Edge Detection: A Statistical approach

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Abstract—**This paper describes a novel edge detection algorithm for gray scale images. The proposed method is based on the neighborhood similarity of a pixel using a pre-defined intensity range and simple statistical approach. Then using three or four neighboring boundary pixel to detect a noise and reduced this noise. Many experiments were carried out to evaluate and compare the performance of the proposed algorithm. This new detector outperforms the previously available classical edge detectors.**

Keywords- Edge Detection; Sobel Operator; Prewitt Operator; Roberts Operator; Noise Reduction.

I. INTRODUCTION

Edges are boundaries between different textures. Edge also can be defined as discontinuities in image intensity from one pixel to another. The edges for an image are always the important characteristics that offer an indication for a higher frequency. Detection of edges for an image may help for image segmentation, data compression, and also help for well matching, such as image reconstruction and so on [1,2]. Variables involved in the selection of an edge detection operator include Edge orientation, Noise environment and Edge structure. The geometry of the operator determines a characteristic direction in which it is most sensitive to edges. Operators can be optimized to look for horizontal, vertical, or diagonal edges. Edge detection is difficult in noisy images, since both the noise and the edges contain high-frequency content. Attempts to reduce the noise result in blurred and distorted edges. Operators used on noisy images are typically larger in scope, so they can average enough data to discount localized noisy pixels. This results in less accurate localization of the detected edges. Not all edges involve a step change in intensity. Effects such as refraction or poor focus can result in objects with boundaries defined by a gradual change in intensity. The operator needs to be chosen to be responsive to such a gradual change in those cases. So, there are problems of false edge detection, missing true edges, edge localization, high computational time and problems due to noise etc. Therefore, the objective is to do the comparison of various edge detection techniques and analyze the performance of the various techniques in different conditions. In the field of image segmentation, there are many methods for edge detection based on different algorithms namely, derivative methods, surface methods, morphological methods, adaptive methods and structural methods.

In this paper we present a new approach to detect edges of a gray scale images. This approach consists of two steps. At step1, determine the all edge pixels for edge detection of the image and in step2, remove impulsive noise from the output of step 1 to enhance the edge map.

The rest of this paper is organized as follows: - in section II, the some classical edge detection technique is provided. Section III gives the concepts of the proposed algorithm and section IV described the experimental results and section V concludes the paper.

II. IMAGE EDGE DETECTION

Edge detection refers to the extraction of the edges in a digital image. It is a process whose aim is to identify the points in an image where discontinuities or sharp changes in intensity occur. This process is crucial to understanding the content of an image and has its applications in image analysis and machine vision. It is usually applied in initial stages of computer vision applications. Edge detection aims to localize the boundaries of objects in an image and is a basis for many image analysis and machine vision applications. Conventional approaches (such as Sobel Operator, Prewitt Operator, Roberts Operator etc.) to edge detection are computationally expensive because each set of operations is conducted for each pixel [1, 2]. In conventional approaches, the computation time quickly increases with the size of the image. A statistical-based approach has the potential of overcoming the limitations of conventional methods. Furthermore, it makes the algorithm easily adaptable for any systems. Various edge detection techniques have been developed for edge detection [4-9].

III. PROPOSED ALGORITHM

We have proposed an efficient edge detection algorithm using simple mathematical approach. This proposed method depends on masking operation. A 5×5 mask centered at pixel f (i, j) is defined as shown in given below:

f(i-2,j-2)	f(i-2,j-1)	f(i-2,j)	f(i-2,j+1)	f(i-2,j+2)
f(i-1,j-2)	f(i-1,j-1)	f(i-1,j)	f(i-1,j+1)	f(i-1,j+2)
f(i,j-2)	f(i,j-1)	**f(i,j)**	f(i,j+1)	f(i,j+2)
f(i+1,j-2)	f(i+1,j-1)	f(i+1,j)	f(i+1,j+1)	f(i+1,j+2)
f(i+2,j-2)	f(i+2,j-1)	f(i+2,j)	f(i+2,j+1)	f(i+2,j+2)

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A. Edge Detection

In this proposed method, using neighboring boundary pixel determines the all edge pixels for edge detection of the image. We considered only 8 bit gray scale image in any arbitrary dimension.

Algorithm:

Step1. Consider a gray scale image f(M,N).

Step2. For each pixel f(i,j) of the image f(M,N)

- **Step2.1** Find the 5×5 mask centering f(i,j)
- **Step2.2** Find s=sum of intensities of all the pixels of the mask except f(i,j)
- **Step2.3** Calculate avg=s/24
- **Step2.4** Set p=0 and for each pixel in that 5×5 mask except the center pixel Increase p by 1 if the pixel has a difference of intensity with (i,j)th pixel less than or equal to 15.
- **Step2.5** if abs(f(i,j)-avg)<=120 && p>=9 then f(i,j)=255; f(i,j)=0; Otherwise

B. Noise Detection

Noise reduction is one of the most important aspects in order to improve image quality. There exist different types of noises (Speckle noise, Gaussian noise, Impulsive noise etc), which damage image quality. This technique is limited only on impulsive noise (or Salt and pepper noise) reduction from binary images (or edge map of a gray scale image). In this paper our approach is greedy one, which is we consider a spoiled pixel (noise) and replace it with the pixel value of its surrounding 4 or 3 neighbors.

Suppose there is a white point in a black background. So, check for its neighbor's pixel value, if all of its 4 neighbor's pixel value is 0 then we also place a 0 on the white point (255). This approach is simply the vice-versa in case of a black pixel in a white background.

If the input image contains much more noise, then both 4 and 3 neighboring pixel values can be considered.

Algorithm:

Step1. Take a binary image f(M,N)

Step2. For all pixel p ϵ f(M,N) do

- **Step2.1** If a pixel pi(f(i,j)) ϵ f(M,N) is black , then check its neighbor pixel pj, where pj ϵ {f(i,j-1),f(i,j+1),f(i-1,j),f(i+1,j)}
  - **Step2.1.1** If all 4 (or 3) neighbors are white, then make the considered point pi is white;
  - **Step2.1.2** Otherwise do nothing;
- **Step2.2** If the pixel pi(f(i,j)) is white, then check its neighbor pixel pj, where pj ϵ {f(i,j-1),f(i,j+1),f(i-1,j),f(i+1,j)}
  - **Step2.2.1** If all 4 (or 3) neighbors are black, then make the considered point pi is black;
  - **Step2.2.2** Otherwise do nothing;

This algorithm performs on some of the standard images. We considered both black and white points and also 4 and 3 neighboring pixels for checking.

IV. EXPERIMENTAL RESULTS

This algorithm developed has been simulated using MATLAB. The input images are considered to be .pgm images. The precision is assumed to be 8 i.e. the number of bits per pixel is 8. All the image files that we have tested are of different sizes.

Various evaluation techniques of edge map have been developed [3, 11]. Comparison of an edge map, obtained by a detector of edges [11], with its ground truth can be achieved through a set of direct measurements, such as the number of correctly detected edge pixels, called true positive (TP), the number of pixels erroneously classified as edge pixels, called false positive (FP), the amount of edge pixels that were not classified as edge pixel, called false negative (FN). From these measures, the following statistical indices have been proposed:

The percentage of pixels that were correctly detected (P_{CO}):

$$P_{co} = \frac{TP}{\max(N_I, N_B)} --------(1)$$

Where N_I represents the number of edge points of the ideal image and N_B the number of edge points detected. The percentage of pixels that were not detected (P_{nd}):

$$P_{nd} = \frac{FN}{\max(N_I, N_B)} --------(2)$$

The percentage of pixels that were erroneously detected as edge pixels, i.e. the percentage of false alarm (P_{fa}):

$$P_{fa} = \frac{FP}{\max(N_I, N_B)} --------(3)$$

The figure of merit of Pratt is another useful measure for assessing the performance of edge detectors. This measure uses the distance between all pairs of points corresponding to quantify, with precision, the difference between the contours [10]. The figure of merit of Pratt, which assesses the similarity between two contours, is defined as:

$$IMP = \frac{1}{\max(N_I, N_B)} \sum_{1}^{N_B} \frac{1}{1+\alpha \times d_i^2} ----(4),$$

Where N_I and N_B are the points of edges in the image and ground truth image, respectively, d_i is the distance between a edge pixel and the nearest edge pixel of the ground truth and α is a empirical calibration constant and was used α = 1/9, optimal value established by Pratt [10]. The figure of merit of Pratt IMP is an indicator of the quality of edge, and reflects the overall behavior of the distances between the edges, being a relative measure, which varies in the range [0,1], where 1 represents the optimal value, i.e., the edges detected coincide with the ground truth.

The values of statistical indices represented by the equations (1), (2) and (3) ranging between 0 and 1, and reach ideal values in case 1 for P_{CO} and 0 for indices P_{nd} and P_{fa}. From the combination of the indices defined by equations (1), (2) and (3), together with the index of merit of Pratt (equation 4), has proposed a new global index, which is defined by Euclidean distance (d^4_{f2}) in R^4 to the point P = (1; 1; 0; 0), where its coordinates are optimum values achieved by indices P_{CO}, IMP, P_{nd} and P_{fa} respectively. The point P represents the optimum point to be reached by an ideal edge detector. The distance to this point can be calculated by the equation (5):

$$d^4_{f2} = \sqrt{(P_{co}-1)^2 + (IMP-1)^2 + P_{nd}^2 + P_{fa}^2} \quad ---(5)$$

The distance defined d^4_{f2} varies between 0 and 2, where the value 0 represents the perfect fit for this measure, i.e., the best edge detector among several detectors will minimize this distance.

This proposed method gives the better result comparison with Roberts, Prewitt and Sobel operator are shown in TABLE I –TABLE VIII for different images.

The proposed algorithm has been applied to well known natural images such as Lena, MRI and peppers etc. Figure1 are shown the some output images using this proposed edge detection method.

TABLE I. QUANTITATIVE MEASURES OBTAINED BY EDGE DETECTORS FOR LENA IMAGE

	Proposed	Sobel	Roberts	Prewitt
IMP	0.8484	0.3406	0.3271	0.3383
FP	30935	1784	3172	1722
FN	8870	13186	14662	13171
TP	8715	4399	2923	4414
P_{nd}	0.7802	0.1015	0.1804	0.0979
P_{co}	0.2198	0.2502	0.1662	0.2510
P_{fa}	0.2237	0.7498	0.8338	0.7490
d^4_{f2}	1.1360	1.2529	1.3696	1.2528

TABLE II. QUANTITATIVE MEASURES OBTAINED BY EDGE DETECTORS FOR WEEL IMAGE

	Proposed	Roberts	Prewitt	Sobel
IMP	0.7945	0.2889	0.2325	0.2329
FP	28570	1870	799	791
FN	9366	13284	13248	13234
TP	6958	3040	3076	3090
P_{nd}	0.8042	0.1146	0.0489	0.0485
P_{co}	0.1958	0.1862	0.1884	0.1893
P_{fa}	0.2636	0.8138	0.8116	0.8107
d^4_{f2}	1.1854	1.3576	1.3816	1.3803

TABLE III. QUANTITATIVE MEASURES OBTAINED BY EDGE DETECTORS FOR PEPPERS IMAGE

	Proposed	Roberts	Prewitt	Sobel
IMP	0.8176	0.3328	0.3297	0.3307
FP	32780	3585	2005	2076
FN	9520	15192	13848	13891
TP	8530	2858	4202	4159
P_{nd}	0.7935	0.1986	0.1111	0.1150
P_{co}	0.2065	0.1583	0.2328	0.2304
P_{fa}	0.2305	0.8417	0.7672	0.7696
d^4_{f2}	1.1600	1.3789	1.2802	1.2829

TABLE IV. QUANTITATIVE MEASURES OBTAINED BY EDGE DETECTORS FOR PARROT IMAGE

	Proposed	Roberts	Prewitt	Sobel
IMP	0.8278	0.3312	0.4023	0.4073
FP	32904	3970	3040	3215
FN	9361	15616	13477	13533
TP	8813	2558	4697	4641
P_{nd}	0.7887	0.2184	0.1673	0.1769
P_{co}	0.2113	0.1408	0.2584	0.2554
P_{fa}	0.2244	0.8592	0.7416	0.7446
d^4_{f2}	1.1508	1.4041	1.2186	1.2213

TABLE V. QUANTITATIVE MEASURES OBTAINED BY EDGE DETECTORS FOR ZELDA IMAGE

	Proposed	Roberts	Prewitt	Sobel
IMP	0.8212	0.2752	0.3494	0.3499
FP	24563	3681	3353	3366
FN	14919	18750	16872	16872
TP	6573	2742	4620	4620
P_{nd}	0.7889	0.1713	0.1560	0.1566
P_{co}	0.2111	0.1276	0.2150	0.2150
P_{fa}	0.4792	0.8724	0.7850	0.7850
d^4_{f2}	1.2273	1.4411	1.2962	1.2960

TABLE VI. QUANTITATIVE MEASURES OBTAINED BY EDGE DETECTORS FOR TOOL IMAGE

	Proposed	Roberts	Prewitt	Sobel
IMP	0.7755	0.2087	0.2185	0.2183
FP	23848	2385	935	940
FN	15176	19535	18020	18028
TP	6806	2447	3962	3954
P_{nd}	0.7780	0.1085	0.0425	0.0428
P_{co}	0.2220	0.1113	0.1802	0.1799
P_{fa}	0.4951	0.8887	0.8198	0.8201
d^4_{f2}	1.2272	1.4891	1.3988	1.3993

TABLE VII. QUANTITATIVE MEASURES OBTAINED BY EDGE DETECTORS FOR MRI IMAGE

	Proposed	Roberts	Prewitt	Sobel
IMP	0.7899	0.2231	0.1937	0.1922
FP	20978	1871	804	805
FN	10025	13448	12939	12962
TP	5132	1709	2218	2195
P_{nd}	0.8034	0.1234	0.0530	0.0531
P_{co}	0.1966	0.1128	0.1463	0.1448
P_{fa}	0.3840	0.8872	0.8537	0.8552
d^4_{f2}	1.2176	1.4809	1.4527	1.4553

V. CONCLUSIONS

A novel approach to image processing utilizing edge detection and reduced the noise within images has been introduced within this paper. This approach gives the better results than the classical edge detection techniques. In future this technique will be applied in colour images. The hypothesis, on which, this work was based, was shown to be mathematically feasible.

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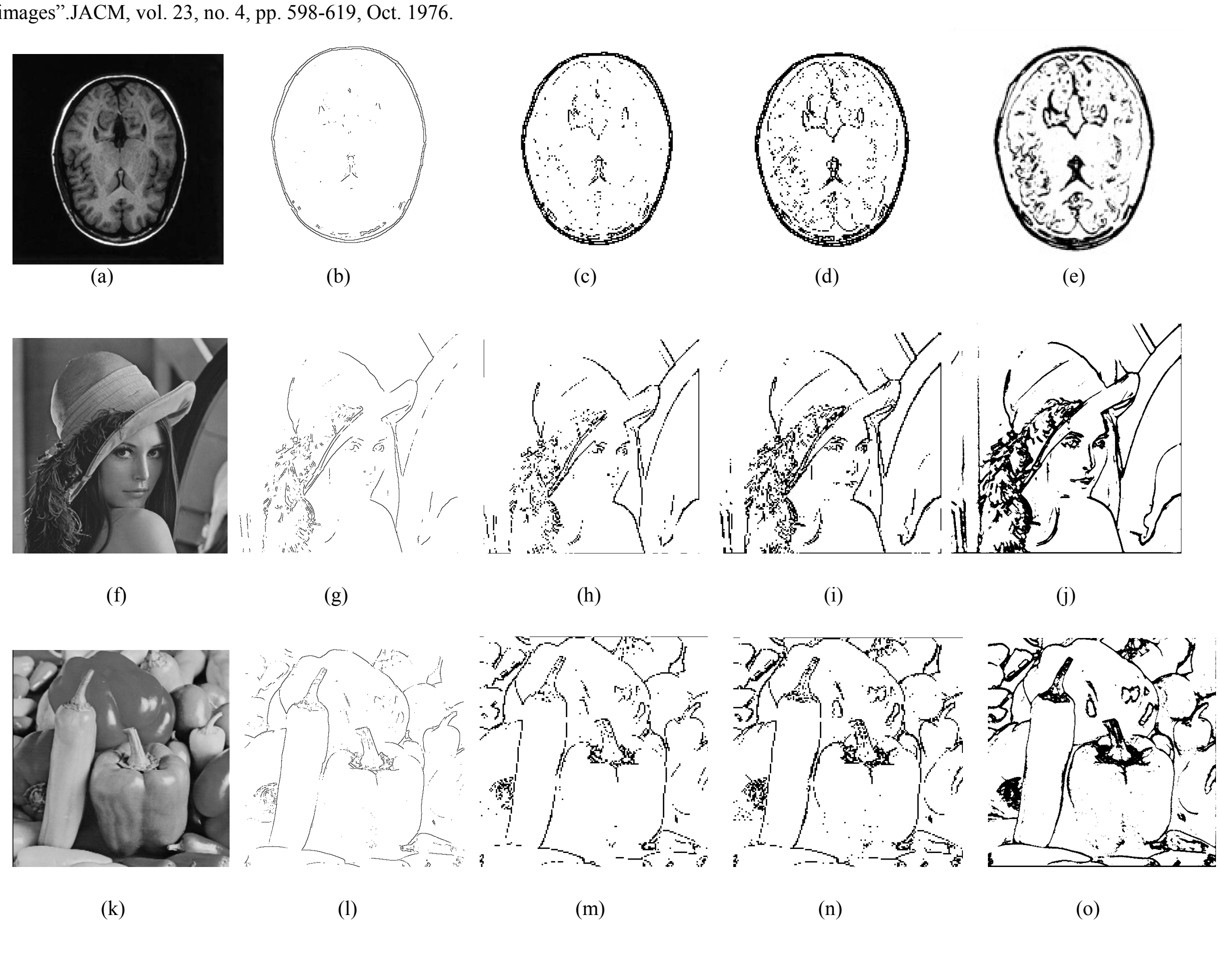

Figure 1: Experimental results for some well known images: (a),(f),(k)-Original Image, (b),(g),(l)- Edge detection using Robert operator, (c),(h),(m)- Edge detection using Prewitt operator, (d),(i),(n)- Edge detection using Sobel operator,(e),(j),(o)- Edge detection using Proposed method.