RESEARCH ARTICLE

Comparative Analysis and Implementation of Image Enhancement Techniques Using MATLAB

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Abstract— Image Enhancement Is As Much An Art As It Is A Science." Image enhancement is one of the key issues in high quality pictures such as digital cameras. The main purpose of image enhancement is to bring out detail that is hidden in an image or to increase contrast in a low contrast image. This technique provides a multitude of choices for improving the visual quality of images. This is the main reason that image enhancement is used in a huge number of applications with important challenges such as noise reduction, degradations, blurring etc. 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 and on spatial filtering.

Key Terms: - Digital Image Processing; Histogram; Image Enhancement; Image restoration; MSE; PSNR; Spatial and Frequency Domain

I. INTRODUCTION

A. Image Enhancement

Image enhancement is to improve the interpretability or perception of information in the images to provide better input for other automated image processing steps. The image acquired from natural environment with high dynamic range includes both dark and bright regions. Due to exceed in dynamic range of human eyes sensing, those images are difficult to perceive by human eyes. Image enhancement is a common approach to improve the quality of those images in terms of human visual perception. Enhancement techniques can be divided into two categories namely:

- Spatial domain methods
- Transform domain methods.

Spatial domain technique enhances an image by directly dealing with the intensity value in an image.

Transform domain enhancement techniques involve transforming the image intensity data into a specific domain by using methods such as DFT, DCT, etc. and the image is enhanced by altering the frequency content of the image.

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,

$s = T(r)$ ………………(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 $L=2^k$, 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].
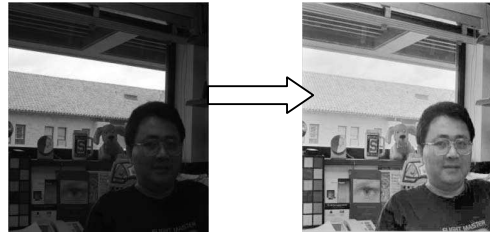

Figure 1. Showing the effect of Image Enhancement

This paper provides an overview of underlying concepts along with the algorithms commonly used for image enhancement and focuses on spatial domain techniques for image enhancement, with particular reference to point processing methods.

B. Image Restoration

Image restoration refers to removal or minimization of known degradations in an image. This includes de-blurring of images degraded by the limitations of a sensor or its environment, noise filtering and correction of non-linearities due to sensors. Image restoration is a process that attempts to reconstruct and recover an image that has been degraded by using the phenomenon of degradation. In this technique an inverse process is used to restore the original image. This technique involves formulating certain criteria of goodness that gives the optimal estimate of the desired result.

The objective of restoration is to obtain an estimate $\hat{f}(x,y)$ of the original image. We want to estimate to be as close as possible to the original input image and in general the more we know about H and η, the closer $f^\wedge(x,y)$ will be to f(x,y). If H is a linear position-invariant process, then the degraded image is given the spatial domain by:

$$g(x,y)= h(x,y)*f(x,y)+ \eta(x,y)\ldots\ldots\ldots\ldots..(2)$$

where h(x,y) is the spatial representation of the degradation function and the symbol * indicates spatial convolution,

g(x,y) is the degraded image and η(x,y) is the noise term.

In Frequency Domain, Equation(2) can be written as:

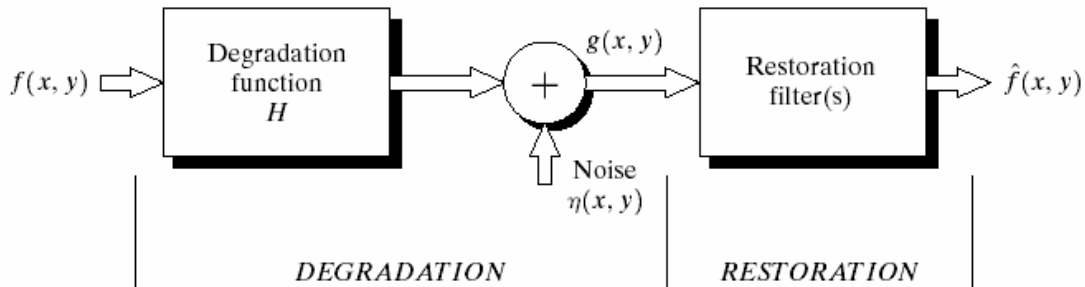$$G(u,v)= H(u,v)F(u,v)+N(u,v)\ldots\ldots\ldots\ldots..(3)$$

Figure 2: A model of the image degradation/restoration process

II. IMAGE ENHANCEMENT TECHNIQUES

A. Gray level transformations

The dynamic range of an image is defined as the difference between the smallest and largest pixel values within the image. We can define certain functional transforms or mappings that alter the effective use of the dynamic range. These transforms are primarily applied to improve the contrast of the image. This improvement is achieved by altering the relationship between the dynamic range of the image and the grey-scale (or color) values that are used to represent the values.

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a) Image Negative:- The most basic and simple operation in digital image processing is to compute the negative of an image. The pixel gray values are inverted to compute the negative of an image. For example, if an image of size R x C, where R represents number of rows and C represents number of columns, is represented by I(r, c). The negative N(r, c) of image I(r, c) can be computed as:

$$N(r, c) = 255 - I(r, c)\ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

where $0 <= r <= R$ and $0 <= c <= C$

It can be seen that every pixel value from the original image is subtracted from the 255. The resultant image becomes negative of the original image. Negative images are useful for enhancing white or grey detail embedded in dark regions of an image.
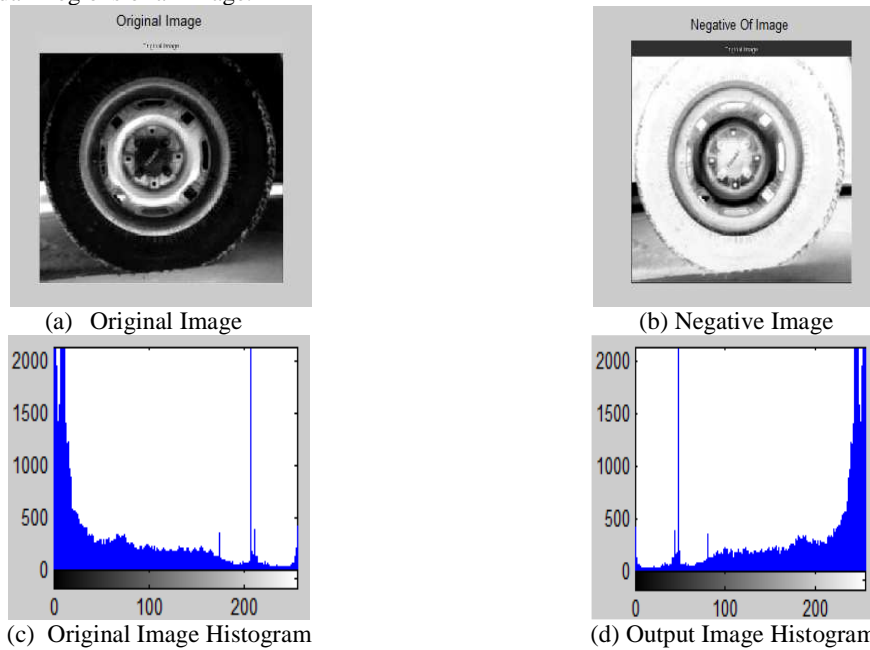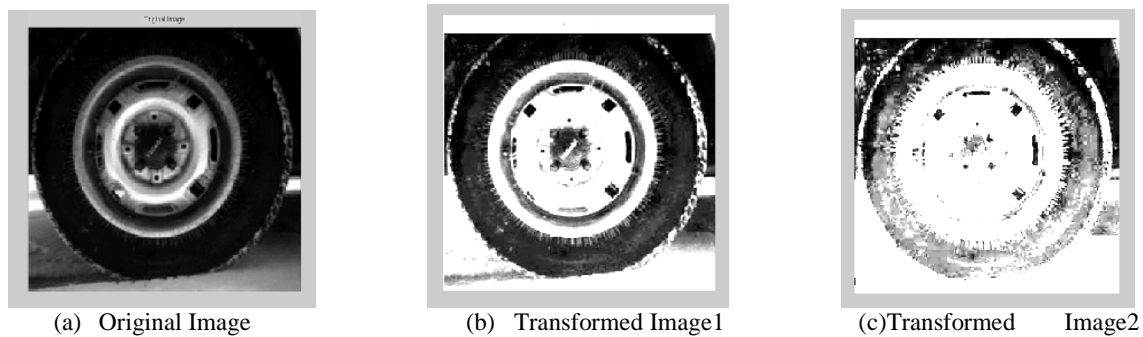

(a) Original Image	(b) Negative Image

(c) Original Image Histogram	(d) Output Image Histogram

Figure 3: Image Negation and corresponding Histograms

b) Log Transformation :- The general form of the log transformation is

$$s = c * \log(1 + r)\ldots\ldots\ldots\ldots\ldots\ldots..(5)$$

The log transformation maps a narrow range of low input grey level values into a wider range of output values. We would use this transformation to expand the values of dark pixels in an image while compressing the higher-level values. The inverse log transformation performs the opposite transformation. We usually set c to 1. Grey levels must be in the range [0.0, 1.0].
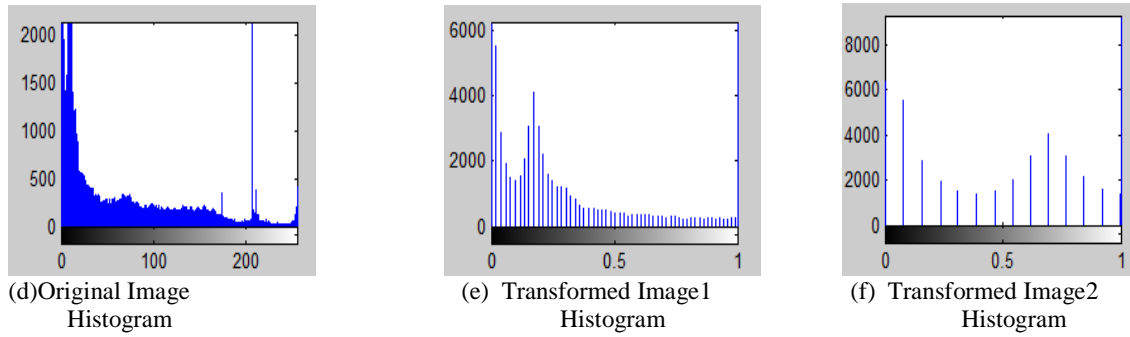

(a) Original Image	(b) Transformed Image1	(c)Transformed Image2

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(d)Original Image
Histogram

(e) Transformed Image1
Histogram

(f) Transformed Image2
Histogram

Figure 4: Log Transformation and its histograms

c) Exponential Transformation :-   The exponential transform is the inverse of the logarithmic transform. Here, the mapping function is defined by the given base e raised to the power of the input pixel value:

$$I_{output}(i,j)=e^{Iinput(i,j)} \dots\dots\dots\dots\dots\dots(6)$$

where I(i,j) is the value of a pixel at a location (i,j) in image I. This transform enhances detail in high-value regions of the image (bright) whilst decreasing the dynamic range in low-value regions (dark) – the opposite effect to the logarithmic transform. The choice of base depends on the level of dynamic range compression required. In general, base numbers just above 1 are suitable for photographic image enhancement.

$$I_{output}(i,j)=c[(1+\alpha)^{Iinput(i,j)} -1]\dots\dots\dots.(7)$$

Here, (1+α) is the base and c is the scaling factor required to ensure the output lies in an appropriate range. As is apparent when $I_{output}(i,j)=0$, this results in $I_{output}(i,j)=c$ unless we add in the -1 to counter this potential offset appearing in the output image.
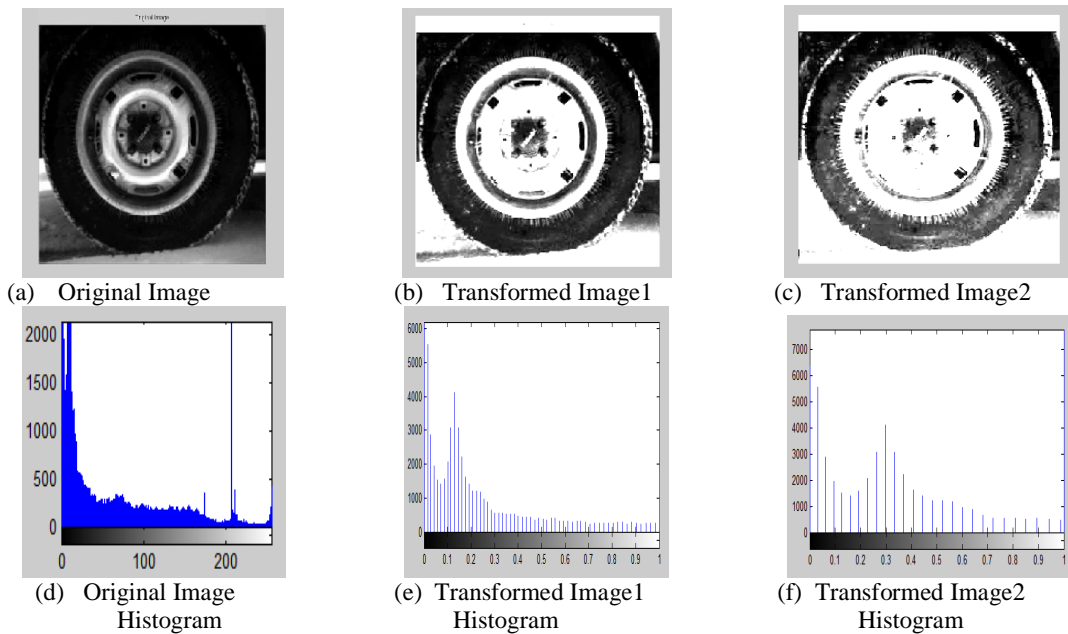

(a)   Original Image

(b)   Transformed Image1

(c)   Transformed Image2

(d)   Original Image
Histogram

(e)   Transformed Image1
Histogram

(f)   Transformed Image2
Histogram

Figure 5: Exponential Transformation and its histograms

d) Power-law Transformation: An alternative to both the logarithmic and exponential transforms is the 'raise to a power' or power-law transform in which each input pixel value is raised to a fixed power:

$$I_{output}(i,j)=c(I_{output}(i,j))^{\gamma}\dots\dots\dots\dots\dots\dots\dots(8)$$

Where c and γ are constants, a value of γ > 1 enhances the contrast of high-value portions of the image at the expense of low-value regions, whilst we see the reverse for γ< 1. This gives the power-law transform properties similar to both the logarithmic (γ < 1) and exponential (γ > 1) transforms. The constant c performs range scaling.
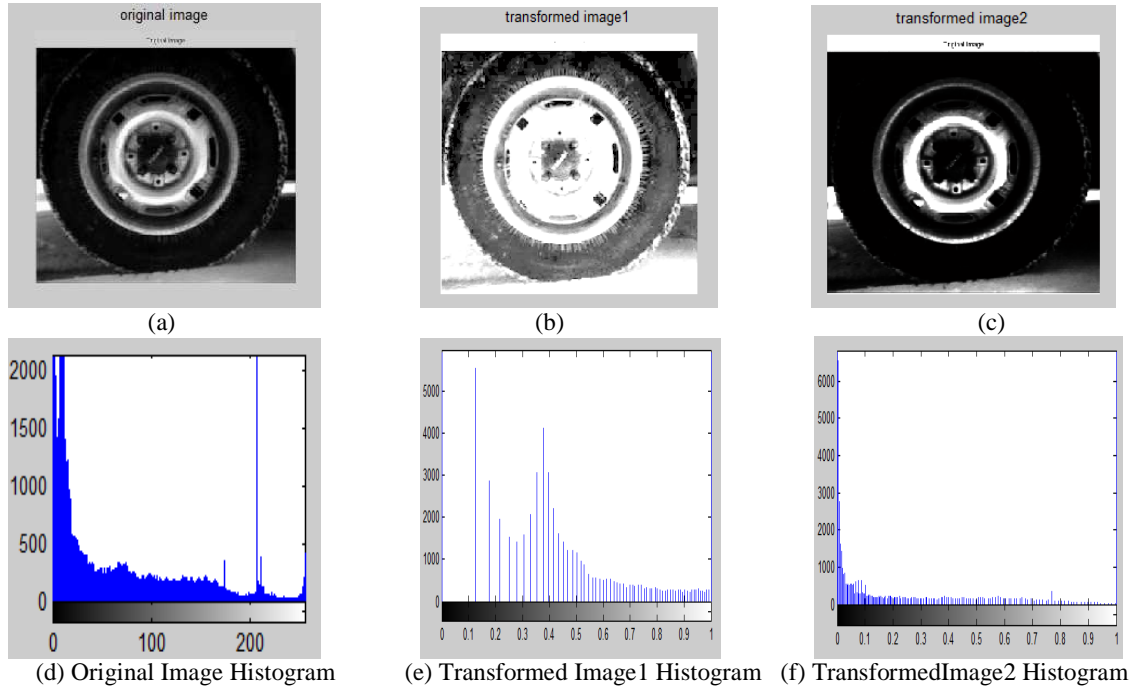
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Figure 6: Power- Law Transformations and its corresponding histograms

e). Gray Level Slicing:- Its purpose is to highlight a specific range of gray values. For this, fixed threshold values are taken. Two different approaches can be adopted for this. They are:

i.   Gray-Level Slicing Without Preserving Background:- This displays high values for range of interest and low values in other areas. The main drawback of this approach is that the background information is discarded.

ii. Gray-Level Slicing with Background:-Its objective is to display high values for the range of interest and original gray level values in other areas. It preserves the background of an image.
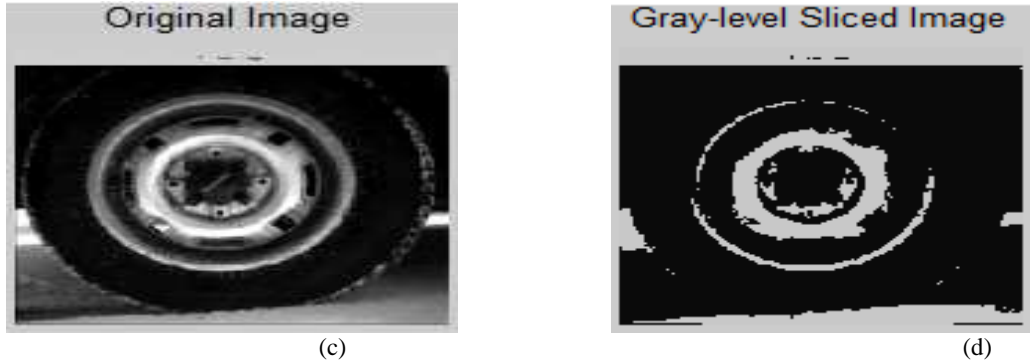
(c)   (d)
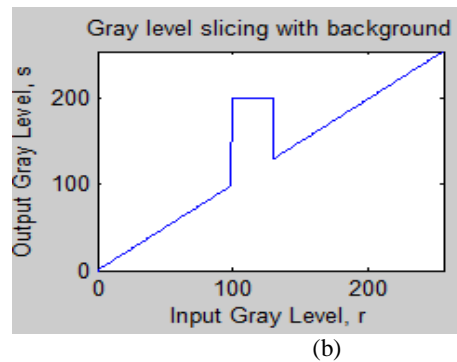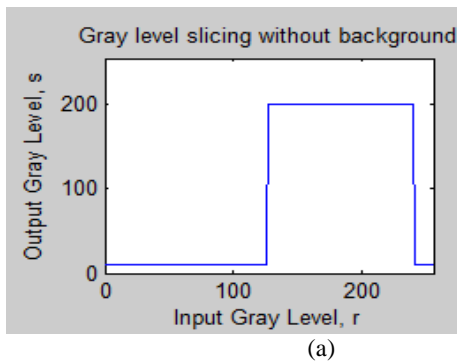
Figure 7: Gray- Level Slicing

f). Contrast Enhancement:- This is one of the simplest piecewise linear function. Low contrast images can result from poor illumination, lack of dynamic range in image sensor or even wrong setting of lens aperture during image acquisition. The idea behind this technique is to increase the dynamic range of gray levels in the image being processed.
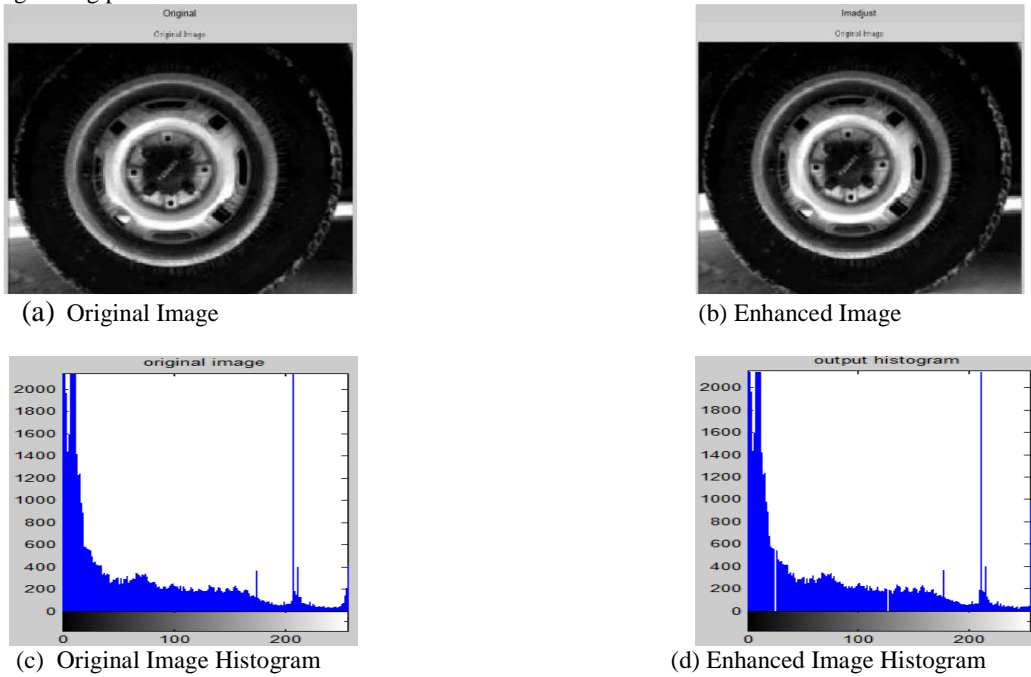

(a) Original Image   (b) Enhanced Image

(c) Original Image Histogram   (d) Enhanced Image Histogram

Figure 8: Contrast Enhancement and its corresponding histograms

B.   Spatial Filtering

a) Mean Filter:- The mean filter is perhaps the simplest linear filter and operates by giving equal weight to all pixels in the neighborhood. A weight of $W_k=1/(NM)$ is used for an N×M neighborhood and has the effect of smoothing the image, replacing every pixel in the output image with the mean value from its N×M neighborhood. Mean filters can be used as a method to suppress noise in an image. Mean Filters works well for Salt noise but fails for pepper noise.

b) Median Filter:- Median filtering overcomes the main limitations of the mean filter, but at the expense of greater computational cost. As each pixel is addressed, it is replaced by the statistical median of N×M neighborhood rather than the mean. The median filter is superior to the mean filter in that it is better at preserving sharp high-frequency detail (i.e. edges) whilst also eliminating noise, especially isolated noise spikes (such as 'salt and pepper' noise). The median operator requires an ordering of the values in the pixel neighborhood at every pixel location. This increases the computational requirement of the median operator.
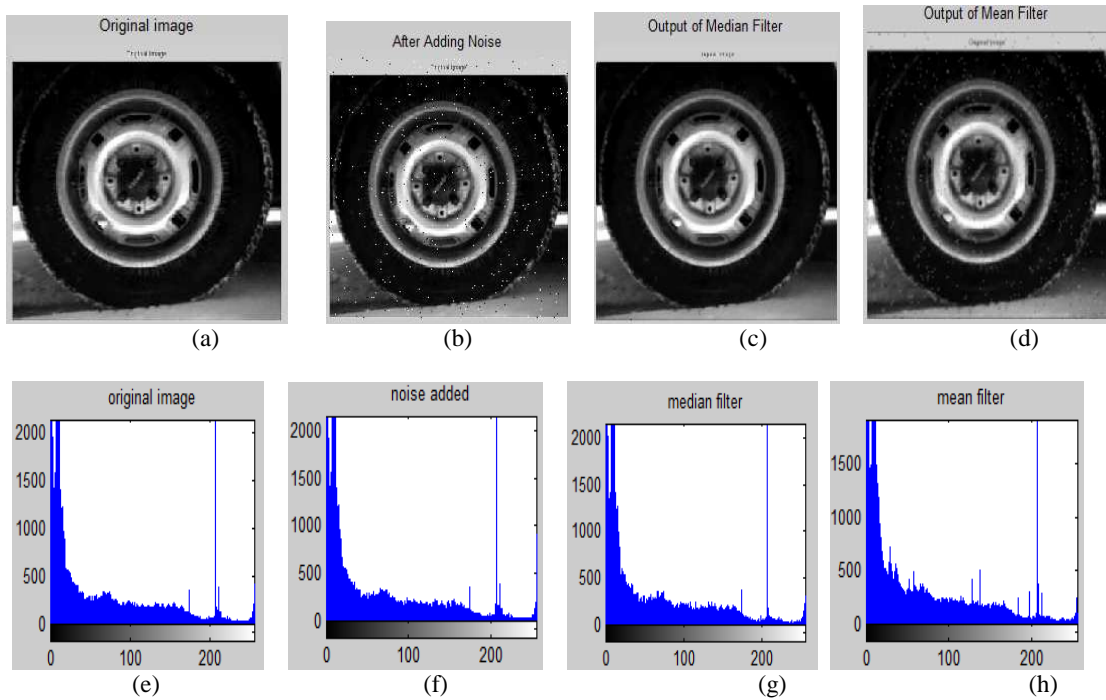
(a) (b) (c) (d)

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

Figure 9: (a) Original Image (b) Noise Added Image (c) Median Filter Output   (d) Mean Filter Output
AND Corresponding histograms fig.(e-h).

III. PERFORMANCE ANALYSIS

The PSNR block computes the peak signal-to-noise ratio, in decibels, between two images. This ratio is often used as a quality measurement between the original and a compressed image. The higher the PSNR, the better the quality of the compressed or reconstructed image.

The Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR) are the two error metrics used to compare image compression quality. The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. The lower the value of MSE, the lower the error. To compute the PSNR, the block first calculates the mean-squared error using the following equation:

$$MSE = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N} \qquad \ldots\ldots\ldots\ldots(9)$$

In the previous equation, *M* and *N* are the number of rows and columns in the input images, respectively. Then the block computes the PSNR using the following equation:

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

Table1: Comparison of Different Measuring Parameters for an image

Sr. No.	Technique	MSE	PSNR
1	Image Negation	3.7355e+004	2.4073
2	Log transform	8.9773e+003	9.0046
3	Exponential transform	6.0269	40.3298
4	Power law transform	0.4139	51.9616
5	Gray level slicing	1.5810e+003	16.1414
6	Contrast enhancement	3.4371	42.7688
7	Mean filter	362.5145	22.5375
8	Median filter	355.5241	22.6221

IV. CONCLUSION

This paper presents a short description of various image enhancement techniques in order to make familiar with the enhancement of a blurred image, noise removal, setting the brightness, contrast of images. The point processing methods are used primarily for contrast enhancement. Image Negative is suited for enhancing white detail embedded in dark regions and has applications in medical imaging. Power-law transformations are useful for general purpose contrast manipulation and for a dark image; an expansion of gray levels is accomplished using this transformation with a fractional exponent. Log Transformation is useful for enhancing details in the darker regions of the image at the expense of detail in the brighter regions the higher-level values. For an image having a washed-out appearance, a compression of gray levels is obtained using a power-law transformation with $\gamma > 1$. The histogram of an image (i.e., a plot of the gray level frequencies) provides important information regarding the contrast of an image. Filters are used to remove noise from an image. Mean filter suppress Gaussian noise well and the median filter is best suited for removing salt and pepper noise as compared to mean filter.

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