Comparative Analysis of Different Image Enhancement Techniques

Article · January 2019

1 author:

Sandeep Dahiya
Bhagat Phool Singh Mahila Vishwavidyalaya
27 PUBLICATIONS   **77** CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Nanotechnology Design and Spintronics View project

Article View project

Comparative Analysis of Different Image Enhancement Techniques

Manisha
ECE Department
BPS Mahila Vishwavidyalaya Khanpur-Kalan, Sonipat, Haryana – 131305, India
E-mail: 2012manishamalik@gmail.com

Sandeep Dahiya
ECE Department
BPS Mahila Vishwavidyalaya Khanpur-Kalan, Sonipat, Haryana – 131305, India
E-mail: Sandy_dahiya2001@yahoo.com

Abstract: Digital image processing is having its significance in different areas such as noise filtering, content enhancement for contrast enhancement, edge sharpening, smoothing and deblurring etc. Many obstacles are associated including blurring, contrast unbalance, lack of number of pixels etc. resulting in poor quality image recognition and lack of number of information etc. In present work, an effort is made using mirror ray transfer matrix for better perception. Two steps are used for proposed work. In first step mirror ray reflection behavior is extracted into ray transfer matrix using paraxial approximation which provides ray input and output relation for a mirror. Ray transfer matrix is applied on sub image of size 2*2 using sliding neighborhood operations. The operation calculates average value of covered area for a single centered pixel in enhanced sub image. Further, mask moves from one pixel to another in an image and each time calculate the average value for the center pixel of selected sub image. The proposed work is implemented in MATLAB environment and tested using different image quality parameters. The obtained result shows that after enhancement mirror provide sharpness and smoothness in image quality.

Keywords: Image enhancement, Smoothing and Sharpening filters, Mirror reflection, Ray transfer matrix filter.

I. INTRODUCTION

Image enhancement employs different image processing techniques to enhance the pictorial information for human interpretation, different kind of applications and analysis. Image quality gets degraded because of noise, poor contrast, blurring or improper focusing of lens etc. Filters are one of the spatial domain techniques which filter noise from images using sliding neighborhood operation [7]. A 3*3 size neighborhood mask operation is as presented in Figure 1.

$W_{-1,1}$	$W_{-1,0}$	$W_{-1,1}$
$W_{0,-1}$	$W_{0,0}$	$W_{0,1}$
$W_{1,-1}$	$W_{1,0}$	$W_{1,1}$

Figure 1.3*3 Mask [4]

$$g(x, y) = \sum_{i=-1}^{1} \sum_{j=-1}^{1} W_{i,j} \, f(x+i, y+j) \qquad (1)$$

A 3*3 neighborhood mask contains $W_{-1,-1}$ to $W_{1,1}$ coefficients which generate the intensity value at center location (x, y) by using Eq. (1).

The following filters are used for analysis of image enhancement techniques for proposed study.

A. Smoothing Filter

These filters remove sharp edge and smooth images by finding averages of the all neighborhood pixels [2].

1. Average or low pass filter

This filter uses 3*3 size mask as in Figure 2 for calculating average information for enhanced image.

$$\frac{1}{9} \times$$

Figure 2. Averaging

1	1	1
1	1	1
1	1	1

filter (low-pass filter) [2]

An expression for average filter can be written as shown in Eq. (2)

$$g(x, y) = \frac{1}{9} \sum_{i=-1}^{1} \sum_{j=-1}^{1} f(x+i, y+j) \qquad (2)$$

2. Weighted average filter

The mask used for the weighted average filter is as shown in Figure 3

$$\frac{1}{16} \times$$

Figure 3. Weighted averaging

1	2	1
2	4	2
1	2	1

filter (low pass filter) [2]

$$g(x, y) = \frac{\sum_{i=-a}^{a} \sum_{j=-b}^{b} w_{i,j} \, f(x+i, y+j)}{\sum_{i=-a}^{a} \sum_{j=-b}^{b} w_{i,j}} \qquad (3)$$

Weighted average mask results in reducing blurring effect which is higher in average filter. General expression for spatial filter can be written as presented in Eq. (3) [2].

Where

$W_{i,j}$ is normalized factor

Mask size =M*N, Where M = 2a + 1, N = 2b + 1

Smoothing filters are used for blurring and noise reduction by replacing each pixel value using a predefined relationship.

B. *Sharpening Filter*

Sharpening filter is used to increase edge information, first edge of the image is detected and then this edge extracted image is added to the original image to sharp edges [10]. The detection of edges using filters is presented in following discussion.

1. *Prewitt operator*

Prewitt operator uses two type of mask to detect horizontal and vertical edges.

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

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

(a)   (b)

Figure 4.Vertical edge and Horizontal edge detector mask [10]

2. *Sobel operator*

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

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

(a)   (b)

Figure 5.Vertical edge and Horizontal edge detector sobel mask [10]

Sobel mask removes limitation of prewitt operator that coefficients of mask are not fixed as shown in Figure 5 [10].

3. *Laplacian Operator*

Laplacian mask represent second order derivative used to detect inward and outward edges. There are two Laplacian operators as presented.

1	1	1
1	-8	1
1	1	1

0	1	0
1	-4	1
0	1	0

(a)   (b)

Figure 6.Positive Laplacian operators [5]

0	-1	0
-1	4	-1
0	-1	0

-1	-1	-1
-1	8	-1
-1	-1	-1

a)   (b)

Figure 7.Negative Laplacian operators [5]

The filter mask having negative center coefficients as shown in Figure 6(a), (b) are used to detect outward edges while positive center coefficients used to detect inward edges as shown in Figure 7(a) & (b). Laplacian mask used to find high frequency information in an image.

Sharpening filter is used to highlight fine details in an image by finding the neighbored difference.

C. *Mirror*

Reflection characteristics of mirror includes r(x, y) and I(x, y) parameters where r(x, y) is the reflection of the surface point and I(x, y) is the intensity of the light falling on the object surface. This results in image enhancement using mirror ray reflection matrix which is analyzed using a small angle paraxial approximation.

$$\begin{bmatrix} 1 & 0 \\ \dfrac{-2}{R_e} & 1 \end{bmatrix}$$

Figure 8.Reflection matrix from a curved mirror

Where

R= Radius of curvature

Ray transfer matrix (RTM) relates input and output ray vector plane which represents optical system between the two reference planes. Thus this matrix can be used to enhance image which acts like filter.

Mirror reflection equation can be extracted into matrix using paraxial approximation method, is suitable for image enhancement.

II. LITERATURE REVIEW

The work carried out by researchers and authors on different image enhancement techniques and mirror ray transfer techniques is presented.

Shailendra Singh Negi *et al.* in 2014 [2] analyzed Image enhancement using spatial domain techniques which include Point processing, Histogram processing, Neighborhood processing, Filters, Smoothing filters, and Sharpening filters. They presented that point processing techniques are primarily used for contrast enhancement and said Transformation is used for enhancing of the image details in the darker regions.

Saloni Lamba, Paru Raj in 2017 [5] demonstrated a Review of Edge Detection and its Techniques in Digital Image Processing and presented that Opposite of smoothing filter, sharpening filter is used to increase edge information, first edge of the image is detected and then this edge extracted image is added to the original image to Sharpe edges and introduction to the Prewitt, Sobel and Laplacian operator is provided which is used to Sharpe image.

Rafael C. Gonzalez *et al.* in 2008 [6] presented different applications area of image. Authors presented that after the invention of photography, one of the digital images applications was in the newspaper industry, then BARTLANE cable picture transmission system introduced in the early 1920s. But after the invention of computer, birth of Digital Image Processing took place.

Komal vij, yaduvir singh [8] reviewed that an digital image is a two dimensional function f(x, y), where x and y are image coordinates, the value of x varies from 0 to H and value of Y varies from 0 to L. where L is the length of image dimension and H is the height of the image dimension and analyzed

different intensity transformation and histogram based image enhancement processing techniques.

Julian Calderon Gonzalez *et al.* [9] provided four different image enhancement techniques such as successive means quantization transform (SMQT), histogram equalization, using MATLAB function and own function, and V transform and conclude that histogram equalization algorithm is the simplest of all, it has a wide variability of grey levels and it is not suitable for color images. V transform algorithm is a good option for color images.

Raman Maini and Himanshu Aggarwal [11] demonstrated Geometric Corrections, Gray Scale Manipulation and Image Enhancement. In spatial domain image enhancement techniques, image negative, logarithmic transformation etc. are described. Authors conclude that to enhance white information, image negative is used and power-law-transformation is best suited for contrast enhancement.

Cristian Ordoyo Casado in 2010 [12] presented spatial domain and frequency domain image enhancement methods. Author concludes that visual evaluation of image quality is a highly subjective process, thus making the definition of a "good image" is an elusive standard to compare algorithm performance.

Brian G. Frock and Richard W. Martin [13] analyzed that noisy images have been improved by first smoothing the original data and then edge enhancing the smoothed data. The resulting sharpened edges improve the visualization of features in the images. The application of digital image enhancement techniques has allowed the imaging of defects in composite materials at frequencies as low as 3.5 MHZ. This use of these lower frequencies permits better imaging of defects in thick composite materials.

Aditi Majumder [14] introduced contrast sensitivity of the human eye and applied this fact effectively to design a contrast enhancement method for images that improves the local image contrast by controlling the local image gradient and achieve this without segmenting the image either in the spatial or frequency domain.

The next section provides a framework of the objectives for the present work.

III. RESEARCH OBJECTIVES

After a detailed review presented by researchers and authors, the objectives of the research work are identified and the same will be achieved by using mirror reflection technique as presented.

1. To present mirror reflection behavior into reflection ray transfer matrix.
2. To apply ray transfer matrix on image using sliding-neighborhood operations.

3. Implementation of traditional spatial domain image enhancement using MATLAB SIMULINK.

The next section provides the model and research methodology used for the present study.

IV. RESEARCH METHODOLOGY

In presented work, an effort is made to improve the quality of the image to get clear and complete image pixels information. A two stage layered framework research methodology for proposed mirror ray transfer matrix technique is shown below. Two stage layered framework of mirror ray transfer matrix is developed. In first step mirror ray reflection behavior is extracted into ray transfer matrix using paraxial approximation.
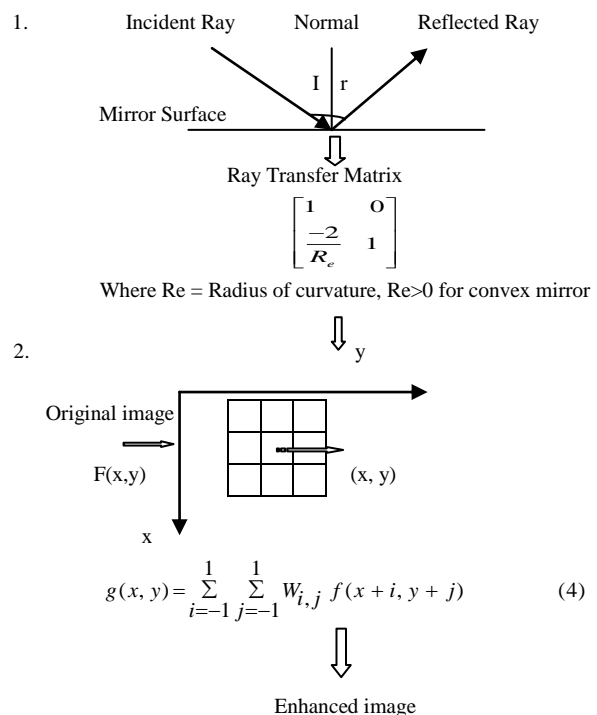

$$g(x, y) = \sum_{i=-1}^{1} \sum_{j=-1}^{1} W_{i,j}\, f(x + i, y + j) \qquad (4)$$

Figure 9.A two layer model for image enhancement mirror ray reflection technique

This extracted ray reflection matrix is processed in second step. The ray transfer matrix is applied on sub image of size 2*2 using sliding neighborhood operations which calculate pixels average value in covered area. Then the average value is placed at center position of selected sub image and then mask moves from one pixel to another pixel in the image and each time calculate average value for the center pixel of selected sub image for getting enhanced image. The output from this second step is considered as an enhanced image as shown in Figure 9.

The next section of proposed model presents a framework of results and discussion.

V. RESULTS & DISCUSSION

Spatial domain image enhancement filters likes Average Filter, Laplacian Filter, Sobel Filter, Gaussian Filter and Mirror Ray Transfer Matrix are implemented using MATLAB for analysis. The image considered in this work is captured from mobile camera in JPG file format. Filters enhancement is analyzed by showing original and enhanced image with their histogram and by making comparison for calculated Image quality parameters such as MSE, PSNR, Entropy, image contrast, NAE, SC and maximum difference for each filter. The histogram for each filter is obtained for gray image and the Image quality parameters are calculated for both color and gray image as presented below:
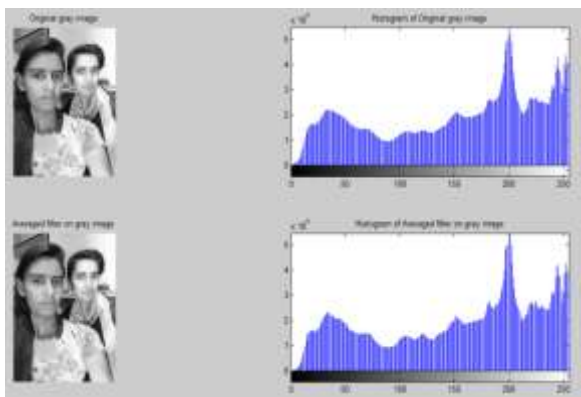
1. Average Filter

Figure 10.Average filter mask on gray image

A colored image is transformed into gray image using MATLAB, on which average filter is applied for image enhancement. Original and average filter enhanced image with their histogram is depicted in Figure 10. It shows that average filter results into a smooth and bright image with a very small change in histogram as compared to original image histogram.
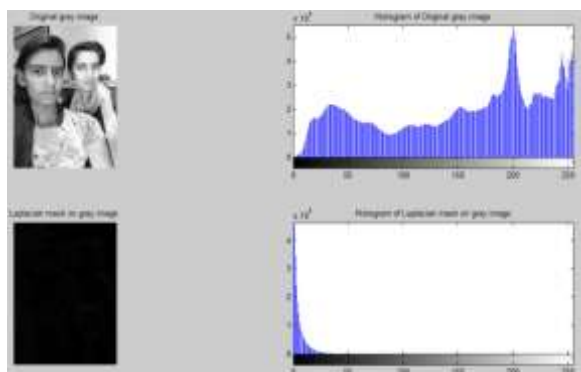
2. Laplacian Filter

Figure 11.Laplacian filter mask on gray image

A colored image is transformed into gray image using MATLAB, on which laplacian filters is applied for image enhancement. Figure 11 presents original and laplacian filter

enhanced image with their histogram. It depicts that laplacian filter sharps the image by detecting inward edges and provide low contrast image.

3. Sobel Filter

A jpg colored image is transformed into gray image using MATLAB, on which sobel filters is applied for image enhancement. Histogram for original and sobel filter enhanced image is shown in Figure 12. It shows that sobel filter detects outward edges and provide low contrast image as compared to original image.
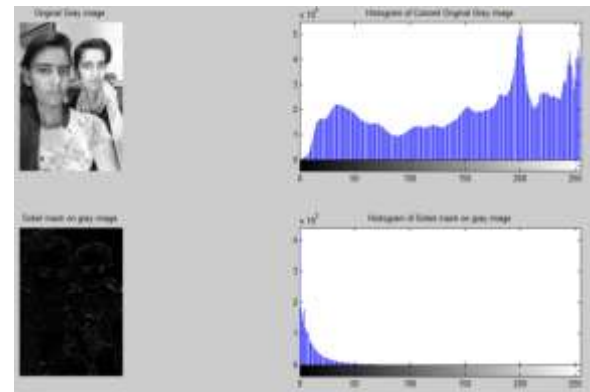

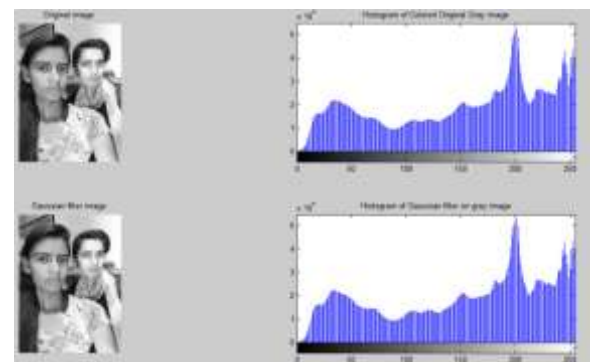Figure 12.Sobel filter mask on gray image

4. Gaussian filter

Figure 13.Gaussian filter mask on gray image

A colored image is transformed into gray image using MATLAB, on which gaussian filters is applied for image enhancement. Histogram for original and gaussian filter enhanced image is shown in Figure 13. It shows that gaussian filter results into bright image with high contrast histogram.
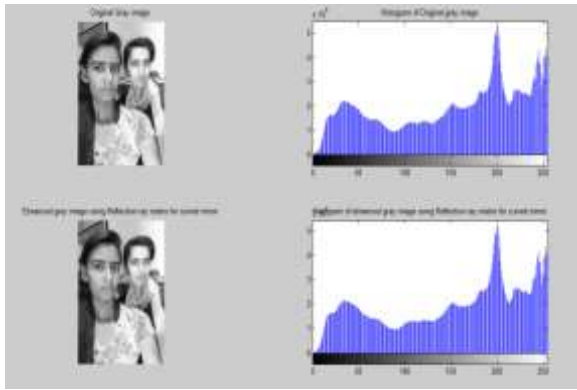
5. Reflection Ray Transfer Filter

Figure 14.Mirror ray transfer filter mask on color image

A jpg colored image is transformed into gray image using MATLAB, on which mirror ray transfer filter (when radius of curvature R= 2) is applied for image enhancement. Original and ray transfer filter enhanced image with their histogram is presented in Figure 14. It depicts that mirror ray transfer filter enhance image with wide range of pixels values and provides high contrast as compared to original image.

The image quality parameters for colored and gray images are tabulated in Table 1(a) and (b).

Table 1(a).Filters Parameters for Colored Image

Parameters	Average Filter	Laplacian Filter	Sobel Filter	Gaussian Filter	Ray Transfer Matrix Filter
Mean Square Error	(:,:,1) = 7.8777e-004	(:,:,1) = 136.9512	(:,:,1) =132.7043	(:,:,1) = 8.1197e-005	(:,:,1) = 0.0025
	(:,:,2) = 7.7694e-004	(:,:,2) = 134.8322	(:,:,2) =130.8787	(:,:,2) = 8.0704e-005	(:,:,2) = 0.0026
	(:,:,3) = 7.1608e-004	(:,:,3) = 137.1529	(:,:,3) =133.0597	(:,:,3) = 7.4222e-005	(:,:,3) = 0.0024
Peak Signal to Noise Ratio	(:,:,1) = 79.1668	(:,:,1) = 26.7651	(:,:,1) =26.902	(:,:,1) = 89.0354	(:,:,1) = 74.1099
	(:,:,2) = 79.2269	(:,:,2) = 26.8329	(:,:,2) =26.9621	(:,:,2) = 89.0618	(:,:,2) = 74.0625
	(:,:,3) = 79.5812	(:,:,3) = 26.7588	(:,:,3) =26.8903	(:,:,3) = 89.4255	(:,:,3) = 74.3277
Original image contrast value	223	223	223	223	223
Enhanced image contrast value	203	108	255	213	224
Difference of original and enhanced image contrast value	0	147	0	0	0
Entropy of original image	7.3936	7.3936	7.3936	7.3936	7.3936
Entropy of enhanced image	7.3815	2.5312	3.1580	7.3880	7.3999
Normalized Absolute Error	0.0081	0.9862	0.9699	0.0023	0.0133
Structural Content	1.0004	1.1794e+003	192.7366	1.0001	0.9993
Maximum Difference	(:,:,1) = 42	(:,:,1) = 250	(:,:,1) = 248	(:,:,1) = 15	(:,:,1) = 48
	(:,:,2) = 40	(:,:,2) = 255	(:,:,2) =255	(:,:,2) = 15	(:,:,2) = 48
	(:,:,3) = 38	(:,:,3) = 255	(:,:,3) =255	(:,:,3) = 14	(:,:,3) = 49

Table 1(b).Filter Parameters for Colored Images

Parameters	Average Filter	Laplacian Filter	Sobel Filter	Gaussian Filter	Ray Transfer Matrix Filter
Mean Square Error	0.00032-337	973.8233	917.5824	0.000032-275	0.0065
Peak Signal to Noise Ratio	83.0338	18.2460	18.5044	93.0421	69.9993
Original image contrast value	255	255	255	255	255
Enhanced image contrast value	253	222	255	254	255
Difference of original and enhanced image contrast value	0	33	0	0	0
Entropy of original image	7.8349	7.8349	7.8349	7.8349	7.8349
Entropy of enhanced image	7.8288	2.6745	3.4038	7.8322	7.8379
Normalized Absolute Error	0.0106	0.9827	0.9563	0.0034	0.0184
Structural Content	1.0008	651.6501	70.7567	1.0003	0.9992
Maximum Difference	54	255	255	20	131

Mean Square Error (MSE) is the average squared difference between the original and enhanced image. After observing all the image quality parameters as shown in Table 1 (a) and (b) for implemented filters in this work, it is concluded that the mean square error (MSE) of Gaussian and Average filters is less than the other filters such as Laplacian and Sobel filters, that's why it provides smoothness in image enhancement, Moreover, Laplacian and Sobel filters have high MSE rate than the other filters, hence provide sharpness in image enhancement. Further, the intermediate state i.e. Ray transfer matrix provide both smoothness and sharpness in image enhancement applications based on the value of mirror reflection matrix parameter R shown in Figure 8.

VI. CONCLUSION

Image enhancement techniques are used to improve quality of images for better human visualization and for different image applications. When image is captured, many factors effects image quality such as noise, wrong camera lens aperture setting, low resolution camera, blurring etc. These factors prevent to observe image for its further use. Thus image enhancement plays a very important role to improve its quality for human perception and different image applications. In present work, a mirror ray transfer technique has been proposed for image enhancement purpose. A two stages model has framed for proposed technique implementation. At first stage, mirror ray reflection behavior has been evaluated in a matrix form using paraxial approximation method, which acts as a filter mask for second stage. At second stage, evaluated mirror ray transfer matrix mask is applied on sub-image of size 2*2 using sliding neighborhood operation. The basic filters and proposed technique is implemented using MATLAB for image enhancement. Image quality parameters likes MSE, PSNR, Entropy, image contrast, NAE, SC and maximum difference is calculated for all filters. Performance is analysis by making comparison between all filters parameters values. The mean square error (MSE) of Gaussian and Average filters is less than the other filters such as Laplacian and Sobel filters, that's why it provide smoothness in image enhancement. Moreover, Laplacian and Sobel filters have high MSE rate than the other filters, hence provide sharpness in image enhancement. Further, the intermediate state *i.e.* Ray transfer matrix provide both smoothness and sharpness in image enhancement applications based on the value of mirror reflection matrix parameter R which is the ultimate goal of proposed work.

REFERENCES

[1] Bernd Jahne, "Digital Image Processing", Library of Congress, Springer, ISBN 3-540-67754-2, 2002.

[2] Shailendra Singh Negi *et al*., "Survey of Various Image Enhancement Techniques In Spatial Domain Using MATLAB," International Journal of Computer Applications, International Conference on Advances in Computer Engineering & Applications, 2014.

[3] Fari Muhammad Abubakar, Tianjin, P.R. China, "Image Enhancement Using Histogram Equalization And Spatial Filtering," International Journal of Science And Research, Vol. 1, Issue 3, 2012.

[4] Lexing Xie, "Spatial Domain Processing and Image Enhancement", Columbia University in the City of New York, Lecture 4, 2009.

[5] Saloni Lamba, Paru Raj, "A Review of Edge Detection and Its Techniques in Digital Image Processing," International Journal of Research in Management, Science & Technology, Vol. 5, 2017.

[6] Rafael C. Gonzalez et al., "Digital Image Processing," Third Edition, Pearson Education, Inc., 2008.

[7] Tinku Acharya, "Image Processing Principles And Applications," A John Wiley & Sons, Mc., 2005.

[8] Komal Vij, Yaduvir Singh, "Comparative Study of Different Techniques of Image Enhancement for Grayscale and Color Images," EIED, TIET, Patiala, 2011.

[9] Julian Calderon Gonzalez, Oscar Daniel Carmona Salazar, "Image Enhancement With MATLAB Algorithm", Blekinge Institute of Technology, Department of Applied Signal Processing, Sweden.

[10] Palak Khandelwal, Gagandeep Kaur, "Study of Various Enhancement Techniques," International Journal of Electronics & Communication Technology, Vol. 7, Issue 2, 2016.

[11] Raman Maini And Himanshu Aggarwal, "A Comprehensive Review of Image Enhancement Techniques," Journal of Computing, Vol. 2, Issue 2010.

[12] Cristian Ordoyo Casado, "Image Contrast Enhancement Methods," Upna 2010.

[13] Brian G. Frock and Richard W. Martin, "Applications of Digital Image Enhancement Techniques for Improved Ultrasonic Imaging of Defects In Composite Materials", University of Dayton, Research Institute Dayton.

[14] Aditi Majumder, Sandy Irani, "Contrast Enhancement of Images using Human Contrast Sensitivity", Computer Science Department, University of California, Irvine.

AUTHOR'S BIOGRAPHIES

Manisha is a M.Tech student in Department of Electronics and Communication Engineering from Bhagat Phool Singh Mahila Vishwavidyalaya, Khanpur-Kalan (Sonepat). She received B.tech degree in ECE from Bhagat Phool Singh Mahila Vishwavidyalaya,Khanpur-Kalan (Sonepat). Her research interest includes Image processing and MATLAB.

Dr. Sandeep Dahiya is presently working as Assistant Professor in Department of Electronics and Communication Engineering, Bhagat Phool Singh Mahila Vishwavidyalaya Khanpur-Kalan, Sonepat since July 2009. He also served as Lecturer in Hindu College of Engineering, Sonepat for 8 years. He is having 17 years of experience in academic frontiers. He received his B.E. in Electronics Engineering in 2000, M.Tech in Electronics and Communication Engineering in 2006 and PhD in Electronics & Communication Engineering from UIET, MDU Rohtak in 2017. He has to his credit published 40 articles published and presented in refereed journals and proceedings. He has convened/coordinated 07 national workshops on design and simulation tools for students and faculty, UGC sponsored faculty development programme and national conference at University. He was also the Training and Placement Officer of Electronics and Communication Engineering Department and member of University Placement and Counseling Cell. He is also the recipient life member of Scientific and Professional societies such as Indian Society for Technical Education (ISTE), Computer Society of India (CSI) and Institution of Electronics and Telecommunication Engineers (IETE). His current area of interest includes Digital circuit design and modeling, High speed interconnects, Low power VLSI design, Nanotechnology design and Spintronics.