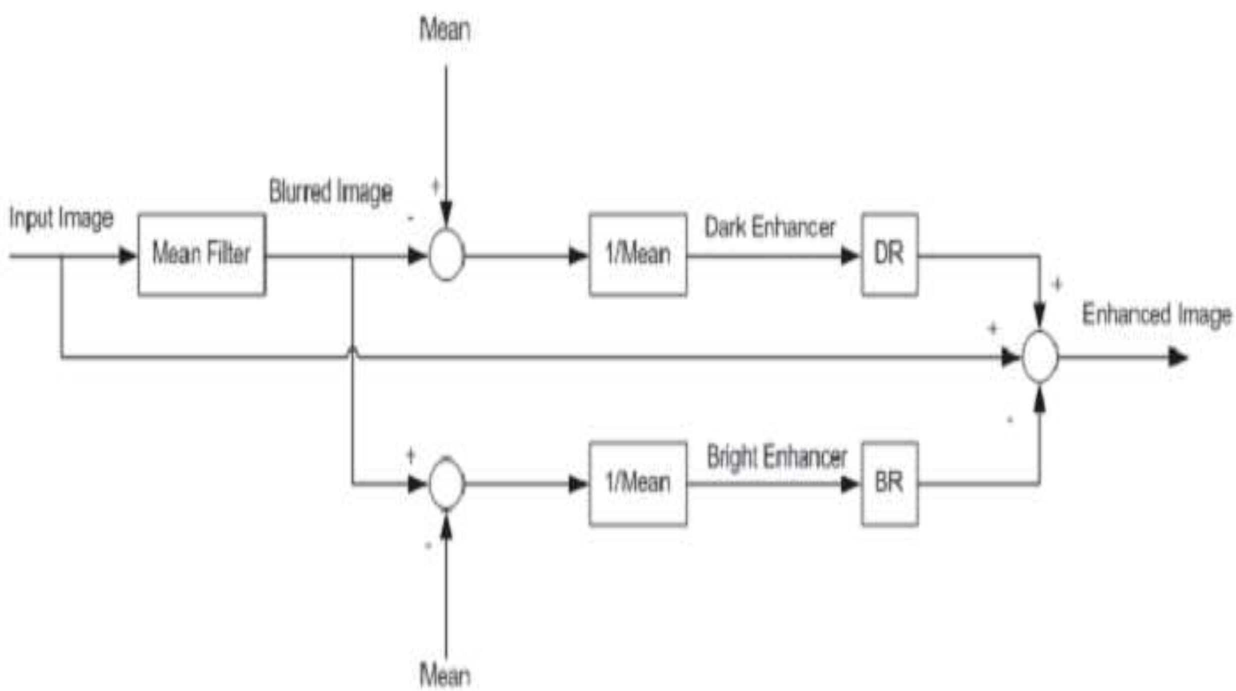
<u>Histogram based Image Enhancement for non-uniformly illuminated low Contrast Image</u>

Proposed Algorithm

In this section, we present the details of the proposed contrast enhancement algorithm. As shown in Figure 1, this technique starts with the blurring of the input image. Then, the blurred images produced are employed to derive two enhancers (i.e., bright and dark enhancers), which play important roles in enhancing the given input images. Finally, the image enhanced by two enhancers is stretched uniformly to improve the contrast.



Histogram based Image Enhancement for non-uniformly illuminated low Contrast Image

A. Image blurring

Prior to the construction of the mentioned enhancers, the given input image needs to be blurred in order to remove details contained. This is because the purposes of introducing both enhancers into the proposed algorithm are to increase and decrease the intensity levels of low and high brightness areas, respectively. If the details of enhancer are not removed, then the details of the output image tends to be removed. For example, the eyes would be low intensity level details of a face. The enhancer with details would increase the intensity level of the eyes and reduce the intensity level of the face. Finally, the face becomes darker but the eyes become brighter, which results the contrast of the face and the eyes become lower as in Figure 2b. In this paper, mean filter is used to blur the input image.

B. Derivation of enhancer

Since the main objective of the proposed algorithm is to increase the intensity levels of low intensity area and to decrease the intensity levels of high intensity area, the input image is divided into two regions: (1) bright region,(2) dark region. However, the enhancement process of these two areas is non-trivial because simply multiplying these areas with a constant tends to introduce the drastic changes in the dark and bright regions. Consequently, the resultant images with less natural and unpleasant visualization are produced. So, we construct an enhancer for each pixel by manipulating the blurred image. As shown in Equations 1 and 2, there are two types of enhancers are introduced for each image pixel, i.e., the(1) bright enhancer, BE, (2) dark enhancer, DE.

$$BE = (BI(bright) - mean)/mean \quad (1)$$

$$DE = (mean - BI(dark))/mean \quad (2)$$

where BI is the blurred image,

Histogram based Image Enhancement for non-uniformly illuminated low Contrast Image

BI (bright) is the bright region of the blurred image and BI (dark) is the dark region of the blurred image. In this paper, we use mean intensity levels of the input image to separate bright and dark regions. Specifically, the image pixels with intensity level lower than the mean intensity level are considered as dark regions, while the pixels with intensity higher than mean intensity are considered as bright regions. The mean intensity value can be calculated as follow

$$mean = \frac{\sum_{i=1}^{H} \sum_{j=1}^{W} L_{ij}}{H \times W}$$

where W and H denote the width and height of the image, respectively; Lij is the intensity level of pixel (i, j). Equations 1 and 2 produce the multiplier to enhance each pixel of input image. The pixels in bright region with higher intensity level would have higher BE, while the pixels closer to the mean intensity have BE closer to zero. So, the brighter pixels will shift more toward to mean but mean pixels will remain as mean intensity value. Opposite scenario are observed in the dark region because the pixels with higher intensity level have DE closer to zero while the pixels with lower intensity level have DE closer to one. This will cause the darker pixels shift more toward to mean but the mean pixels maintained as mean intensity value

Histogram based Image Enhancement for non-uniformly illuminated low Contrast Image

C. Enhancement of input image

Once the BE and DE enhancers for each image pixel are obtained , they are employed to enhance the input image as follow:

$IE = I + (DR \times DE \times I) - (BR \times BE \times I)$ Eq-4

Where

IE =enhanced image,

I =input image

DR =dark ratio, a constant used to adjust the increment of intensity levels in the dark region;

BR =bright ratio used to adjust the decrement of intensity in the bright region.

DR and BR are required because it is necessary to limit level of enhancement of each image to prevent over enhancement and to preserve the naturalness of each image.

In Previous equation $(DR \times DE \times I)$ is used to increase the intensity levels of low brightness areas where each pixel's intensity increased in different ratio, $(BR \times BE \times I)$ is used to reduce the intensity levels of high brightness area where each pixel's intensity decreased in different ratio. Hence, this will reduce non-uniform illumination of input image but the details of image are preserved. After Equation 4 is applied, the image IE with lower contrast is produced. This is because we have increased the intensity levels of dark regions and decreased the intensity levels of bright region.

The enhanced image Iout is finally produced by performing the contrast by ratio stretching on IE as follows:

$Iout = (IE - a) \times ((L-1) / (b-a))$

where Iout = output image;

a = minimum intensity level in the histogram;

b = maximum intensity level in the histogram;

L = total intensity level of the image, here for uint8 L=256.

Histogram based Image Enhancement for non-uniformly illuminated low Contrast Image

RESULT AND DISCUSSION

The performance of proposed algorithm is compared with Histogram Equalization (HE),available in Matlab R2013a Image Processing Toolbox .The proposed method is implemented on Intel Core i7 CPU 5500U 2.40GHz using Matlab R2013a. A non-uniformly illuminated grayscale images (size:256X256) selected from the Internet considered as test images. Both qualitative and quantitative analyses are performed to evaluate the performance of the proposed algorithm.

A. Qualatative Analysis

In this section, we evaluate the enhanced image by naked eyes. The enhanced images are evaluated visually based on the amount of information details contained in the images and naturalness of enhanced images. For the input test it can be observed that the man's face is shaded,while the background is very bright The conventional Histogram Equalizer is proven promising in improving the brightness of the man's face, but it tends to over-enhance the background. In other words, the proposed technique tends to produce the reasonable amount of illumination enhancement, while preserving the naturalness of the resultant image face .The proposed technique provides the best result in termof brightness enhancement while preserving the naturalness of the image in this test.

B. Quantitative analysis

In this subsection, we perform quantitative analysis to verify the qualitative analysis result. Two performance metrics are considered in this quantitative analysis, i.e.

a. Peak signal-to-noise ratio (PSNR)

PSNR analysis is used to compare noise level exists in the image. Considering that a good enhancement technique is expected not to amplify the existing noises, it tends to produce higher PSNR value. PSNR can be computed using equation

$$PSNR = 20log\left(\frac{L-1}{\sqrt{MSE}}\right)$$

where L- 1 is maximum gray level in the image

$$MSE = \frac{1}{WH}\sum_{i=1}^{W}\sum_{j=1}^{H}(R_{ij}-I_{ij})^2$$

Where R_{ij} = enhanced image;

I_{ij} = original image..

Histogram based Image Enhancement for non-uniformly illuminated low Contrast Image

b. Entropy(E)

Entropy is used to measure the amount of information contained in the image. The resultant image with higher entropy value implies that the corresponding enhancement technique has better details preservation capability.

Image entropy is a quantity which is used to describe the `business' of an image, i.e. the amount of information which must be coded for by a compression algorithm. Low entropy images, such as those containing a lot of black sky, have very little contrast and large runs of pixels with the same or similar DN values. An image that is perfectly flat will have an entropy of zero. Consequently, they can be compressed to a relatively small size. On the other hand, high entropy images such as an image of heavily cratered areas on the moon have a great deal of contrast from one pixel to the next and consequently cannot be compressed as much as low entropy images.

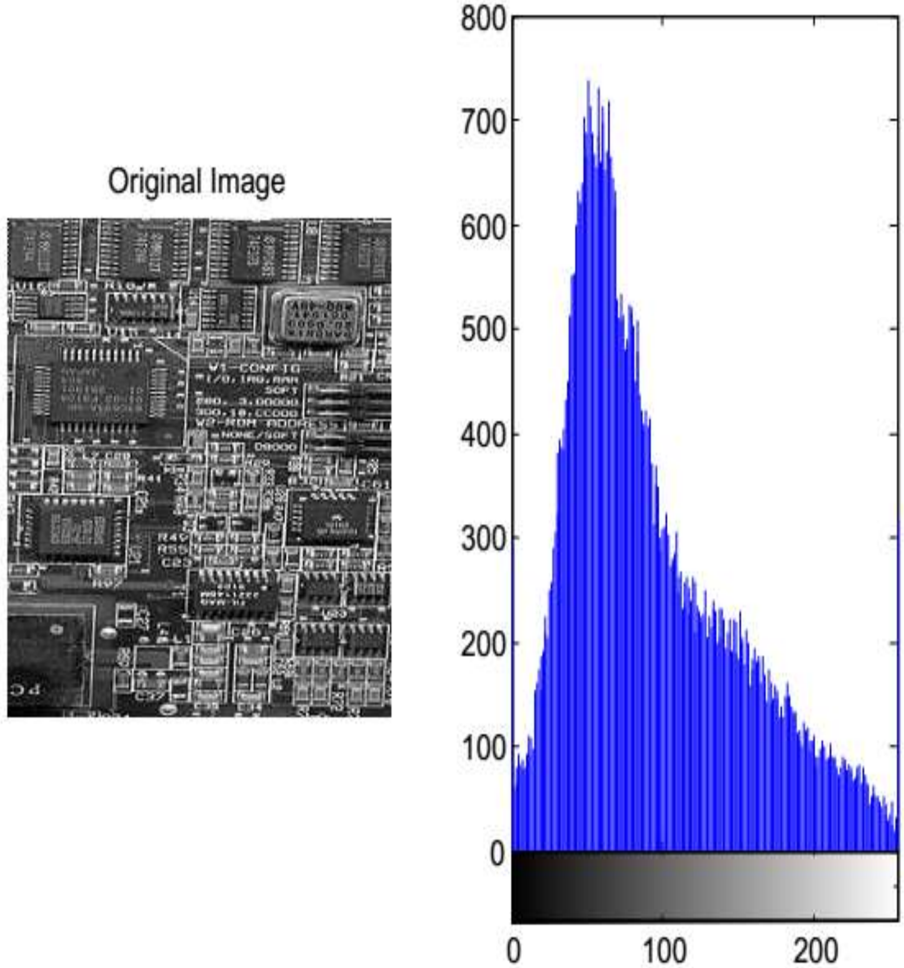
$$E = -\sum_{i=1}^{N} p(i) log_2\ p(i)$$

where p(i) is the probability of the gray levels i as observed in the images histogram

Histogram based Image Enhancement for non-uniformly illuminated low Contrast Image

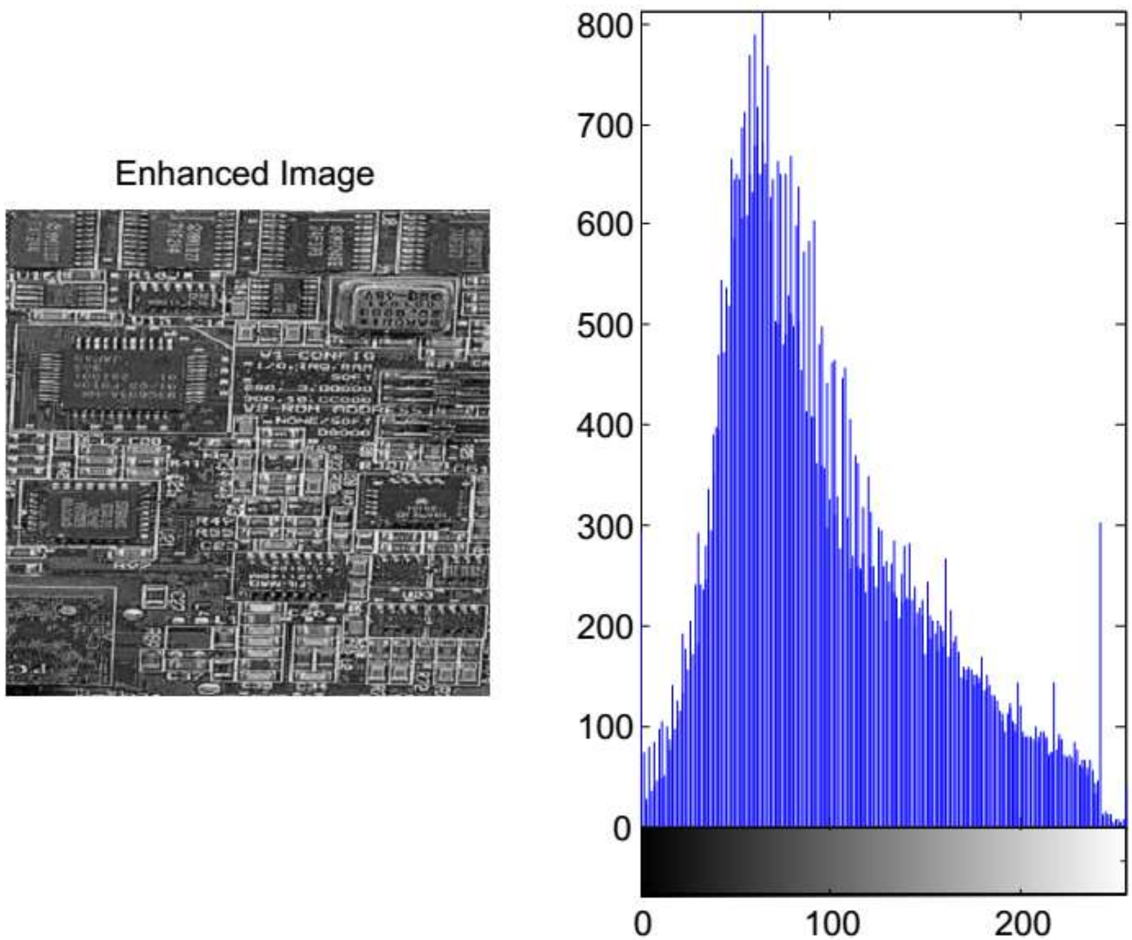
Output

A. Figure 1



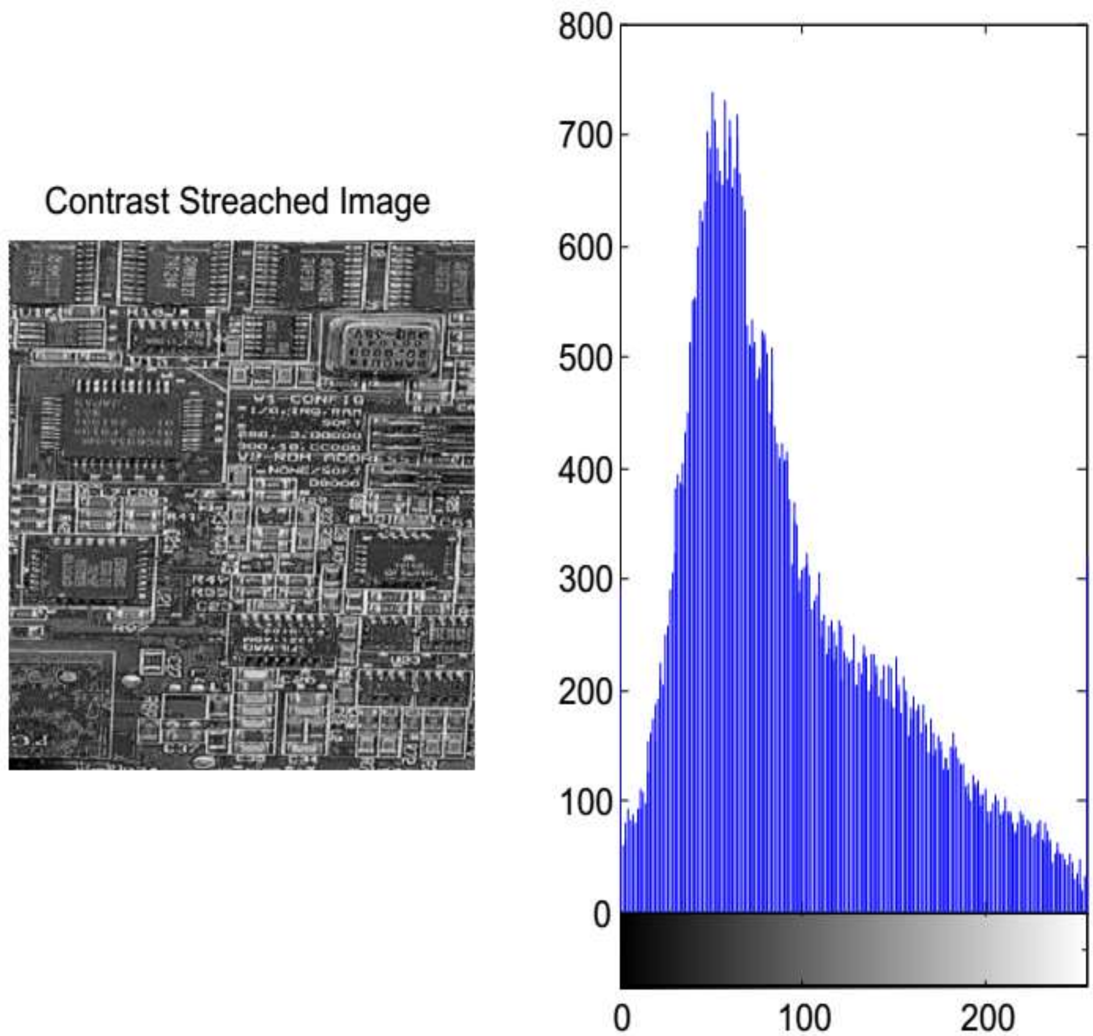
Histogram based Image Enhancement for non-uniformly illuminated low Contrast Image

B. Figure 2



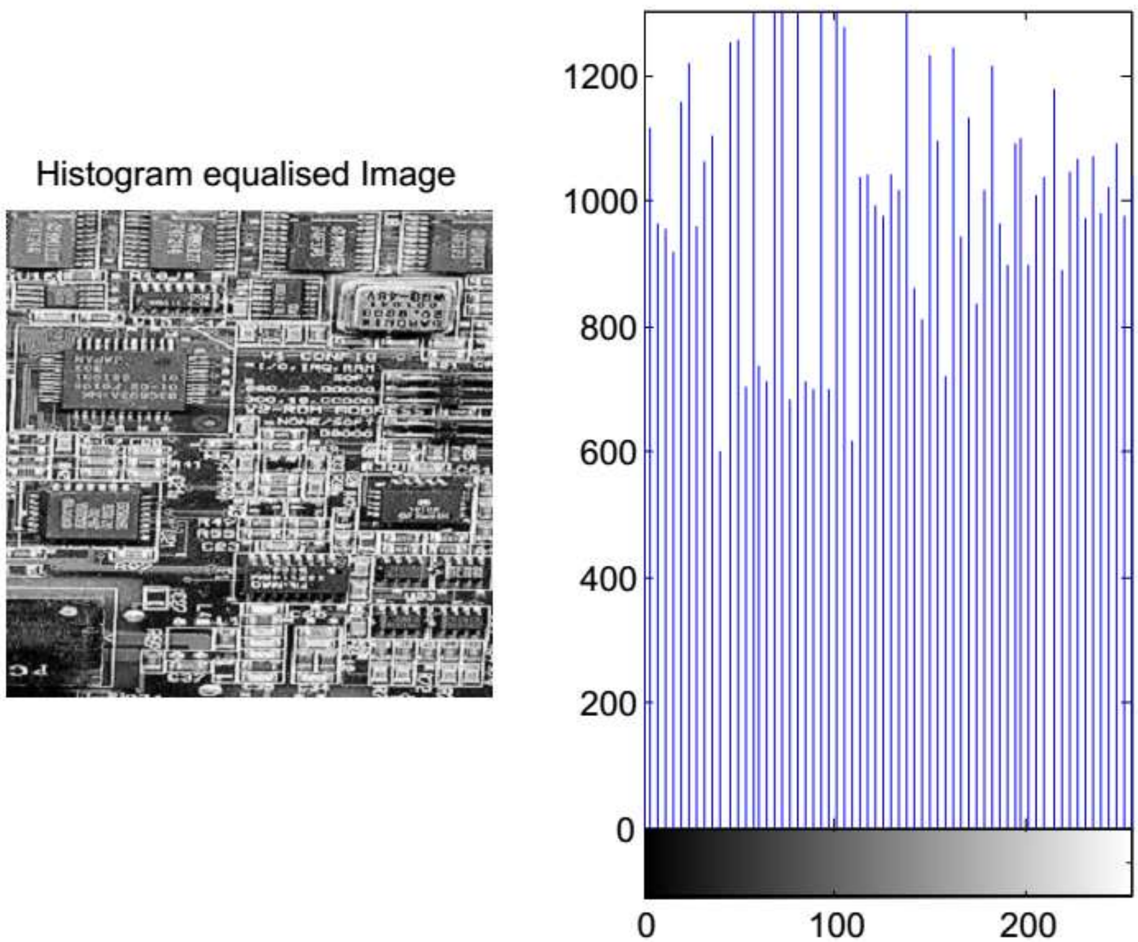
Histogram based Image Enhancement for non-uniformly illuminated low Contrast Image

C. Figure 3



<u>Histogram based Image Enhancement for non-uniformly illuminated low Contrast Image</u>

D. Figure 4



<u>Histogram based Image Enhancement for non-uniformly illuminated low Contrast Image</u>

RESULTS OF QUANTITATIVE ANALYSIS

Technique	**Entropy**	**PSNR**
Original Image	7.6215	inf
Histogram image	5.9713	86.7532
Proposed technique	7.5690	72.2302