International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-1 Issue-5, June 2012

Image Enhancement using Guided Image Filter Technique

Aditya Goyal, Akhilesh Bijalwan, Pradeep Kumar, Kuntal Chowdhury

Abstract- ***In this paper we study and implement image enhancement aspect of guided image filtering. Principle objective of Image enhancement is to process an image so that result is more suitable than original image for specific application. Digital image enhancement techniques provide a multitude of choices for improving the visual quality of images. Guided image filter is an explicit image filter, derived from a local linear model; it generates the filtering output by considering the content of a guidance image, which can be the input image itself or another different image. Moreover, the guided filter has a fast and non-approximate linear-time algorithm, whose computational complexity is independent of the filtering kernel size. This paper will provide an overview of underlying concepts, along with algorithms commonly used for image enhancement.***

Index Terms—Digital Image Processing, Explicit image filter, Guided Image Filtering, Image Enhancement, Kernel.

I. INTRODUCTION

Image enhancement improves the quality (clarity) of images for human viewing. It basically improves the interpretability or perception of information in images for human viewers and providing `better' input for other automated image processing techniques. The principal objective of image enhancement is to modify attributes of an image to make it more suitable for a given task and a specific observer.

During this process, one or more attributes of the image are modified. The choice of attributes and the way they are modified are specific to a given task. Moreover, observer-specific factors, such as the human visual system and the observer's experience, will introduce a great deal of subjectivity into the choice of image enhancement methods. Removing blurring and noise, increasing contrast, and revealing details are examples of enhancement operations. For example, an image might be taken of an endothelial cell, which might be of low contrast and somewhat blurred. Reducing the noise and blurring and increasing the contrast range could enhance the image. The original image might, have areas of very high and very low intensity, which mask details. An adaptive enhancement algorithm reveals these details. Adaptive algorithms adjust their operation based on the image information (pixels) being processed. In this case the mean intensity, Contrast and sharpness (amount of blur removal) could be adjusted based on the pixel intensity statistics in various areas of the image. There exist many techniques that can enhance a digital image without spoiling it.

Manuscript published on 30 June 2012.
***** Correspondence Author (s)
Aditya Goyal, Computer Science and Engineering, Uttarakhand Technical University/ Dehradun Institute of Technology / Dehradun, India.
Akhilesh Bijalwan, Computer Science and Engineering, Uttarakhand Technical University/ Dehradun Institute of Technology / Dehradun, India.
Pradeep Kumar, Information Security and Management, Uttarakhand Technical University/ Dehradun Institute of Technology / Dehradun, India.
Mr. Kuntal Chowdhury, Computer Science and Engineering, Uttarakhand Technical University/ Dehradun Institute of Technology / Dehradun, India.

The image enhancement methods can broadly be divided in to the following two categories:

1. Spatial Domain Methods
2. Frequency Domain Methods

In spatial domain techniques [1], we directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. In frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier Transform of the image is computed first. All the enhancement operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. These enhancement operations are performed in order to modify the image brightness, contrast or the distribution of the grey levels. As a consequence the pixel value (intensities) of the output image will be modified according to the transformation function applied on the input values.

Image enhancement is applied in every field where images are ought to be understood and analyzed. For example, medical image analysis, analysis of images from satellites etc. Image enhancement simply means, transforming an image f into image g using T. (Where T is the transformation. The values of pixels in images f and g are denoted by r and s, respectively. As said, the pixel values r and s are related by the expression,

$$s = T(r) \qquad (1)$$

Where T is a transformation that maps a pixel value r into a pixel value s. The results of this transformation are mapped into the grey scale range as we are dealing here only with grey scale digital images. So, the results are mapped back into the range [0, L-1], where L=2k, k being the number of bits in the image being considered. So, for instance, for an 8-bit image the range of pixel values will be [0, 255].

We will consider only gray level images. The same theory can be extended for the color images too. A digital gray image can have pixel values in the range of 0 to 255.

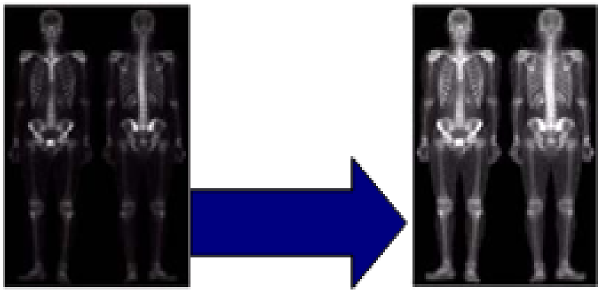


Figure1. Showing the effect of Image Enhancement.

Many different, often elementary and heuristic methods [2] are used to improve images in some sense. The problem is, of course, not well defined, as there is no objective measure for image quality. Here, we discuss a few recipes that have shown to be useful both for the human observer and/or for machine recognition [4]. These methods are very problem-oriented: a method that works fine in one case may be completely inadequate for another problem. In this paper basic image enhancement techniques have been discussed with their mathematical understanding. This paper will provide an overview of underlying concepts, along with algorithms commonly used for image enhancement. The paper focuses on spatial domain techniques for image enhancement, with particular reference to point processing methods, histogram processing.

II. RELATED WORK

A. Grey Scale Manipulation

The simplest spatial domain operations occur when the neighborhood is simply the pixel itself. In this case *T* is referred to as a grey level transformation function or a point processing operation. Point processing operations take the form shown in equation (1)

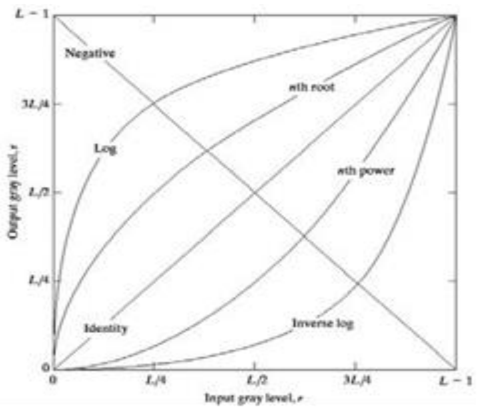


Figure 2. Showing basic grey level transformations.

B. Thresholding Transformations

Thresholding transformations [3] are particularly useful for segmentation in which we want to isolate an object of interest from a background as shown in figure below.

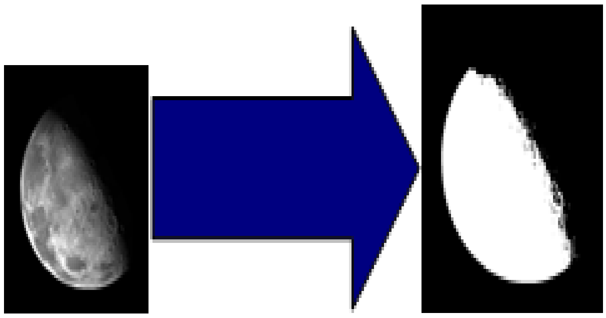
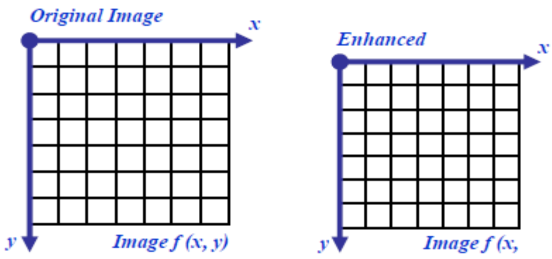


Figure 3. Showing effect of thresholding transformation for isolating object of interest.



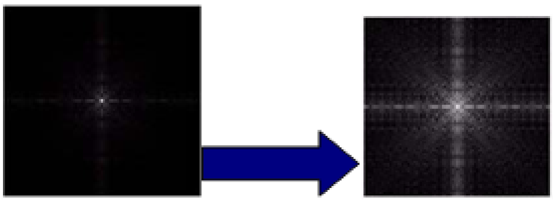
$$S = \begin{cases} 1.0 & r > threshold \\ 0.0 & r <= threshold \end{cases}$$

C. Logarithmic Transformations

The general form of the log transformation [11] is

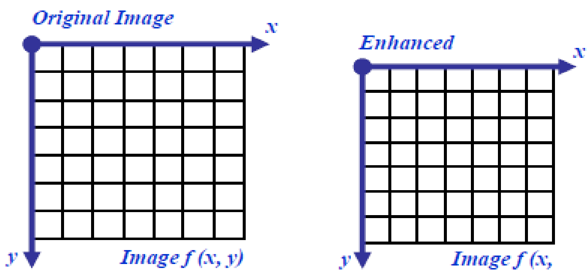
$$s = c * \log(1 + r) \qquad (2)$$

The log transformation maps [5] a narrow range of low input grey level values into a wider range of output values. The inverse log transformation performs the opposite transformation. Log functions are particularly useful when the input grey level values may have an extremely large range of values. In the following example the Fourier transform [11] of an image is put through a log transform to reveal more detail.



s = log (1 + r)

Figure4. Example showing effect of Logarithmic transformation.



$$s = \log(1 + r) \qquad (3)$$

We usually set *c* to 1. Grey levels must be in the range [0.0, 1.0]

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

D. Histogram Equalization

Histogram equalization [9] is a common technique for enhancing the appearance of images. Suppose we have an image which is predominantly dark. Then its histogram would be skewed towards the lower end of the grey scale and all the image detail is compressed into the dark end of the histogram. If we could `stretch out' the grey levels at the dark end to produce a more uniformly distributed histogram then the image would become much clearer.

The histogram of a digital image with intensity levels in the range [0, L-1] is a discrete function:-

$$h(r_k) = n_k$$

Histograms are frequently normalized by the total number of pixels in the image. Assuming an M x N image, a normalized histogram is related to probability of occurrence of *rk* in the image.

$$p(r_k) = \frac{n_k}{MN}, \quad k=0,1\ldots\ldots L-1$$

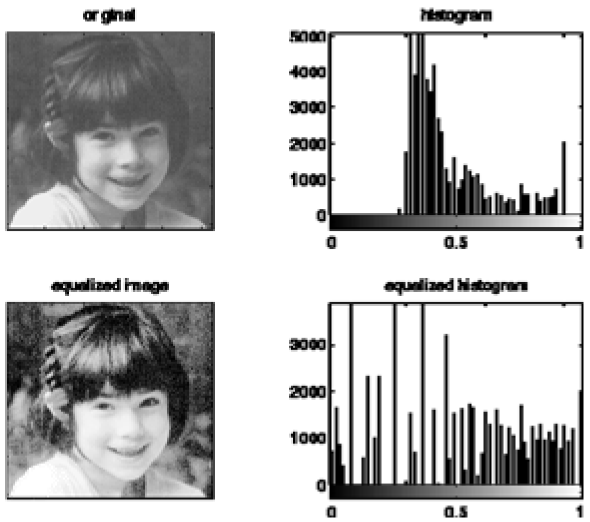


Figure 5. The original image and its histogram, and the equalized versions. Both images are quantized to 64 grey levels.

E. High Boost Filtering

We can think of high pass filtering [10] in terms of subtracting a low pass image from the original image, that is,

High pass = Original − Low pass.

However, in many cases where a high pass image is required, we also want to retain some of the low frequency components to aid in the interpretation of the image. Thus, if we multiply the original image by an amplification factor A before subtracting the low pass image, we will get a high boost or high frequency emphasis filter. Thus,

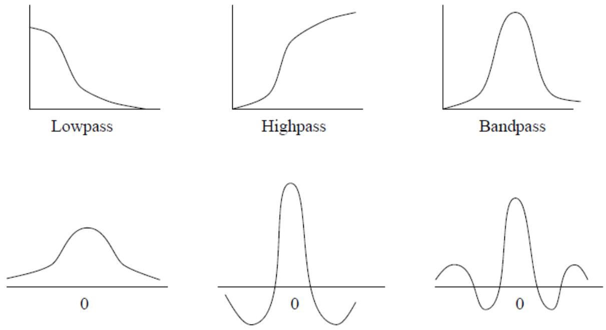


Figure 6: Frequency domain filters (top) and their corresponding spatial domain counter- parts (bottom).

High boost= A.Original − Low pass

= (A − 1). (Original) + Original − Low pass

= (A − 1).Original + High pass.

Now, if A = 1 we have a simple high pass filter. When A > 1 part of the original image is retained in the output.

A simple filter for high boost filtering is given by

$$\begin{array}{ccc} -1/9 & -1/9 & -1/9 \\ -1/9 & \omega/9 & -1/9 \\ -1/9 & -1/9 & -1/9 \end{array}$$

where $\omega = 9A - 1$.

F. Low Pass Filtering

Low pass filtering [8] involves the elimination of the high frequency components in the image. It results in blurring of the image (and thus a reduction in sharp transitions associated with noise). An ideal low pass filter (see Figure 7) would retain all the low frequency components, and eliminate all the high frequency components. However, ideal filters suffer from two problems: blurring and ringing [7]. These problems are caused by the shape of the associated spatial domain filter, which has a large number of undulations. Smoother transitions in the frequency domain filter, such as the Butterworth filter, achieve much better results.

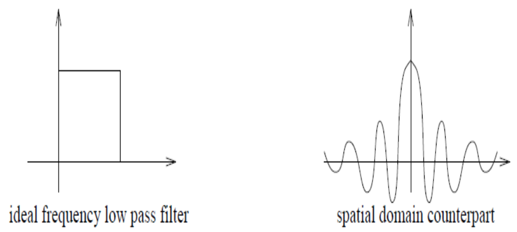


Figure 7: Transfer function for an ideal low pass filter.

G. Homomorphic Filtering

Images normally consist of light reflected from objects. The basic nature of the image F (x, y) may be characterized by two components: the amount of source light incident on the scene being viewed, and the amount of light reflected by the objects in the scene. These portions of light are called the illumination and reflectance components, and are denoted i(x, y) and r(x, y) respectively. The functions i and r combine multiplicatively to give the image function F:-

$$F(x, y) = i(x, y)r(x, y),$$

where $0 < i(x, y) < \infty$ and $0 < r(x, y) < 1$.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

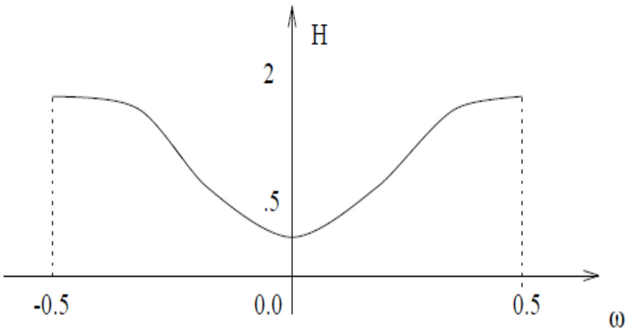


Figure 8: Transfer function for homomorphic filtering.

III. GUIDED IMAGE FILTER

Guided image filter [6] is an explicit image filter, derived from a local linear model; it generates the filtering output by considering the content of a guidance image, which can be the input image itself or another different image. Moreover, the guided filter has a fast and non-approximate linear-time algorithm, whose computational complexity is independent of the filtering kernel size. The guided filter output is locally a linear transform of the guidance image. This filter has the edge-preserving [12] smoothing property like the bilateral filter, but does not suffer from the gradient reversal artifacts. It is also related to the matting Laplacian matrix, so is a more generic concept and is applicable in other applications beyond the scope of "smoothing". Moreover, the guided filter has an O(N) time (in the number of pixels N) exact algorithm for both gray-scale and color images. Experiments show that the guided filter performs very well in terms of both quality and efficiency in a great variety of applications, such as noise reduction, detail smoothing/enhancement, HDR compression, image matting/feathering, haze removal, and joint up sampling.

A. Guided Filter Kernel

We first define a general linear translation- variant filtering process, which involves a guidance image I, an input image p, and output image q. Both I and p are given beforehand according to the application, and they can be identical.

The filtering output at a pixel I is expressed as a weighted average:-

$$q_i = \sum_j W_{ij}(I)\, p_j. \qquad (4)$$

Where i and j are pixel indexes. The filter kernel Wij is a function of the guidance image I and independent of p. This filter is linear with respect to p.

The guided filtering kernel W_{ij} is given by:-

$$W_{ij}(I) = \frac{1}{|\omega|^2} \sum_{k:(i,j)\in\omega_k} \left(1 + \frac{(I_i-\mu_k)(I_j-\mu_k)}{\sigma_k^2+\epsilon}\right) \qquad (5)$$

Where I is guidance image, p is input image, q is output image, W_{ij} is filter kernel, σ is variance, K_i is normalizing parameter, W_k is window centered at pixel k and μ_k is mean of I.

B. Guided Filter Algorithm:-

1. Read the image say I (gray scale image), it acts as a guidance image.
2. Make p=I, where p acts as our filtering image (gray scale image).
3. Enter the values assumed for r and eps, where r is the local window radius and eps is the regularization parameter.
4. Compute the mean of I, p, I*p.
5. The compute the covariance of (I,p) using the formula:-
   cov_Ip = mean_Ip - mean_I .* mean_p;
6. Then compute the mean of (I*I) and use it to compute the variance using the formula:-
   var_I = mean_II - mean_I .* mean_I
7. Then compute the value of a, b. where a,b are the linear coefficents.
8. Then compute mean of both a and b.
9. Finally obtain the filtered output image q by using the mean of a and b in the formula
   q = mean_a .* I + mean_b;
10. Display the output along with the input image, compare the output with other linear and nonlinear filters.
11. Use MSE and PSNR as performance measures to display the comparisons.

IV. RESULT AND DISCUSSION

We implement image enhancement aspect of guided image filtering. We also show comparisons with other linear and nonlinear filters use various performance measures to depict the comparison result in tabular form. Principle objective of Image enhancement is to process an image so that result is more suitable than original image for specific application. When we compare image enhancement using guided filter with other linear and nonlinear filters for gray scale images we find that the guided filter is both effective and efficient and the MSE and PSNR parameters also shows that guided filter performs well as compared to others. Moreover, the guided filter has a fast and non-approximate linear-time algorithm, whose computational complexity is independent of the filtering kernel size.

A. Image Enhancement Using Guided Filter:-

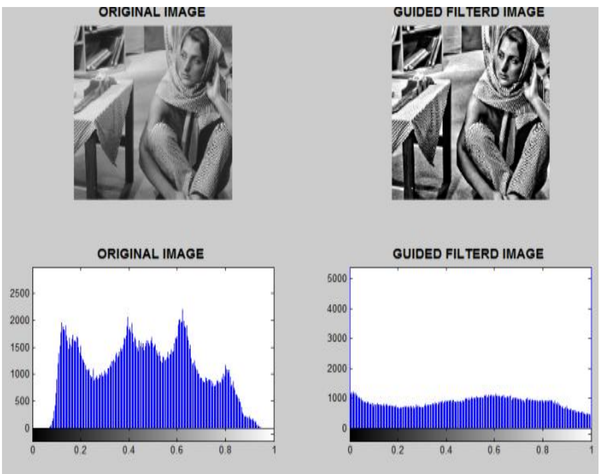


Figure 9: Guided filtering output for Barbara image.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

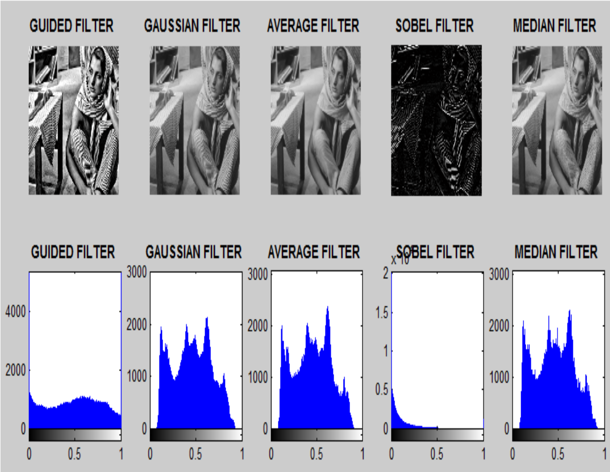
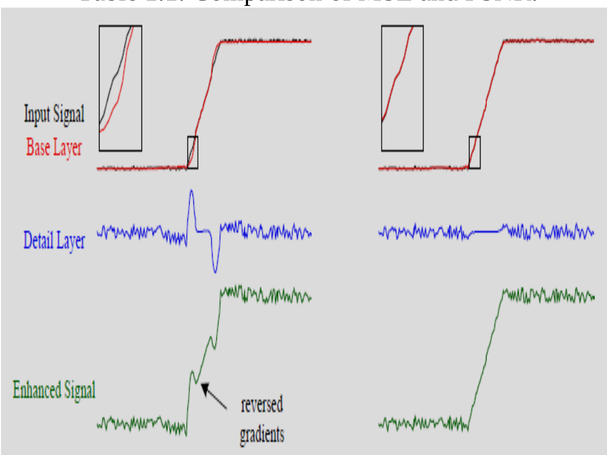


Figure 10: Comparison of Guided, linear and nonlinear filters.

Table1.1 shows the comparison of MSE and PSNR performance measures for image enhancement using Guided filter, linear and nonlinear filters on gray scale images.

Performance Measures	**Methods**				
	Gaussian filter	Average filter	Sobel filter	Median filter	Guided image filter
MSE	0.0071	0.0504	5.338	0.0458	0.0015
PSNR	21.48	12.98	-7.28	13.4	28.26

Table 1.1: Comparison of MSE and PSNR.



Other filters Guided filter

Figure 11. 1-D Illustration for Image Enhancement.

V. CONCLUSION

Image enhancement algorithms offer a wide variety of approaches for modifying images to achieve visually acceptable images. The choice of such techniques is a function of the specific task, image content, observer characteristics, and viewing conditions. The histogram of an image (i.e., a plot of the gray- level frequencies) provides important information regarding the contrast of an image. As a locally based operator, the guided filter is not directly applicable for sparse inputs like strokes. It also shares a common limitation of other explicit filter - it may have halos near some edges. The guided filter has a fast and non-approximate linear-time algorithm, whose computational complexity is independent of the filtering kernel size. Although we did not discuss the computational cost of enhancement algorithms in this article it may play a critical role in choosing an algorithm for real-time applications. Despite the effectiveness of each of these methods when applied separately, in practice one has to devise a combination of such methods to achieve more effective image enhancement. We believe that the simplicity and efficiency of the guided filter still make it beneficial for image enhancement.

REFERENCES

[1] Bhabatosh Chanda and Dwijest Dutta Majumder, 2002, Digital Image Processing and Analysis.
[2] R.W.Jr. Weeks,(1996). Fundamental of Electronic Image Processing. Bellingham: SPIE Press.
[3] A. K. Jain, Fundamentals of Digital Image Processing.Englewood Cliffs, NJ: Prentice Hall, 1989.
[4] R.M. Haralick, and L.G. Shapiro, Computer and RobotVision, Vol-1, Addison Wesley, Reading, MA, 1992.
[5] R. Jain, R. Kasturi and B.G. Schunck, Machine Vision, McGraw-Hill International Edition, 1995.
[6] Hek., sun j., tang x.: Guided image filtering. In Proc. of the European Conference on Computer Vision (2010), vol. 1, pp. 1–14.
[8] Xing-fang huang; jiang-she zhang.: Edge-Preserving Filtering for Grey and Color Image. In Proc. of the IEEE / Computer Science and Information Engineering, (2009), vol. 5, pp. 139-143.
[9] R Hummel, “Histogram modification techniques“, Computer Graphics and Image Processing, Vol. 4, pp. 209-224, 1975.
[10] S. E. Umbaugh, “Computer Vision & Image Processing,”Prentice Hall PTR, 1998
[11] Rafael C. Gonzalez and Richard E. Woods. Digital Image Processing. Addison-Wesley Publishing Company, 2010, chapter 4.
[12] Pablo Bauszat, Martin Eisemann and Marcus Magnor.: Guided Image Filtering for Interactive High-quality Global Illumination. In The Eurographics Association and Blackwell Publishing Ltd.(2011) volume 30 number 4.

Aditya Goyal, B.Tech (IT), MBA (Marketing) and pursuing M.Tech (CSE) from Dehradun Institute of Technology Dehradun.
Akhilesh Bijalwan, M.Sc (IT) and pursuing M.Tech (CSE) from Dehradun Institute of Technology Dehradun.
Pradeep Kumar, B.Tech and pursuing M.Tech (ISM) from Dehradun Institute of Technology Dehradun.
Mr. Kuntal Chowdhury, Assistant Professor, Dehradun Institute of Technology, Dehradun.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)