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A New Approach for Edge Detection

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ABSTRACT
A problem of fundamental importance in image processing is edge detection since an edge characterizes the boundaries. Edge detection filters out useless data, noise and frequencies while preserving the important structural properties in an image for further analysis and implementation. Due to limitations of the existing techniques finding a better method for edge detection is still an active area of research.. In order to augment the high-frequency components of an image in this paper we propose a new class of filter by name 'PSS filter' which implies a spatial filter shape with a high positive component at the centre. It is found that sharpening with PSS filter high lights some of the fine details of an image and enhances the clarity of its boundaries. Since the perception of human of image quality is not adequate some image quality metrics like Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Average Difference (AD), Normalized Absolute Error (NAE), Structural Content (SC), Normalized Cross Correlation (NCC) and Maximum Difference (MD) were employed for measurement of image quality. Experimental results show that the proposed PSS filter displayed better performance and superior noise resilience.

Keywords
Image processing, spatial filter, image sharpening, image smoothing, PSS filter, image quality metrics

1. INTRODUCTION
An image may be defined as a two dimensional function, f(x, y), where x and y are spatial (Plane) coordinates, and the amplitude at any pair of co-ordinates (x, y) is called the intensity or grey level of the image at that point.

Edge detection is a low level operation used in image processing and computer vision applications. The main goal of edge detection is to locate and identify sharp discontinuities from an image. These discontinuities are due to abrupt changes in pixel intensity which characterizes boundaries of objects in a scene. Edges give boundaries between different regions in the image. These boundaries are used to identify objects for segmentation and matching purpose .These object boundaries are the first step in many of computer vision algorithms like edge based face recognition, edge based obstacle detection, edge based target recognition, image compression etc.

So the edge detectors are required for extracting the edges. There are many edge detection operators available [2]. These operators identifying vertical, horizontal, corner and step edges. The quality of edges detected by these operators is highly dependent on noise, lighting conditions, objects of same intensities and the density of edges in the scene.

There are two ways through which image quality can be assessed, Subjective and Objective. The evaluation based on observers is called Subjective which are time consuming and less accurate. Whereas the subsequent method is objective method of testing the image quality based on mathematical calculations [9].

2. SHARPENING FILTERS
The important area in the field of computer vision is edge detection. Edges classify the boundaries flanked by regions in an image an edge is the boundary between an object and the background, and indicates the boundary between overlapping objects [6]. As the color and brightness values for each pixel are interpolated some image softening is applied to even out any fuzziness that has occurred. To preserve the impression of depth, clarity and fine details, the image processor must sharpen edges and contours. It therefore must detect edges correctly and reproduce them smoothly and without over-sharpening.

Sobel, Prewitt and Laplacian filters are one among the sharpening filters where each point in the image are done convolution with these two kernels. One kernel has a maximum response to the usual vertical edges and the other kernel has a maximum response to the horizontal edge. It is estimated in 8 possible directions and convolution result of greatest magnitude indicates the greatest direction.

3. PSS Filter
PSS operators perform a 2-Dimensional spatial ascent measurement on an image. Typically it can be used to unearth the approximate absolute gradient magnitude in an input gray scale image at every point. This edge detector uses a pair of 3x3 convolution masks, one estimating the gradient in the x-direction (columns) and the other estimating the gradient in the y-direction (rows). The size of a convolution mask is typically much smaller than the actual image. The ensuing image is untrained by sliding mask over an area of the input image, changing that pixel's value and then shifts one pixel to the right and continues until it reaches the end of a row. It then starts at the beginning of the next row. The proposed operators are in the form of a non singular matrix whose determinant is equal to zero.

The Gx mask brightens the edges in the horizontal direction while the Gy mask highlights the edges in the vertical direction

After taking the magnitude of both, the resulting output detects edges in both directions. The value of the gradient of proposed operators (both in X and Y-directions) is positive so it identifies the boundaries clearly.

-1	-1	-2
-1	12	-2
-1	-2	-2

Gx

-1	-1	-1
-1	12	-2
-2	-2	-2

Gy

Gx= (- (Z1+Z2+Z4+Z7)-2(Z3+Z6+Z8+Z9) +12Z5)
Gy= (-(Z1+Z2+Z3+Z4)-(Z6+Z7+Z8+Z9) +12Z5)

The above formula shows the way value of a particular pixel in the output image is calculated. The centre of the mask is placed over the pixel to be manipulated in the image.

PSS FILTER OF 3*3

In the present case we use simplest approximations to a first derivative that satisfy the condition in equation [1] is used and the appropriate filter mask may be formulated as

$$\nabla f \approx \left|12Z5\ \right| - \left|-(z1+z2+z4+z7)-2(Z3+Z6+Z8+Z9)\ \right| + \left|12z5-(z1+Z2+Z3+Z4)\text{-}(Z6+Z7+Z8+Z9)+z3\ \right| - \left|z7+2z9\ \right| \rightarrow 1$$

The above equation can be implemented with the two masks and these are referred as PSS – gradient operators.Generalized formula is used to generalize the given filter, but the filter can be generalized only by generalizing the equation i.e in this case it is equation [1]. Later one may increase or decrease the filter size according to quality of the image.

In a situation where one has to apply 3*3 filter, then it is needed to divide the image into 3*3 matrixes and then 3*3 PSS mask has to slide over an area of the input image. Changing that pixel's value, and shifting one pixel to the right. It will then continue to the right and moves till the end of a row is reached. It then starts at the beginning of the next row.

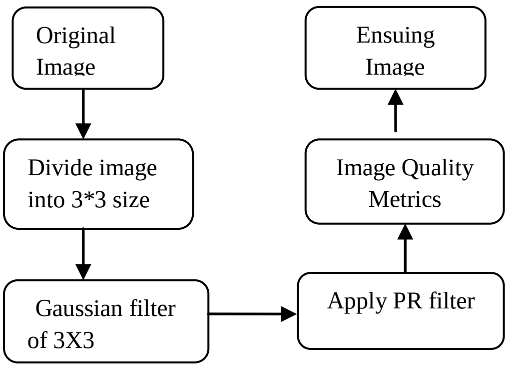


Figure 1: The Process of evaluation of PSS filter.

Algorithm-I

Step1: Read the Image.
Step2: partition the image into 3*3 sizes.
Step3: Finding the edges of the image.

Work out the derivatives G_X and G_Y in x and y directions. This can be done by the application of PSS filter which is of 3*3 sizes for finding the edges of the image.

Step4: Smoothening the edges

Apply Gaussian filter of 3X3 size with sigma equal to 1.4 for smoothening the image.

4. EXPERIMENTAL RESULTS

This section presents the simulation results illustrating the performance of the proposed PSS filter. The fundamental significance in image processing is the measurement of image quality. In many image processing applications, assessment is required for image quality. The perception of human of image quality is not adequate. So we require some more image quality metrics like Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Average Difference (AD), Normalized Absolute Error (NAE), Structural Content (SC) and Maximum Difference (MD), Normalized Cross Correlation (NCC) and Maximum Difference for efficient measurement of image quality

Image quality metric Formulae

Image Quality Metric	**Procedure to Calculate**
Average Difference	$(1\div MN)\ \sum_{J=1}^{M}\sum_{k=1}^{N} [F(X,Y)-F'(X,Y)]$ Where M and N are image rows and columns in spatial form
Peak-Signal to Noise Ratio	**20 $\log_{10}$(255/MSE)** Where MSE is Mean Square Error
Mean Square Error	$(1\div MN)\ \sum_{J=1}^{M}\sum_{k=1}^{N} [F(X,Y)-F'(X,Y)]^2$ Where M and N are image rows and columns in spatial form
Maximum Distance	MAX{|F(X,Y)-F'(X,Y)|}
Structural Content	$\sum_{J=1}^{M}\sum_{k=1}^{N} (F(X,Y))^2 \div \sum_{J=1}^{M}\sum_{k=1}^{N} (F'(X,Y))^2$ Where M and N are image rows and columns in spatial form
Normalized Absolute Error	$\sum_{J=1}^{M}\sum_{k=1}^{N} \lvert [F(X,Y)-F'(X,Y)] \rvert / \sum_{J=1}^{M}\sum_{k=1}^{N} \lvert F(X,Y) \rvert$ Where M and N are image rows and columns in spatial form
Normalized Cross Correlation	$\sum_{J=1}^{M}\sum_{k=1}^{N} \lvert [F(X,Y)*F'(X,Y)] \rvert / \sum_{J=1}^{M}\sum_{k=1}^{N} \lvert F(X,Y) \rvert^2$ Where M and N are image rows and columns in spatial form
Fidelity criteria	$1-\sum_{J=1}^{M}\sum_{k=1}^{N} \lvert [F(X,Y)-F'(X,Y)] \rvert^2 / \sum_{J=1}^{M}\sum_{k=1}^{N} \lvert F(X,Y) \rvert^2$ Where M and N are image rows and columns in spatial form

0.0924	0.1192	0.0924
0.1192	0.1538	0.1192
0.0924	0.1192	0.0924

Mean Square Error	**(1÷MN)** $\sum_{J=1}^{M} \sum_{k=1}^{N} [F(X,Y)-F'(X,Y)]^2$ Where M and N are image rows and columns in spatial form

4.1 Tabular values of quality metrics for each filter

Table 1: Comparison of Image Quality Metrics for PSS Filter.

Sno	Image	PSNR	MSE	NAE	AD	MD	SC	RMSE	NCC
1	Calculator.tif	11.12	0.501	0.81	58.04	255	3.60	70.82	0.30
2	Building_original	5.21	1.95	0.84	105.19	255	7.18	139.93	0.16
3	Skull.tif	10.94	0.523	0.864	28.28	243	7.83	72.35	0.158
4	Brain.tif	5.804	1.708	0.95	121.33	226	22.89	130.70	0.062
5	Brain.thumb.tif	11.552	0.454	0.821	16.875	144	0.97	67.439	0.666
6	Pills.tif	5.136	1.992	0.902	130.24	214	15.64	141.16	0.108
7	Region.tif	4.861	2.123	0.924	83.258	255	13.244	145.70	0.075
8	Rose1024.tif	11.214	0.491	0.837	31.886	255	6.244	70.11	0.205
9	Tungsten_flmt.tiff	7.953	1.041	0.845	82.263	253	6.247	102.063	0.12
10	u.tif	7.295	1.212	0.947	47.53	255	19.099	110.092	0.052
11	Utk.tif	19.384	0.749	0.619	2.824	255	2.139	27.374	0.436
12	Turbine.tif	6.814	1.354	0.743	88.134	255	3.247	116.36	0.333
13	Cholesterol.tif	9.680	0.699	0.752	25.153	251	1.004	83.66	0.698
14	Cameraman.tif	6.661	1.402	0.852	84.897	248	3.025	118.42	0.275

Table 2: Comparison of Image Quality Metrics for Sobel Filter

Sno	Image	PSNR	MSE	NAE	AD	MD	SC	RMSE	NCC
1	Calculator.tif	10.13	0.631	0.8964	62.01	255	4.64	79.43	0.1848
2	Building_original	4.84	2.13	0.8954	111.00	255	8.79	146.04	0.1170
3	Skull.tif	10.62	0.562	0.90	29.04	243	10.74	75.02	0.111
4	Brain.tif	5.76	1.7248	0.949	121.69	228	36.84	131.33	0.0493
5	Brain.thumb.tif	9.92	0.66	1.008	32.574	239	2.086	81.307	0.2329
6	Pills.tif	4.907	2.100	0.925	132.29	250	16.868	144.93	0.0831
7	Region.tif	4.528	2.3	0.998	84.428	255	15.99	151.40	0.0322
8	Rose1024.tif	10.6	0.566	0.89	40.678	255	22.502	75.256	0.0905
9	Tungsten_flmt.tiff	7.52	1.15	0.89	85.644	255	8.26	107.26	0.14
10	u.tif	7.04	1.28	1.003	48.680	255	33.978	113.313	0.0128
11	Utk.tif	17.10	0.126	1.0217	3.645	255	3.299	35.594	0.1484
12	Turbine.tif	5.68	1.755	0.892	118.92	255	23.39	132.50	0.1056
13	Cholesterol.tif	7.99	1.031	0.9163	36.467	254	1.40	101.55	0.4156
14	Cameraman.tif	6.0164	1.6272	0.9300	99.417	253	6.712	127.56	0.1220

The mean square error (MSE) is the measure of difference between actual and estimated value of the quantity]. Larger the value of MSE implies poor quality of the image. The most familiar image quality metric is PSNR. If PSNR value is high then the difference between the original image and reconstructed image will be small. Large the value of SC indicates that the image is of pitiable quality. In order to obtain an uncontaminated and less noisy image the value of Average Difference (AD) should be reduced. The quality of the image increases with decrease in the value of NAE, Higher the value of NAE means the quality of the image lower. NCC is the measure of calculating the degree of resemblance between two objects.

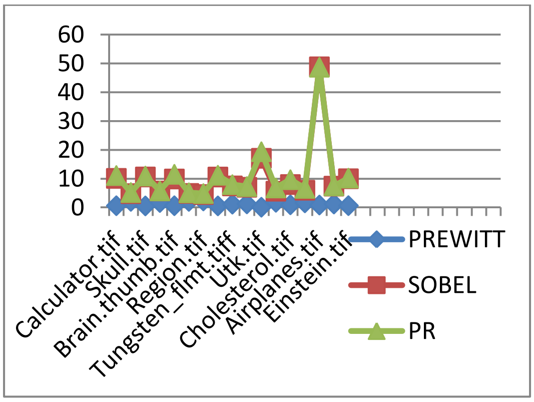
Table 3: Comparison of Image Quality Metrics for Prewitt Filter

Sno	Image	PSNR	MSE	NAE	AD	MD	SC	RMSE	NCC
1	Calculator.tif	10.06	0.64	0.911	64.64	255	6.04	80.04	0.1534
2	Building_original	4.788	2.15	0.90	116.18	255	13.71	146.93	0.09
3	Skull.tif	10.52	0.575	0.91	30.38	243	17.10	75.88	0.0839
4	Brain.tif	5.70	1.75	0.96	123.49	228	53.69	132.31	0.0381
5	Brain.thumb.tif	10.03	0.644	0.99	36.52	239	2.903	80.306	0.177
6	Pills.tif	4.81	2.14	0.93	135.68	250	25.25	146.49	0.0636
7	Region.tif	4.52	2.3	0.998	84.43	255	16.00	151.40	0.0322
8	Rose1024.tif	10.45	0.585	0.9152	42.336	255	39.89	76.49	0.0665
9	Tungsten_flmt.tiff	7.3893	1.18	0.9125	90.095	255	13.349	108.91	0.1045
10	u.tif	7.045	1.28	1.003	48.680	255	33.978	113.313	0.0128
11	Utk.tif	17.15	0.125	1.01	3.696	255	3.487	35.381	0.14
12	Turbine.tif	5.49	1.83	0.92	123.15	255	43.53	135.51	0.076
13	Cholesterol.tif	8.32	0.956	0.865	47.26	254	2.064	97.795	0.3327
14	Cameraman.tif	5.997	1.64	0.9377	103.535	253	9.608	128.13	0.0955

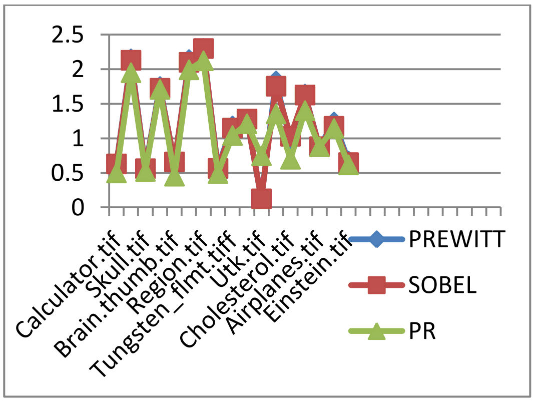
Table 4: Comparison of Image Quality Metrics for Laplacian Filter

Sno	Image	PSNR	MSE	NAE	AD	MD	SC	RMSE	NCC
1	Calculator.tif	9.70	0.70	0.94	70.96	255	54.81	83.47	0.04
2	Building_original	4.49	2.31	0.95	126.81	255	108.12	152.05	0.02
3	Skull.tif	10.15	0.62	0.97	32.72	243	42.84	79.21	0.0263
4	Brain.tif	5.50	1.83	0.99	128.03	229	0.186	135.28	0.0076
5	Brain.thumb.tif	9.527	0.724	1.096	35.314	255	3.165	85.145	0.102
6	Pills.tif	4.569	2.27	0.976	143.15	250	300.7	150.68	0.018
7	Region.tif	4.323	2.402	1.05	85.476	255	21.59	155.01	0
8	Rose1024.tif	10.331	0.602	0.922	42.769	255	95.188	77.615	0.046
9	Tungsten_flmt.tiff	7.021	1.29	0.963	98.367	255	107.644	113.618	0.033
10	u.tif	6.841	1.345	1.054	47.44	255	19.214	115.99	0
11	Utk.tif	16.432	0.147	1.223	3.914	255	5.189	38.452	0.009
12	Turbine.tif	5.469	1.845	0.910	121.29	255	34.354	135.84	0.077
13	Cholesterol.tif	7.841	1.068	0.908	68.224	255	8.515	103.38	0.101
14	Cameraman.tif	5.78	1.718	0.966	108.49	253	22.413	131.07	0.044

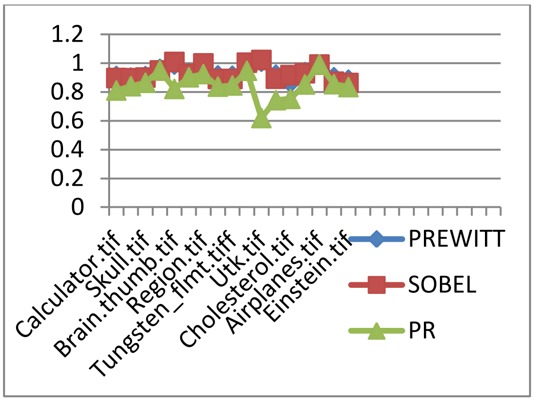
4.2 Graphical comparison of filters for each quality metric



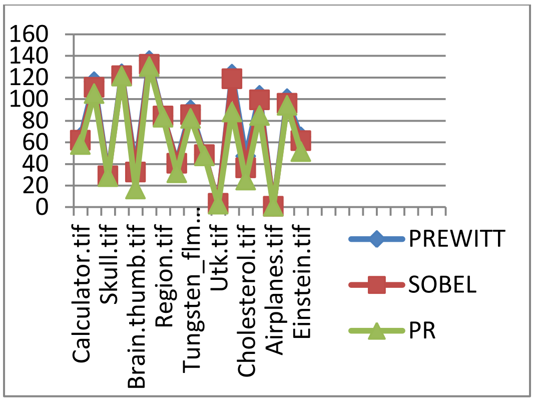
PSNR



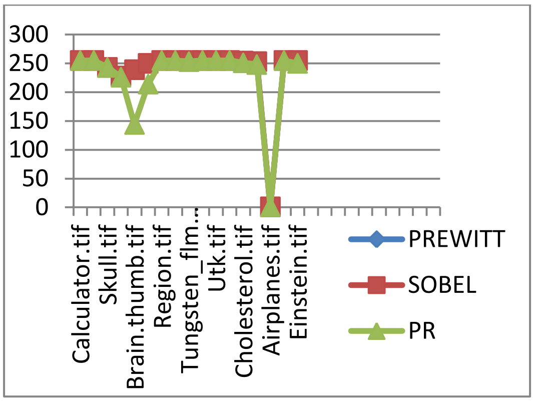
MSE



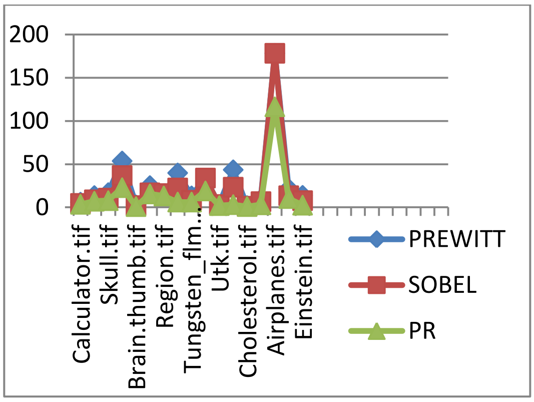
NAE



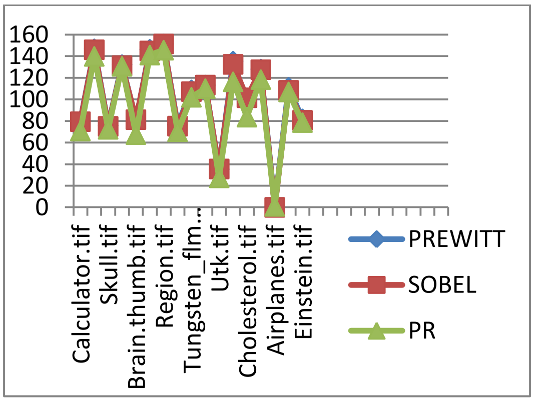
AD



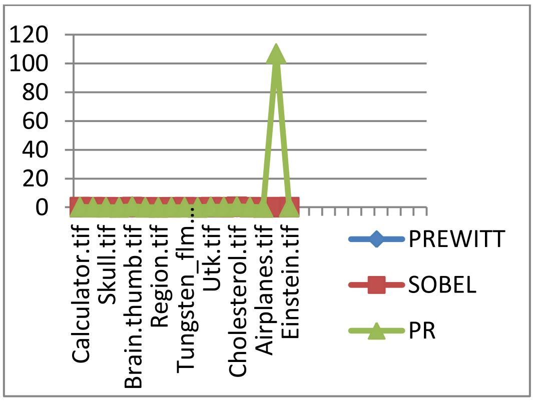
MD



SC

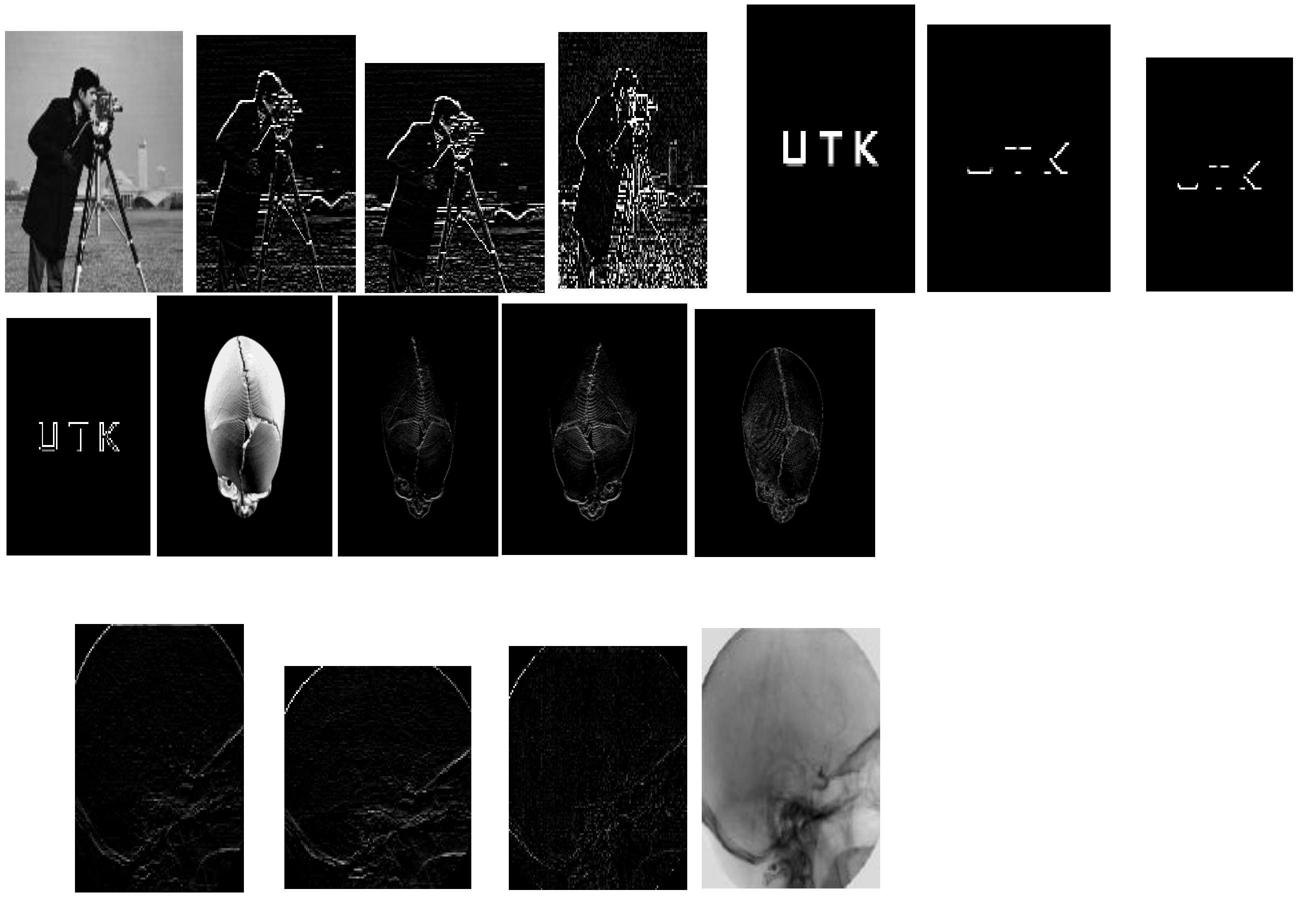


RMSE



NAE

4.3 Visual comparison of filters

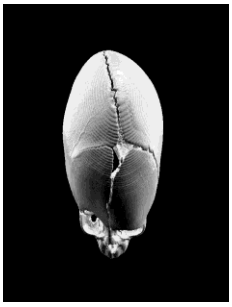


a) Original image **(b) Sharpened with Prewitt** **(c) Sharpened with Sobel** **(d) Sharpened with PSS filter**

4.4 Tabular comparison of filters

Table 5: Tabular comparison of filters image wise

Image	Filter	PSNR	MSE	NAE	AD	MD	SC	RMSE	NCC
	Prewitt	5.997	1.64	0.9377	103.535	253	9.608	128.13	0.0955
	Sobel	6.0164	1.6272	0.9300	99.417	253	6.712	127.56	0.1220
	PSS	6.661	1.402	0.852	84.897	248	3.025	118.42	0.275

	**Prewitt**	17.15	0.125	1.01	3.696	255	3.487	35.381	0.14
	Sobel	17.10	0.126	1.0217	3.645	255	3.299	35.594	0.1484
	PSS	19.384	0.749	0.619	2.824	255	2.139	27.374	0.436
	**Prewitt**	10.52	0.575	0.91	30.38	243	17.10	75.88	0.0839
	Sobel	10.62	0.562	0.90	29.04	243	10.74	75.02	0.111
	PSS	10.94	0.523	0.864	28.28	243	7.83	72.35	0.158
	**Prewitt**	5.70	1.75	0.96	123.49	228	53.69	132.31	0.0381
	Sobel	5.76	1.7248	0.949	121.69	228	36.84	131.33	0.0493
	PSS	5.804	1.708	0.95	121.33	226	22.89	130.70	0.062

The above results of the work show that among the analyzed schemes the proposed PSS filter exhibits better results.

5. CONCLUSION

In this effort we proposed a new approach called PSS filter. It has wide applicability in many areas like satellite image enhancement, medical diagnostics, etc. The trialing and simulations with real images have shown that the filter is efficient than other existing filters. Several existing techniques for edge detection in image processing have been compared with PSS filter. Some of image processing metrics such as MSE, PSNR, AD, MD, SC, NAE, NCC are employed in this assessment. The code for these new filters has been generated and the obligatory strategies of comparisons between proposed and existing filters are tabulated. The values of MSE, SC, NAE, MD, AD are low and the values of PSNR and NCC are high for regular images are enhanced with PSS filter than Prewitt, Sobel and Laplacian operators, indicates the PSS filter identifies better edges than Prewitt , Sobel and Laplacian filters.

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