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PERFORMANCE AND ANALYSIS OF DIRECTIONAL EDGEDETECTORS ON 3-PLANAR IMAGES CORRUPTED WITH IMPULSIVE NOISE

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Abstract -
Edge detection is a research field within Image processing and Computer vision, in particular within the area of feature extraction. It is extensively used in image segmentation when we want to divide the image into areas corresponding to different objects. Representing an image by its edges has the further advantage that the amount of data is reduced significantly while retaining most of the image information. In this paper edge detection from the application of various 1-directional as well as 8-directional masks or edge detection operators on the images corrupted with different levels of Impulsive noise is presented. Further, 1-Dimensional operators: Kirsch, Prewitt, Sobel and Robinson used for edge detection are applied on RGB (3-planar) images. Subjective and Objective methods are used to evaluate the different edge operators. Results show that 8-directional operators give better performance than 1-directional operators in presence of impulsive noise, which implies as number of orientations increases we get better results and effect of noise decreases.

Keywords: *Edge detection, image processing, impulsive noise, 3-planar image.*

I. INTRODUCTION

Detecting edges is a basic operation in image processing. The edges of items in an image hold much of the information in the image. In an image, an edge usually corresponds to the boundaries between different regions and reflects a discontinuity of a local image characteristic, for example, a break from the gray-value and an abrupt change in the color, and so on. Edge is the basic feature of images, which preserves most information about the shapes of objects in a scene. Edge detection can not only extract useful structural information about object boundaries but also drastically reduce the amount of data to be processed; so many algorithms about image processing and recognition are based on edge detection. Both an edge point and a noise point are a discontinuity of a local property in an image, but the difference of them is that an edge takes on the edge attributive character with the order, the direction and the structure more than a noise [1]. The edges tell you Where items are, their size, shape, and something about their texture. An edge is where the intensity of the image moves from an area of low values to high values or vice versa. The edge itself is at the centre of this transition. The detected edge gives a bright spot at the edge and dark areas everywhere else. This means it is the slope or rate of change of the intensities. The slope of the edge is always positive or zero and it reaches its maximum at the edge. For this reason, edge detection is often called image differentiation.

With respect to gray-scale pictures, color images generally include richer measurement information that can be successfully exploited in order to improve the performance of image based instrumentation and/or extend its application range [2]. Edge detection in gray-level images is a well-established area, while edge detection in color images has not received the same attention. The fundamental difference between color images and gray-level images is that, in a color image, a color vector (which generally consists of three components) is assigned to a pixel, while a scalar gray-level is assigned to a pixel of a gray-level image. Thus, in color image processing, vector-valued image functions are treated instead of scalar image functions (as in gray-level image processing). Color edge operators are able to detect more edges than gray-level edge operators. Thus, additional features can be obtained in color images that may not be detected in gray-level images [3] [4].In this framework, edge detection plays a very relevant role in the realization of a complete image understanding system.

In this paper edge detection on 3-planes of a colored image i.e. on Red, Green and Blue planes of an image has been presented by taking in to account 1-directional as well as 8-directional orientation of various operators. The proposed work makes use of four 1-Dimensional operators namely Kirsch, Prewitt, Sobel and Robinson. The edge detection has been performed in the presence of different levels of impulsive noise. In order to further increase the accuracy of results four levels of corruption has been considered namely, 20%, 40%, 60% and 90%. For analysis PSNR (Peak signal to noise ratio) is taken as objective parameter and subjective study of the resultant image has also been considered. The analysis which is being done in this paper is helpful in various domains where RGB color space is not required instead we can consider single plane with much prominent results. This saves memory and processing can be done at much higher speed. Further, on different planes the effect of 1-Directional and 8-Directional operators has been studied.

II. THE APPROACH

Our approach is to consider a particular image in its 3-planes (red, green and blue) and then convolve it in all the three respective planes.Further,corrupt the image in all the three planes with four different levels of impulsive noise and hence convolve them.Finally,PSNR is calculated between original convolved image and corrupted convolved image in all the three planes. This work is being done for four different edge detectors considering their one orientation as well as eight orientation i.e 1-Directional masks as well as 8-Directional masks.

2.1 Convolution

The problem in edge detection is how to calculate the derivative (the slope) of an image in all directions? Convolution [5] of the image with masks is the most often used technique of doing this. Convolution is a simple mathematical operation which is fundamental to many common image processing operators. Convolution provides a way of multiplying together' two arrays of numbers, generally of different sizes, but of the same dimensionality, to produce a third array of numbers of the same dimensionality. An article by Wesley Faler in the C Users Journal discussed this technique. The idea is to take a n x n array of numbers (mask) and multiply it point by point with a n x n section of the image. Then sum the products and place the result in the centre point of the image. The purposed work has been done by using 1-Dimensional edge detectors namely Kirsch, Prewitt, Robinson and Sobel which are known as compass gradient or directional edge detectors. This means that each of the eight masks detects an edge in one direction. Given a pixel, there are eight directions to travel to an adjacent pixel (above, below, left, right, upper left, upper right, lower left, and lower right). Therefore, there are eight possible directions for an edge. The directional edge detectors can detect an edge in only one of the eight directions. To detect only left to right edges, use only one of the eight masks. To detect all of the edges, perform convolution over an image eight times using each of the eight masks.

I_{11}	I_{12}	I_{13}	I_{14}	I_{15}	I_{16}	I_{17}	I_{18}	I_{19}
I_{21}	I_{22}	I_{23}	I_{24}	I_{25}	I_{26}	I_{27}	I_{28}	I_{29}
I_{31}	I_{32}	I_{33}	I_{34}	I_{35}	I_{36}	I_{37}	I_{38}	I_{39}
I_{41}	I_{42}	I_{43}	I_{44}	I_{45}	I_{46}	I_{47}	I_{48}	I_{49}
I_{51}	I_{52}	I_{53}	I_{54}	I_{55}	I_{56}	I_{57}	I_{58}	I_{59}
I_{61}	I_{62}	I_{63}	I_{64}	I_{65}	I_{66}	I_{67}	I_{68}	I_{69}

K_{11}	K_{12}	K_{13}
K_{21}	K_{22}	K_{21}

An example image intensities (up) and mask (down) for illustrating convolution. The labels within each grid square are used to identify each square.

The convolution is performed by sliding the mask over the image, generally starting at the top left corner, so as to move the mask through all the positions where the mask fits entirely within the boundaries of the image. Each mask position corresponds to a single output pixel, the value of which is calculated by multiplying together the mask value and the underlying image pixel value for each of the cells in the mask, and then adding all these numbers together. So in our example, the value of the bottom right pixel in the output image will be given by:

$$O_{57} = I_{57}K_{11} + I_{58}K_{12} + I_{59}K_{13} + I_{67}K_{21} + I_{68}K_{22} + I_{69}K_{23}$$

If the image has *M* rows and *N* columns, and the mask has *m* rows and *n* columns, then the size of the output image will have *M*-*m*+1 rows, and *N*-*n*+1 columns. Mathematically we can write the convolution as:

$$o(i, j) = \sum_{k=1}^{m} \sum_{l=1}^{n} I(i + k - 1, j + l - 1)K(k, l)$$

Where *i* runs from 1 to *M*-*m*+1 and *j* runs from 1 to *N*-*n*+1.

2.2 Impulsive Noise Model

The Salt and Pepper (SP) noise is also called as fixed valued impulse noise will take a gray level value either minimal (0) or maximal (255) (for 8-bit monochrome image) in the dynamic range (0-255). It

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is generated with the equal probability. In the case of salt and pepper noise, the image pixels are randomly corrupted by either 0 or 255[6]. That is, for each image pixel at location (*i*, *j*) with intensity value *Oi*, *j*, the corresponding pixel of the noisy image will be *Xi*, *j*, in which the probability density function of *Xi*, *j* is:

$$p(x) = \begin{cases} p/2 & \text{for } x = 0 \\ 1-p & \text{for } x = O_{i,j} \\ p/2 & \text{for } x = 255 \end{cases}$$

2.3 Edge Detectors

Various Kirsch, Prewitt[7], Robinson and Sobel[8] masks are used for edge detection. They are also known as compass edge detectors or differential gradient edge detectors. The whole set of 8 masks is produced by taking one of the masks and rotating its coefficients circularly. Each of the resulting masks is sensitive to an edge orientation ranging from 0° to 315° in steps of 45°, where 0° corresponds to a vertical edge. The compass edge detector is an appropriate way to estimate the magnitude and orientation of an edge. Whereas differential gradient edge detection needs a rather time-consuming calculation to estimate the orientation from the magnitudes in x- and y-direction, the compass edge detection obtains the orientation directly from the mask with the maximum response. The compass operator is limited to (here) 8 possible orientations; however experience shows that most direct orientation estimates are not much more accurate. On the other hand, the compass operator needs (here) 8 convolutions for each pixel, whereas the gradient operator needs only 2, one mask being sensitive to edges in the vertical direction and one to the horizontal direction.

-1	+1	+1
-1	-2	+1
-1	+1	+1

0°

+1	+1	+1
-1	-2	+1
-1	-1	+1

45°

Two prewitt mask templates out of the set of *8* are shown below which are sensitive to *0°* and *45°*:

Figure 1: Prewitt mask templates sensitive to *0°* and *45°*.

Similarly, for other edge detectors two templates out of the set of 8 are shown below:

Sobel

0°

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

45°

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

Kirsch

-3	-3	5
-3	0	5
-3	-3	5

-3	5	5
-3	0	5
-3	-3	-3

Robinson

-1	0	1
-1	0	1
-1	0	1

0	1	1
-1	0	1
-1	-1	0

Figure 2: Examples of the most common compass edge detecting masks, each example showing two masks out of the set of eight.

III. RESULTS AND ANALYSIS

In this section 3-planar (RGB) images are taken then we have corrupted them with different percetages of Impulsive noise. Lena and Baboon (512*512) are the standard images that are chosen for demonstration. Further images in different planes without the corruption of noise as well as with corruption of impulsive noise are used for edge detection (using 1-directional as well as 8-directional Kirsch, Prewitt, Sobel and Robinson edge detectors). Noisy versions of these images are used with different percentages of 20%, 40%, 60% and 90%.The performance evaluation is objectively quantified by the PSNR (peak signal to noise ratio) computed using following formula:

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right)$$

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[I(i,j) - I'(i,j)]^2$$

Where M and N are the total number of pixels in the horizontal and the vertical dimensions of the image, *I* and *I'* denote the original and noised image, respectively while MSE denote Mean Square Error. PSNR readings have been taken for edge detectors in 1-direction and 8-directions for all the three planes with impulsive noise corruption of 20%, 40%, 60% and 90%. The PSNR performance of sobel for leena image is plotted in fig.3 for 1-direction and in fig. 4 for 8-directions.The Common pattern that has been analyzed by plotting such graphs for all four edge detectors is that in case of 1-directional operators there is steep variation in comparison to 8-directional operators. There is very less variation or almost constant PSNR in 8-directional operators after 40% of impulsive corruption. In fig.5 and fig.6 some of the test images, noisy images and their corresponding convolved images are shown for different edge detectors.

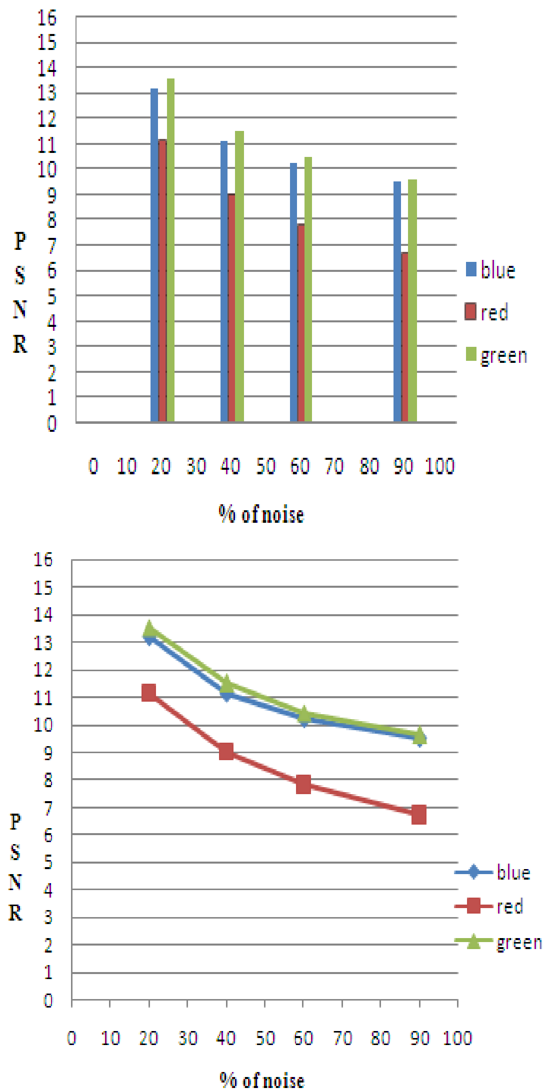


Figure 3: PSNR Plot of Sobel (1-direction) for Lena image corrupted with different noise density.

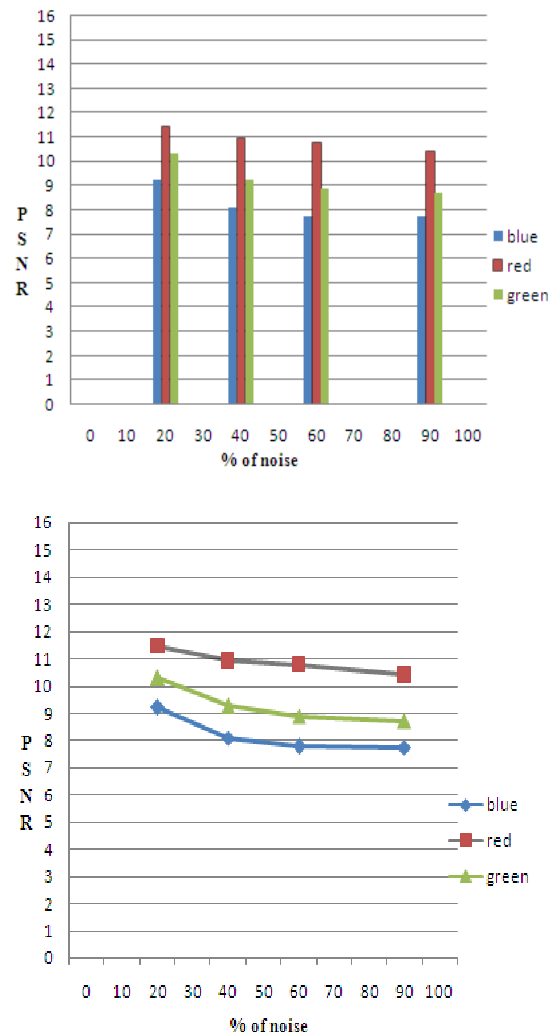
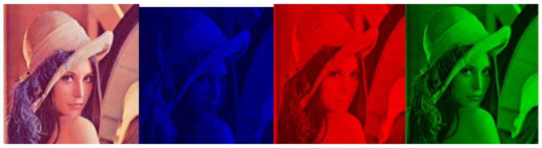


Figure 4: PSNR Plot of Sobel (8-directions) for Lena image corrupted with different noise density.



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

(e) (f) (g) (h)

(i) (j) (k)
(l)

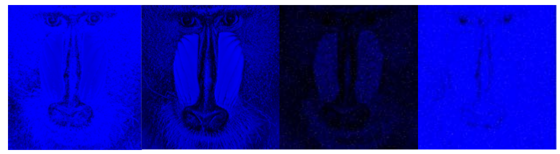
(m) (n)

Figure 5: (a) Original Leena image (b) Blue plane (c) Red plane (d) Green plane (e) Sobel in 8-directions on blue plane (f) Sobel in 1-direction on blue plane (g) Impulsive noised blue planar image (90%) (h) Sobel in 8-directions on noised blue plane (i) Sobel in 1-direction on noised blue plane (j) Robinson in 8-directions on red plane (k) Robinson in 1-direction on red plane (l) Impulsive noised red planar image (90%) (m) Robinson in 8-directions on noised red image (n) Robinson in 1-direction on noised red image

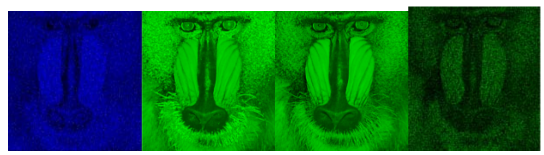
In Subjective analysis scoring of the noised edge detected images (in 1-direction as well in 8-directions) is being done in terms of the effect of noise on connectivity of the edges detected and their number as well.

In Table 1 and Table 2 Subjective analysis of corrupted Leena image for Sobel operator in 1-direction as well as 8-directions are shown.

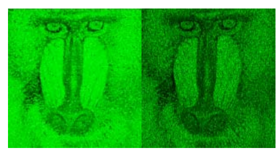
(a) (b) (c)
(d)



(e) (f) (g) (h)



(i) (j) (k)
(l)



(m) (n)

Figure 6: (a) Original Baboon image (b) Blue plane (c) Red plane (d) Green plane (e) Kirsch in 8-directions on blue plane (f) Kirch in 1-direction on blue plane (g) Impulsive noised blue planar image (90%) (h) Kirsch in 8-directions on noised blue plane (i) Kirsch in 1-direction on noised blue plane (j) Prewitt in 8-directions on green plane (k) Prewitt in 1-direction on green plane (l) Impulsive noised green planar image (90%) (m) Prewitt in 8-directions on noised green image (n) Prewitt in 1-direction on noised green image.

The Subjective fidelity scoring scales are:

1-Connectivity

2-Connectivity with annoyance

3-Discontinuity

4-Discontinuity with annoyance

5-Not usable

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SUBJECTS	IMPULSIVE NOISE	Sobel
Subject1	20%(Blue)	3
	40%	4
	60%	4
	90%	5
	20%(Green)	3
	40%	4
	60%	4
	90%	5
	20%(Red)	3
	40%	4
	60%	4
	90%	5
Subject2	20%(Blue)	3
	40%	4
	60%	5
	90%	5
	20%(Green)	3
	40%	3
	60%	4
	90%	5
	20%(Red)	3
	40%	4
	60%	5
	90%	5

Table 1: For 1-Direction Sobel of Leena image

SUBJECTS	IMPULSIVE NOISE	Sobel
Subject1	20%(Blue)	1
	40%	2
	60%	2
	90%	2
	20%(Green)	2
	40%	2
	60%	4
	90%	4
	20%(Red)	3
	40%	4
	60%	4
	90%	4
Subject2	20%(Blue)	2
	40%	2
	60%	2
	90%	2
	20%(Green)	2
	40%	4
	60%	4
	90%	4
	20%(Red)	3
	40%	3
	60%	4
	90%	4

Table 2: For 8-Directions Sobel of Leena image

Table 1. Subjective analysi

IV. CONCLUSION

To demonstrate the performance of 1-directional and 8-directional operators on 3-planar images in presence of impulsive noise subjective and objective analysis have been conducted on two standard test images. Subjective and Objective analysis indicate that value of PSNR decreases as the level of corruption increases in both 8-directional operators as well as 1-directional operators. Further, 8-directional operators provide significantly better results than 1-directional operators on 3-planar images.So,as the number of orientations of a mask increases probability of getting efficient results also increases.

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