^{IP-1} g * Prob(g) \quad (2)$$

Standard Deviation

$$\sigma = \sqrt{\sum_{g=0}^{IP-1} [g - \mu(g)]^2 * Prob(g)} \quad (3)$$

Variance

$$\sigma^2 = \sum_{g=0}^{IP-1} [g - \mu(g)]^2 * Prob(g) \quad (4)$$

Skewness

$$Skew = \sum_{g=0}^{IP-1} [g - \mu(g)]^3 * Prob(g) \quad (5)$$

Kurtoses

$$Kurt = \sum_{g=0}^{IP-1} [g - \mu(g)]^4 * Prob(g) \quad (6)$$

Energy

$$Energy = \sum_{g=0}^{IP-1} [Prob(g)]^2 \quad (7)$$

Entropy

$$Entropy = \sum_{g=0}^{IP-1} Prob(g) * \log_2[Prob(g)] \quad (8)$$

B. Edge detection Evaluation Metrics

Evaluating the quality of edges in an image is an important topic because it helps measure the performance of edge detectors and edge-aware filters used in a wide variety of image processing tasks. Therefore, the authors utilized the most common image quality metrics [27, 28], such as FOM, SSIM, PSNR, and MSE measures, for evaluating and justifying edge quality [29].

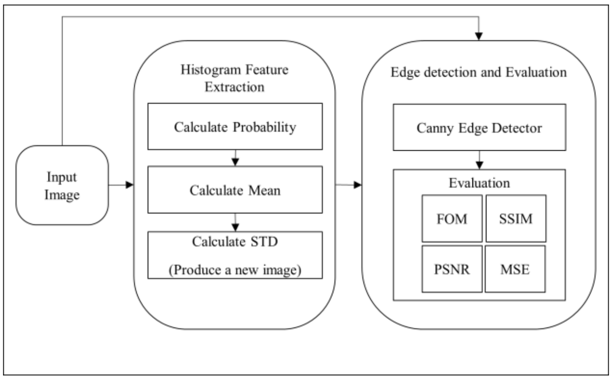


Fig. 1 Architecture of the proposed method

The proposed method works with the following steps:

Algorithm of MFI edge detection
Input: Image (I)
Output: Edge detection
//Image Acquisition Phase Step1: Read an image (I). Step2: If the image (I) has three channels, then convert it to gray; otherwise, the image (I). **//Feature Extraction Phase** Step3: Calculate the histogram probability using equation 1 and kernel 3X3. Step4: Calculate the mean using Eq 2. Step5: Calculate the STD using Eq 3, then replace the result with the kernel focal pixel to produce a new image F. **//Edge Detection Phase** Step6: Find the edge for the image I using the Canny edge detector to produce an edge image E1. Step7: Find the edge for image F using the Canny edge detector to produce an edge image E2. **//Evaluation Phase** Step8: calculates edge detection evaluation measures, the image I as reference for image E1 and image F as reference for image E2. FOM (I, E1), SSIM (I, E1), PSNR (I, E1), and MSE (I, E1) FOM (F, E2), SSIM (F, E2), PSNR (F, E2), and MSE (F, E2)

IV. EXPERIMENTAL RESULTS

In this part, the authors will present our method for testing the performance of the proposed approach. Firstly, the authors have used a comparative approach to analyze the performance of the proposed method concerning Canny algorithms. Secondly, the authors used twenty standard images with different sizes for comparisons, as shown in Fig 1, Fig 2, Fig 3, and Fig 4. However, the results obtained were presented in the following order, see TABLE I.

TABLE I
EDGE DETECTION RESULTS FOR THE PROPOSED METHOD

Original image	Canny for the original image
Proposed method	Canny for the proposed method

Fig. 2 Applying the proposed method to Lena image

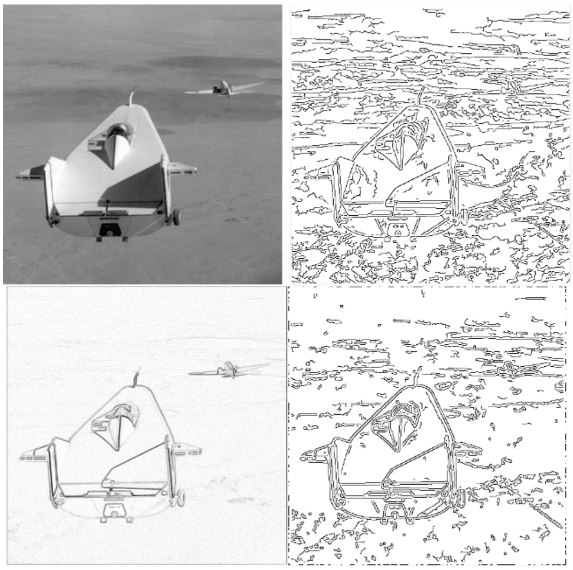


Fig. 3 Applying the proposed method to Lifting body image

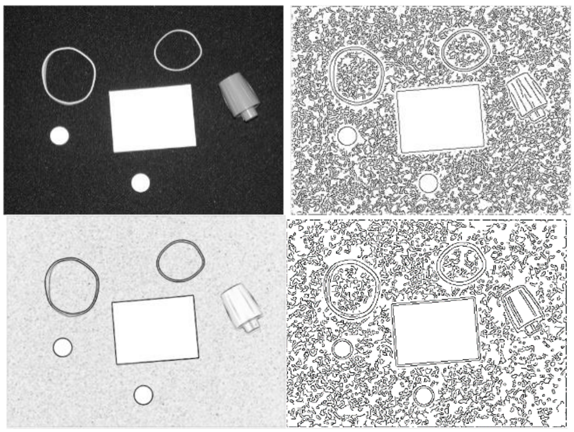


Fig. 4 Applying the proposed method to Toy objects image

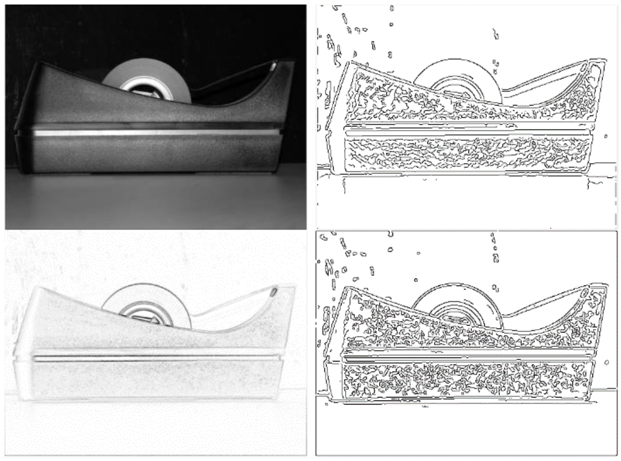
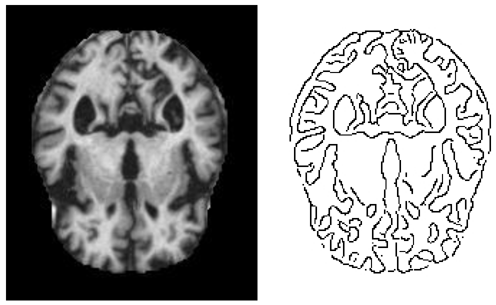


Fig. 5 Applying the proposed method to tape image

Also, the authors utilized Alzheimer's Disease Neuroimaging Initiative (ADNI) dataset, which contains 6400 Magnetic Resonance Image (MRI) brain images divided into four groups (Mild Demented 896, Very Mild Demented 2240, Moderate Demented 64, and Non-Demented 3200) with (176×208) image size [30] as shown in Fig 6, Fig 7, Fig 8, and Fig 9.

Fig. 6 Applying the proposed method to a non-Demented image



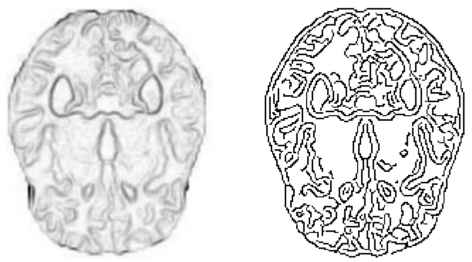


Fig. 7 Applying the proposed method to a Moderate Demented image

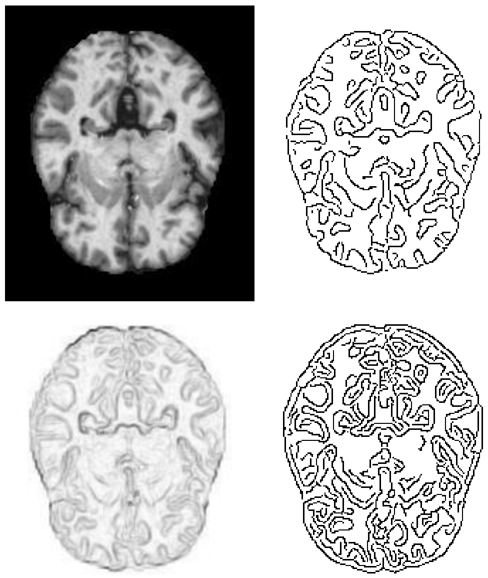


Fig. 8 Applying the proposed method to a Very Mild Demented image

Fig. 9 Applying the proposed method to a Mild Demented image

Fig 2 through Fig 9 show that the proposed method works well with the Canny edge detector. The proposed method has detected edges excel from the original image as detailed edges and shapes. Furthermore, the proposed method allows the Canny edge detector to highlight the edges with double lines. This characteristic makes the detected edge of an image transparent and high detailed.

However, the detected edges of the proposed method were better than the source image. However, a comparative analysis was performed on the four image quality metrics to evaluate the proposed method's performance. TABLE II shows the results for calculating FOM and SSIM for each proposed method and the source images.

TABLE II
FOM AND SSIM RESULTS FOR THE PROPOSED METHOD AND TWENTY SOURCE IMAGES

Images	Proposed method		Original image	
	FOM	SSIM	FOM	SSIM
Lena	57.68	0.9934	44.5378	0.9921
hands1-mask	68.9124	1	25.2885	1
hands1	41.6972	0.9974	13.4235	0.9966
hands2	41.1044	0.9974	11.3056	0.9966
threads	46.0969	0.9976	17.8807	0.9939
circles	73.8515	1	37.9234	1
blobs	88.0818	1	77.2485	1
glass	46.8139	0.9975	27.0082	0.996
lifting body	44.8781	0.9969	45.8177	0.9952
lighthouse	41.0148	0.9942	32.6644	0.9919
pillsetc	80.2439	0.9944	16.1513	0.9939
tape	53.896	0.9963	46.2718	0.9941
testpat1	89.3203	0.9719	44.0867	0.9756
toy objects	91.7126	0.9986	9.671	0.9984
circbw	86.4119	1	55.3275	0.9999
circuit	61.1079	0.9947	45.7171	0.9922
eight	40.0425	0.9951	15.429	0.9941
forest	56.7482	0.9906	36.1751	0.9893
kids	63.2656	0.9987	44.7901	0.9981
MRI	90.3781	0.996	86.8215	0.9956

It is evident from TABLE II that the FOM values for the detected edges of the proposed method are better than the detected edge for the source images. Moreover, the SSIM values in both detected edges are the same in many cases. However, while the SSIM values are remarkably high, the detected edge for the proposed method has scored the highest values in most images. Consequently, Fig 10 demonstrates the differences in the PSNR ratios for the proposed method and original image detected edges.

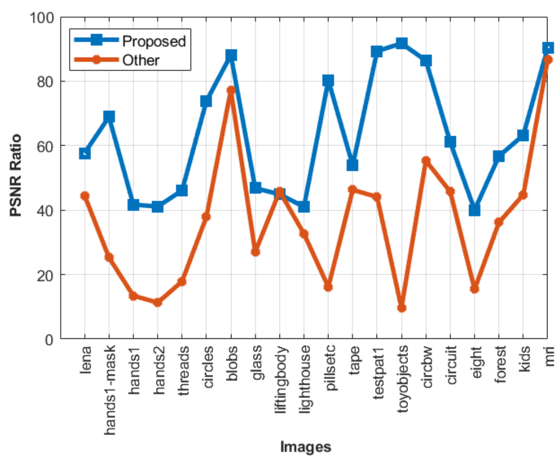


Fig. 10 FOM results.

From Fig 10, the obtained FOM ratios show that the proposed method enhanced the edge detection approach for all input images.

TABLE III shows the results for calculating PSNR and MSE for each proposed method and the source images.

TABLE III
PSNR AND MSE RESULTS FOR THE PROPOSED METHOD AND TWENTY SOURCE IMAGES

Images	Proposed method		Original image	
	PSNR	MSE	PSNR	MSE
Lena	16.8437	0.0207	5.662	0.2715
hands1-mask	59.8194	0	52.941	0
hands1	21.238	0.0075	2.9841	0.503
hands2	21.1512	0.0077	2.8082	0.5238
threads	24.2877	0.0037	3.0235	0.4985
circles	60.2663	0	54.8511	0
blobs	54.1336	0	54.9585	0
glass	21.3274	0.0074	5.1535	0.3052
lifting body	21.8975	0.0065	4.9804	0.3177
lighthouse	17.3589	0.0184	4.4079	0.3624
pillsetc	17.5628	0.0175	8.3035	0.1478
tape	21.7822	0.0066	9.6354	0.1088
testpat1	8.726	0.1341	1.7502	0.6683
toy objects	26.3199	0.0023	5.7808	0.2642
circbw	53.7796	0	51.3153	0
circuit	20.5809	0.0087	9.1093	0.1228
eight	17.7586	0.0168	1.8898	0.6472
forest	13.6478	0.0432	1.0484	0.7855
kids	30.9215	0.0008	17.9271	0.0161
MRI	20.9335	0.0081	16.0921	0.0246

It is evident from TABLE III that the PSNR value for some of the images such as 'Lena' is three times more than PSNR for the detected edge in the source image, while PSNR for some images such as 'hands1', 'hands2', 'eight,' and 'forest' images are about ten times more than of the original image. Also, MSE values indicated that the edges detected for the proposed method are better than the edges detected in the source image. This result shows that the proposed method has a performance of at least as good as this comparison.

However, comparing the proposed method with recent other methods on the Lena image is established. TABLE IV shows a comparison of MSE and PSNR results.

TABLE IV
COMPARISON OF EDGE DETECTION RESULTS OF LENA IMAGE.

Method	MSE	PSNR
GA [18]	0.5871	20.4430
SVD-GO [19]	-	10.9100
ANS [20]	-	21.1933
NLS [21]	0.0034	23:610
FTMF [22]	0.1898	5.348
KF-ANN [23]	0.1295	13.6274
Canny and DWT [24]	-	40.5062
Proposed method	0.0207	16.8437

TABLE IV presents the MSE and PSNR results from the various methods tested on the Lena image. Results denote that the proposed method is similar to or better than other operators in terms of MSE and PSNR.

V. CONCLUSIONS AND FUTURE WORKS

This paper proposed a new method to extract histogram features from an image to enhance the edge detection approaches. First, we applied the proposed method to extract STD histogram features from twenty MATLAB standard images and the 6400 ANIA brain images. Then, we used the Canny edge detector to extract the edge from the proposed method and the original image. After that, we employed four measures (FOM, SSIM, PSNR, and MSE) to evaluate the detected edges of the proposed method. Finally, the proposed method was compared with recent edge detection algorithms. Furthermore, the experimental results show that the proposed method performs better in visual and statistical edge quality than both classical and fractional-order edge detection methods.

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