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Effect of Impulsive Noise on Edge Detectors for RGB Planar Images

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Abstract—Edge detection is considered to be fundamental step in the field of image processing and computer vision, particularly in the areas of feature detection and feature extraction. Detecting edges is a basic operation in image processing because an edge in an image usually refers to the boundaries between different regions and reflects a break in the continuation of any image characteristic. The purpose of this paper is convoluting original images (512x512) with the various edge detectors in presence of impulsive noise and analyse the results on the RGB planes distinctively to look for their performances in terms of PSNR as an objective parameter.

Keywords: Edge Detection, Edge detection operators, Impulsive Noise, Convolution, RGB planes.

I. Introduction

Digital image processing is defined as the use of computer algorithms to perform different kinds of processing on digital images.

Image **processing** is defined as a technique where data is collected from an image and converted into digitized form and various image processing related algorithms and operators are applied to the data, generally with the use of a digital computer, in order to create an enhanced image that is more useful or pleasing to a human observer. It is also known as picture processing [7].

Various techniques have been developed in Image Processing during the last four to five decades. Most of the techniques are developed for enhancing images obtained from unmanned spacecrafts, space probes and military reconnaissance flights.

Image Processing is used in various applications such as: Remote Sensing, Medical Imaging, Non-destructive Evaluation, Forensic Studies Textiles, Material Science, Military, Film industry, Document processing, Graphic arts, Printing Industry.

A. Methods of Image Processing

Analog image processing: here the image is enhanced through electrical signals.

Digital image processing: Here digital computers are used to enhance the image. An image is enhanced using computer algorithms.

Image Segmentation: The goal of segmentation is to simplify and/or change the representation of an image like transformation to grayscale, gradient that is more meaningful and easier to analyze.

B. Edge Detection

Edge detection is considered to be an important step in image processing. It could be defined as detecting the edges in an image rather than objects. Efficient detection of edges would lead ultimately to accurate isolation of objects in an image.

Edge detection not only extracts structural information of objects in an image but also reduces the data to be processed. The main aim of the edge detection is to mark the points of abrupt discontinuity in intensity of pixels. Noise also corresponds to the same definition but the difference comes when edge takes on edge characteristic in order along with its direction and structure.

Sharp changes in image properties usually reflect important events and changes in properties of the world. These include:

a) Discontinuities in depth,
b) Discontinuities in surface orientation,
c) Changes in material properties and
d) Variations in scene illumination.

Edge detection in colored images has not gained much attention as in grayscale images. 10% more edges can be detected in colored images due to change in color. In colored images, color vector is assigned to each pixel because color component comprises of three color values.

C. Convolution

Convolution is defined as the calculation of derivative of an image in all the directions. 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.

Steps of Convolution:

(1) For each pixel in the input image, the mask is conceptually placed on top of the image with its origin lying on that pixel.

(2) The values of each input image pixel under the mask are multiplied by the values of the corresponding mask weights.

(3) The results are summed together to yield a single output value that is placed in the output image at the location of the pixel being processed on the input.

The convolution is performed by sliding the kernel over the image, generally starting at the top left corner, so as to move the kernel through all the positions where the kernel fits entirely within the boundaries of the image.

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

$$\begin{matrix} K_{11} & K_{12} & K_{13} \\ K_{21} & K_{22} & K_{21} \end{matrix}$$

Fig1: Input and convolution mask

The value of the bottom right pixel in the output image will be given by:

$$O_{57} = I_{57}K_{11} + I_{58}K_{12} + I_{59}K_{13} + I_{67}K_{21} + I_{68}K_{22} + I_{69}K_{23} \quad (1)$$

If the image has *M* rows and *N* columns, and the kernel 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:

$$O(i,j) = \sum_{k=1}^{m}\sum_{l=1}^{n} I(i+k-1, j+l-1)K(k,l) \quad (2)$$

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

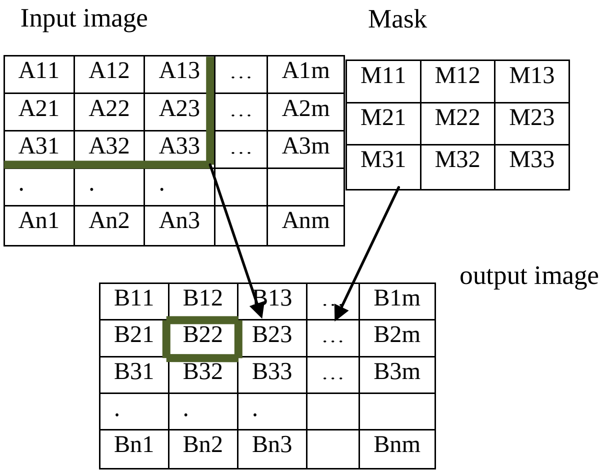

Fig2: How convolution is performed

B22 = (A11*M11) + (A12*M12) + (A13*M13) + (A21*M21) + (A22*M22) + (A23*M23) +(A31*M31) + (A32*M32)

+ (A33*M33)

D. Impulsive Noise

This type of noise is also caused by errors in data transmission and is a special case of data dropout noise when in some cases single, single pixels are set alternatively to zero or to the maximum value, giving the image a salt and pepper like appearance[10].Unaffected pixels always remain unchanged. The noise is usually quantified by the percentage of pixels which are corrupted.

This impulsive noise is also called salt and pepper noise taking intensity value minimum as 0 and maximum as 255 in the range (0-255).

For each image pixel at location (*i*, *j*) with intensity value $O_{i,j}$, the corresponding pixel of the noisy image will be $X_{i,j}$, in which the probability density function of $X_{i,j}$ is

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

II. Edge Detectors

Several masks are used for edge detection. The four such masks are the Kirsch, Prewitt, Robinson and Sobel masks. These are known as compass gradient or directional edge detectors. Firstly the whole set of 8 masks is produced using rotations of 45^0 till 315. Every edge detector has its own advantages and disadvantages. Edge detection is based on either first order derivative or second order derivative. In case of first order differentials the criterion used is a search-based approach where local maxima of the gradient magnitude is calculated. Various masks have been proposed, few of them have been discussed here.

A. Sobel operator

One of the operator used for convolution is Sobel operator. The Sobel operator is as a mask for performing convolution in edge detection algorithms. Technically, it is a discrete differentiation operator. It calculates the opposite of the gradient of the image intensity at each point, giving the direction of the largest possible change from light to dark. The value shows the change in intensity value whether it be abrupt or smooth and therefore represents how likely it is a part of an edge and its orientation.

Mathematically, the gradient of a two-variable function is at each image point a 2D vector with the components given by the derivatives in the horizontal and vertical directions. At each image point, the gradient vector points in the direction of largest possible intensity increase. This implies that the result of the Sobel operator at an image point if at a region of constant image intensity is a zero vector and if it is at a point on an edge is a vector which points across the edge, from brighter to darker values.

$$S1 = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad S2 = \begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix} \quad S3 = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \quad S4 = \begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{bmatrix}$$

$$S5 = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad S6 = \begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix} \quad S7 = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad S8 = \begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$$

Fig3:Sobel Mask

B. Prewitt operator

The idea behind using the Prewitt operator is that it in digital images it is necessary to locate the sharp intensity transition points. During Prewitt edge detection the image is convolved with the 8-directional masks. For each pixel the local edge gradient *magnitude* is estimated with the maximum response of all *8* kernels at this pixel location:

$$|G| = \max(|G_i|: i=1 \text{ to } n) \qquad (1)$$

Where G_i is the response of the kernel *i* at the particular pixel position and *n* is the number of convolution kernels. The local edge orientation is estimated with the orientation of the kernel that yields the maximum response. Various kernels can be used for this operation. [15].

Total of 8 masks are produced by rotating the 3X 3 matrix around the center pixel at location (i, j) of the matrix. Each of the 8 orientations is obtained by rotating at an angle of 45^0 at a time till 315^0.

$$y1=\begin{bmatrix}-1 & -1 & -1\\ 0 & 0 & 0\\ 1 & 1 & 1\end{bmatrix} y2=\begin{bmatrix}0 & -1 & -1\\ 1 & 0 & -1\\ 1 & 1 & 0\end{bmatrix} \quad y3=\begin{bmatrix}1 & 0 & -1\\ 1 & 0 & -1\\ 1 & 0 & -1\end{bmatrix} \quad y4=\begin{bmatrix}1 & 1 & 0\\ 1 & 0 & -1\\ 0 & -1 & -1\end{bmatrix}$$

$$y5=\begin{bmatrix}1 & 1 & 1\\ 0 & 0 & 0\\ -1 & -1 & -1\end{bmatrix} y6=\begin{bmatrix}0 & 1 & 1\\ -1 & 0 & 1\\ -1 & -1 & 0\end{bmatrix} \quad y7=\begin{bmatrix}-1 & 0 & 1\\ -1 & 0 & 1\\ -1 & 0 & 1\end{bmatrix} \quad y8=\begin{bmatrix}-1 & -1 & 0\\ -1 & 0 & 1\\ 0 & 1 & 1\end{bmatrix}$$

After the calculation of magnitudes of first order derivative, the threshold needs to be calculated such that it should neither be too low nor too high for complete edge detection. If it is too low even the irrelevant features would also be picked out and if its too high subtle edge lines will be missed out. The output of the thresholding stage is extremely sensitive. The strengths of using Prewitt edge detector are that it is simple to implement, less computational cost as compared to other edge detectors. The mask of sufficiently larger size provides good smoothing operation and reduces noise to a good level. So, Prewitt edge detector is an appropriate way to estimate the magnitude and orientation of an edge.

C. Kirsch Operator

The Kirsch operator or Kirsch compass kernel is a non-linear edge detector that finds the maximum edge strength in a few predetermined directions.

The operator is calculated as follows for directions with 45° difference:

$$h_{n,m} = \max_{z=1,\ldots,8} \sum_{i=-1}^{1} \sum_{j=-1}^{1} g_{ij}^{(z)} \cdot f_{n+i,m+j}$$

where the direction kernels are as follows

$$K1=\begin{bmatrix}-3 & -3 & 5\\ -3 & 0 & 5\\ -3 & -3 & 5\end{bmatrix} \quad K2=\begin{bmatrix}-3 & 5 & 5\\ -3 & 0 & 5\\ -3 & -3 & -3\end{bmatrix} \quad K3=\begin{bmatrix}5 & 5 & 5\\ -3 & 0 & -3\\ -3 & -3 & -3\end{bmatrix} K4=\begin{bmatrix}5 & 5 & -3\\ 5 & 0 & -3\\ -3 & -3 & -3\end{bmatrix}$$

$$K5=\begin{bmatrix}5 & -3 & -3\\ 5 & 0 & -3\\ 5 & -3 & -3\end{bmatrix} \quad K6=\begin{bmatrix}-3 & -3 & -3\\ 5 & 0 & -3\\ 5 & 5 & -3\end{bmatrix} \quad K7=\begin{bmatrix}-3 & -3 & -3\\ -3 & 0 & -3\\ 5 & 5 & 5\end{bmatrix} \quad K8=\begin{bmatrix}-3 & -3 & 5\\ -3 & 0 & 5\\ -3 & 5 & 5\end{bmatrix}$$

D. Robinson Operator

The robinson edge detector is similar to sobel edge detector. Its row, column and corner masks are given as below:

$$R1=\begin{bmatrix}1 & 1 & 1\\ 1 & -2 & 1\\ -1 & -1 & -1\end{bmatrix} \quad R2=\begin{bmatrix}1 & 1 & 1\\ -1 & -2 & 1\\ -1 & -1 & 1\end{bmatrix} \quad R3=\begin{bmatrix}-1 & 1 & 1\\ -1 & -2 & 1\\ -1 & 1 & 1\end{bmatrix} \quad R4=\begin{bmatrix}-1 & -1 & 1\\ -1 & -2 & 1\\ 1 & 1 & 1\end{bmatrix}$$

$$R5=\begin{bmatrix}-1 & -1 & -1\\ 1 & -2 & 1\\ 1 & 1 & 1\end{bmatrix} R6=\begin{bmatrix}1 & -1 & -1\\ 1 & -2 & -1\\ 1 & 1 & 1\end{bmatrix} \quad R7=\begin{bmatrix}1 & 1 & -1\\ 1 & -2 & -1\\ 1 & 1 & -1\end{bmatrix} \quad R8=\begin{bmatrix}1 & 1 & 1\\ 1 & -2 & -1\\ 1 & -1 & -1\end{bmatrix}$$

It is symmetrical by the axis. The maximum value is found in the edge magnitude and the edge direction is defined by the edge magnitude.

E. General Algorithm for all the operators

1. Input to this algorithm is the 1 D 3-planar (Red, Green and Blue) image matrix(without noise as well as with noise, one at a time).

2. Convolution of the image matrix is done with the respective masks of the operator being used(whether it be Sobel, Prewitt, Kirsch, Robinson) which are already defined for all the eight directions. The sum of every mask is zero in this algorithm.
3. The resultant images which consist of the detected edges of the planar image are stored as the output images.
4. This is done for mask in 1-Direction as well as mask in 8 possible Directions.

F. Color Edge Detection

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 [3]. 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 [4] [5]. In color images, intensity, hue and saturation of a color all play a part in determining object boundaries. A physical boundary produces an edge which needs to be determined using a measure in an appropriate color space that would capture these different color characteristics. The concept of color similarity within the context of a color space becomes important since pixel intensities alone cannot be used to determine the existence of an edge. It is well known, however, that the generation of an accurate edge map becomes a very critical issue when the images are corrupted by noise [10] [11].

III. Results And Analysis

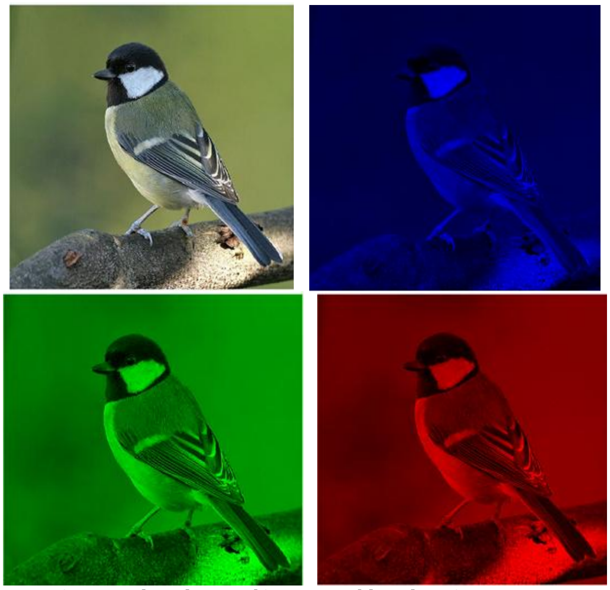

Fig1:a) Original Bird Image b) Image in blue planec) Image in Green plane d) Image in Red plane.

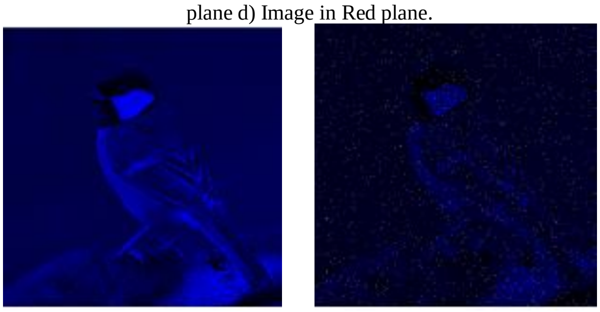

Fig2:a)edge detected using 1-d Sobel operator on Blue plane. b) Noised edge detected using 1-d Sobel operator on Blue plane in 90% noise.

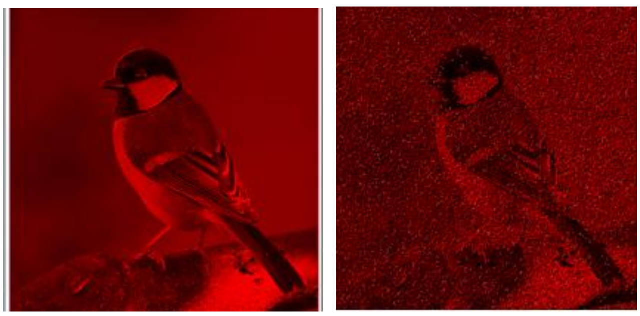

Fig3:a)Edge Detected using 1-D Prewitt Operator b) Noise Edge

Detected using Prewitt Operator

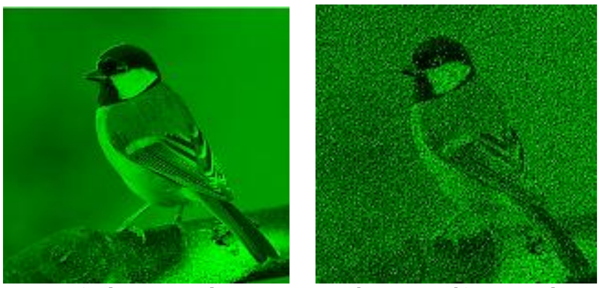

Fig 4:a)Edge Detected using 1-D Kirsch Operator b) Noise Edge Detected using 1-D Kirsch Operator in 90% noise.

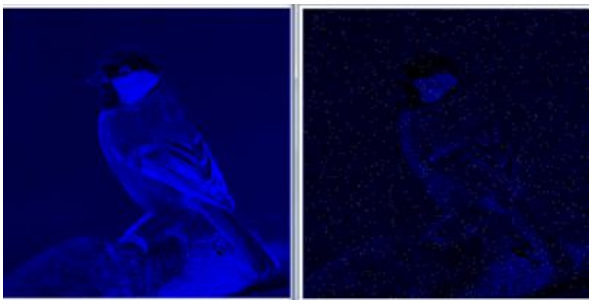

Fig 5:a)Edge Detected using 8-D Robinson Operator b)Noise Edge Detected using 8-D Robinson Operator at 75% noise level.

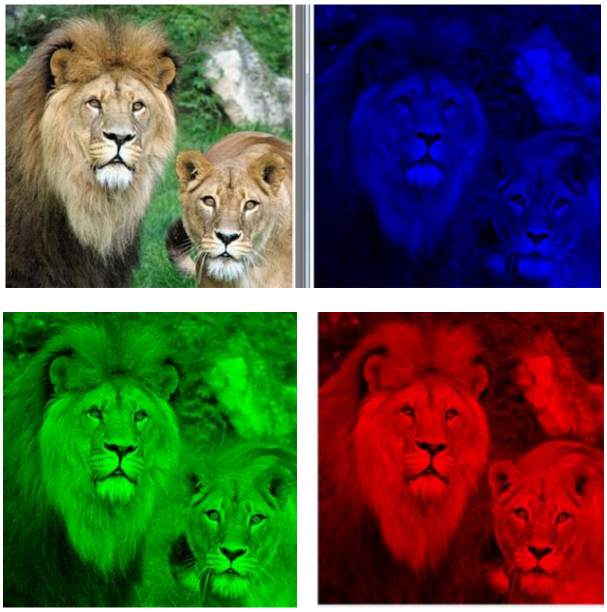

Fig 6:a) Original(512X512) Lion Image b)Lion image in Blue Plane c) Lion image in Green plane d) Lion image in Red plane

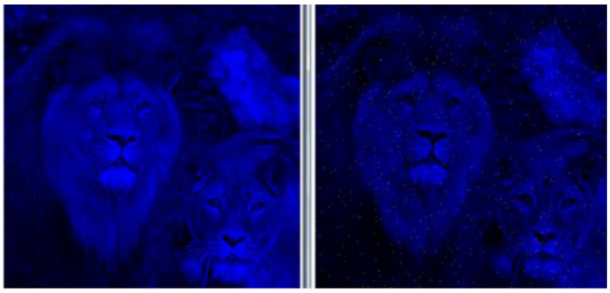

Fig 8: a)Edge Detected using 1-D Prewitt Operator b)Noise Edge Detected using 1-D Prewitt Operator at 50% noise.

Fig9:a)Edge Detected using 8-D Robinson Operator b) Noise Edge Detected using 8-D Robinson Operator at 50% noise level.

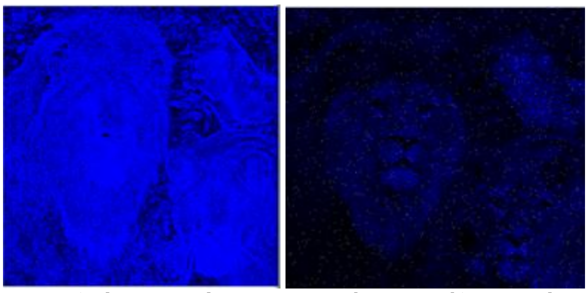

Fig10:a)Edge Detected using 8-D Kirsch Operator b) Noise Edge Detected using 8-d Kirsch Operator at 75% noise level.
Fig7:a)Edge Detected using1-D Sobel Operator b) Noise Edge Detected using 1-D Sobel Operator at 25% noise.

Table I: PSNR Values for 1-D Edge Detectors of Bird Image

		Blue	green	Red
SOBEL	25%	15.329	11.885	12.215
	50%	12.783	9.979	10.312
	75%	11.485	9.098	9.442
	90%	11.001	8.753	9.129
PREWITT	25%	14.542	13.000	13.536
	50%	12.293	10.732	11.246
	75%	11.075	9.667	10.183
	90%	10.600	9.253	9.775
KIRSCH	25%	11.634	9.143	9.033
	50%	10.091	8.045	7.958
	75%	9.183	7.595	7.502
	90%	8.812	7.361	7.297
ROBINSON	25%	14.104	13.801	13.868
	50%	11.996	11.418	11.629
	75%	10.854	10.274	10.536
	90%	10.383	9.806	10.105

Table II: PSNR Values for 8-D Edge Detectors of Bird Image

		Blue	Green	Red
Sobel	25%	11.791	8.918	8.907
	50%	10.199	8.262	8.096
	75%	9.289	8.085	7.917
	90%	8.893	8.042	7.872
Prewitt	25%	12.973	12.011	12.217
	50%	11.20	10.388	10.471
	75%	10.092	10.031	10.084
	90%	9.667	9.997	10.060
Kirsch	25%	7.924	8.022	7.386
	50%	6.905	7.536	6.837
	75%	6.252	7.474	6.741
	90%	5.952	7.433	6.705
Robinson	25%	12.256	10.824	10.617
	50%	10.605	9.305	9.023
	75%	9.664	8.977	8.674
	90%	9.244	8.969	8.677

Table III: PSNR Values for 1-D Edge Detectors of Lion Image

		Blue	Green	Red
SOBEL	25%	12.848	11.836	11.932
	50%	10.617	9.844	9.903
	75%	9.412	8.857	8.846
	90%	8.940	8.454	8.426
PREWITT	25%	13.337	12.651	12.576
	50%	10.941	10.371	10.316
	75%	9.724	9.237	9.177
	90%	9.205	8.791	8.608
KIRSCH	25%	9.268	9.563	9.529
	50%	7.873	8.103	8.038
	75%	7.032	7.436	7.326
	90%	6.670	7.133	7.015
ROBINSON	25%	13.199	14.269	14.668
	50%	10.877	11.616	11.817
	75%	9.615	10.284	10.348
	90%	9.130	9.754	9.724

Table IV: PSNR Values for 8-D Edge Detectors of Lion Image

		Blue	Green	Red
SOBEL	25%	10.923	9.938	10.703
	50%	9.168	9.245	9.900
	75%	8.165	9.061	9.661
	90%	7.767	8.991	9.550
PREWITT	25%	12.274	12.468	13.188
	50%	10.181	11.065	11.743
	75%	9.059	10.747	11.434
	90%	8.593	10.701	11.307
KIRSCH	25%	4.977	11.518	11.389
	50%	4.073	10.951	10.778
	75%	3.486	10.766	10.595
	90%	3.224	10.556	10.419

ROBINSON	25%	11.737	11.396	11.946
	50%	9.807	10.117	10.616
	75%	8.725	9.856	10.314
	90%	8.295	9.864	10.309

IV. GRAPH ANALYSIS

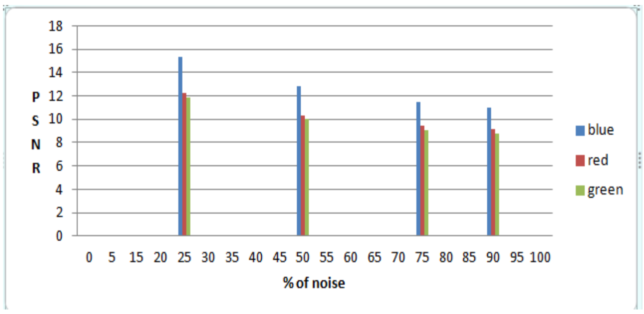

Fig11. PSNR Plot for 1-d Sobel Operator of Bird Image

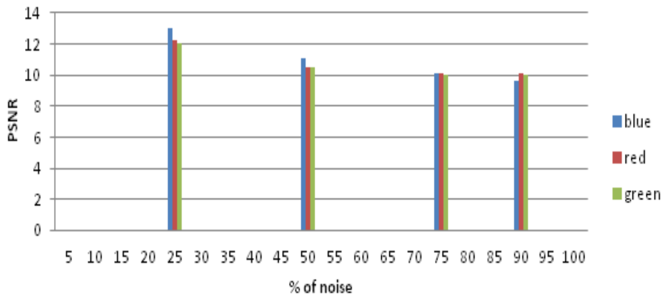

Fig12: PSNR Plot for 8-d Prewitt Operator of Bird Image

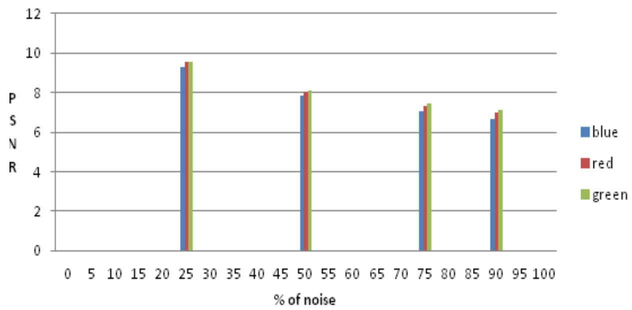

Fig13: PSNR Plot for 1-d Kirsch Operator of Lion Image

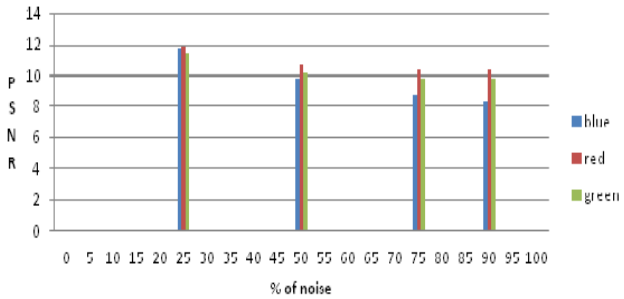

Fig14: PSNR Plot for 8-d Robinson Operator of Lion Image

V. Conclusion

In this paper, we have presented various edge detectors convoluting in both 1-d and 8-d on the RGB planar images in presence of impulsive noise. Both subjective and objective analysis is done. Tables of PSNR values has shown some distinct results and therefore graphs are constructed for more effective analysis. Pattern of graph in Red, Green, Blue planes for the two images lion and bird respectively is not same. PSNR graphs have shown decreasing trends with increase in %ge of impulsive noise. In both cases of 1-d as well as 8-d, for each of the operators(Sobel, Prewitt, Kirsch, Robinson) good results have been observed for blue plane. Irrespective of the operator being used(both in 1-d and 8-d), nearby values have been observed in red and green planes. Blue plane has shown visibly clear images with increase in %ge of noise in every domain image(PSNR values in blue plane are incredibly high in comparison with other two planes). Further considering 8-d operator in presence of impulsive noise, 8-d Prewitt operator works better for both images(lion and bird) as compared to others. In case of 1-d, it is observed that robinson operator with increase in noise has shown constant degradation of almost equal PSNR values in all the three planes.1-d sobel operator has shown great large PSNR values for bird image i.e better results.

VI. Future Scope

As we have seen different planes show different performances of the edge detectors for various images and neither of the operators has shown good performance in either red or green planes but the results are somewhat better in blue plane in presence of impulsive noise. Lack of uniformity is observed in the results. So therefore a better noise removal approach can be used as an initial step to reduce the impulsive noise significantly. The better edge detector thus found after applying the noise removal approach can be applied to real MRI scanned images for inclusive brain analysis.

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