IMAGE CONTRAST ENHANCEMENT

A

PROJECT REPORT

SUBMITTED TO

VEER SURENDRA SAI UNIVERSITY OF TECHNOLOGY, BURLA, ODISHA

In partial fulfilment of the requirements for the award of Bachelor of Technology

In

ELECTRONICS AND TELECOMMUNICATION ENGINEERING

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BONAFIED CERTIFICATE

This is to certify that the project work entitled “IMAGE CONTRAST ENHANCEMENT” submitted by Hiten Kumar Behera, Chetana Pradhan & Disha Das of 7th Semester, Veer Surendra Sai University of Technology, Burla, Odisha has been carried out under my supervision and guidance in partial fulfillment of the requirements for the degree of Bachelor of Technology in Electronics & Telecommunication Engineering, during session 2015 in the Department of Electronics & Telecommunication Engineering, VSSUT, Burla.

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Finally, we would like to thank our friends and those who helped us a lot and provided us sufficient materials during the preparation of our project work.

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Abstract:

In this paper, a new method of contrast enhancement is proposed which takes into account the 2D Histogram equalization of an image. In 1D Histogram equalization process, the neighbourhood of a pixel is not considered which results in the highlighting of undesirable artefacts in the image. To get rid of the shortcomings of 1DHE, 2DHE has been implemented. In this paper, the results of some previously proposed techniques of contrast enhancement have been compared qualitatively and quantitatively with the newly devised 2DHE process. This process takes into account the local contrast information which along with the dynamic range information produces an improved equalized distribution. This method can be applied to both grayscale as well as colour images with small modification without any complexity.

Keywords: Contrast enhancement, Histogram Equalization, 2D Histogram.

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1. Introduction

An image is a two dimensional signal. It is defined by the mathematical function of horizontal and vertical. The value of the function at any point gives the pixel value at that point of an image. If the pixel values are quantized and the spatial coordinates are discrete, the image is called a digital image, as opposed to its analog counterpart, where the values in both the domains are continuous.

Image enhancement entails the modification of an image such that the output image is either more pleasing to the human eye, or contains more information and less noise, useful for further processing. Image enhancement techniques can be used as preprocessing steps so that further modifications can benefit from it, or as post-processing steps to make the image more pleasing to the human eye. Enhancement is used as a preprocessing step in some computer vision applications to ease the vision task, and where human viewing of an image is required before further processing. Image enhancement is used for post-processing to generate a visually desirable image. This includes various contrast enhancement techniques to enhance the edges in the image. Image enhancement plays important roles in many fields, such as medical image analysis, remote sensing, high definition television (HDTV), hyper spectral image processing, industrial X-ray image processing, microscopic imaging etc.

Contrast is an important factor in any subjective evaluation of image quality. Contrast is the difference in visual properties that makes an object distinguishable from other objects and the background. In visual perception, contrast is determined by the difference in the color and brightness of the object with other objects. Many algorithms for accomplishing contrast enhancement have been developed and applied to problems in image processing. If the contrast of an image is highly concentrated on a specific range, e.g. an image is very dark; the information may be lost in those areas which are excessively and uniformly concentrated. The problem is to optimize the contrast of an image in order to represent all the information in the input image.

Many methods for image contrast enhancement have been proposed which can be broadly categorized into two methods: direct methods and indirect methods. Among the indirect methods, the histogram modification techniques have been widely utilized because of its simplicity and explicitness in which the histogram equalization (HE) is one of the most frequently used techniques. The fundamental principle of HE is to make the histogram of the enhanced image approximate to a uniform distribution so that the dynamic range of the image can be fully exploited. Contrast enhancement changing the pixels intensity of the input image to utilize maximum possible bins. Contrast enhancement is based on five techniques such as local, global, partial, bright and dark contrast.

Histogram equalization is widely used for contrast enhancement in a variety of applications due to its simple function and effectiveness. It works by flattening the histogram and stretching the dynamic range of the gray levels by using the cumulative density function of the image. One problem of the histogram equalization is that the brightness of an image is changed after the histogram equalization, hence not suitable for consumer electronic products, where preserving the original brightness and enhancing contrast are essential to avoid annoying artefacts. The general idea adopted by the WTHE method is to modify the histogram before equalization is conducted. Such modifications reduce visual artefacts. During the image enhancement the impulse noise in the image also enhanced. Adaptive Gamma Correction with Weighting Distribution (AGCWD) technique is based on histogram modification method. This technique combines both gamma correction and histogram equalization techniques. Gamma correction method had problem that unvaried modification results for every image because a predefined value was used for all images. Histogram equalization had problem of under enhancement and over enhancement. So the AGCWD technique removed disadvantages of both gamma correction and Histogram Equalization techniques by combining both techniques and using a weighting function. Two-dimensional histogram equalization (2DHE) algorithm utilizes contextual information around each pixel to enhance the contrast of an input image. The algorithm is based on the observation that the contrast in an image can be improved by increasing the grey-level differences between each pixel and its neighbouring pixels. The image equalization is achieved by assuming that for a given image, the modulus of the grey-level differences between pixels and their neighbouring pixels are equally distributed.

2. Existing Methods of Image Contrast Enhancement:

There exists some standard methods of image contrast enhancement such as logarithmic transformation, power law transformation, adaptive gamma correction, histogram equalization and weighted histogram equalization. Along with these methods, 2-D histogram equalization has also been implemented with different approaches to get better correction. Some of those standard methods as well as 2-D histogram equalization are described in brief below.

Logarithmic Transformation

The log transformations [1] can be defined by this formula

$$s = c \times \log(r+1) \tag{1}$$

Where s and r are the pixel values of the output and the input image and c is a constant. The value 1 is added to each of the pixel value of the input image because if there is a pixel intensity of 0 in the image, then log (0) is equal to infinity. So 1 is added to make the minimum value at least 1.

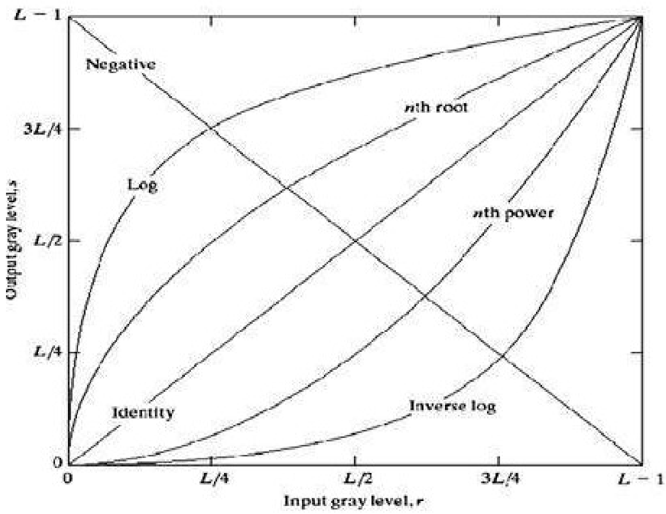


Figure 1: Plot of Input gray level vs Output gray level for a Logarithmic Transform

During log transformation, the dark pixels in an image are expanded as compared to the higher pixel values. The higher pixel values are compressed in log transformation. The value of c in the log transform adjusts the kind of enhancement we are looking for.

Power Law Transformation

There are further two transformations in power law transformations [1]. They include nth power and nth root transformation. These transformations can be given by the expression:

$$s = c \times r^{\gamma} \tag{2}$$

The symbol γ is called gamma, due to which this transformation is also known as gamma transformation. For $\gamma<1$, it maps a narrow range of dark input values into a wider range of output values and with the opposite being true for higher values of input. By varying γ we obtain a family of possible transformations. For curves generated with values $\gamma>1$, effect is exactly the opposite.

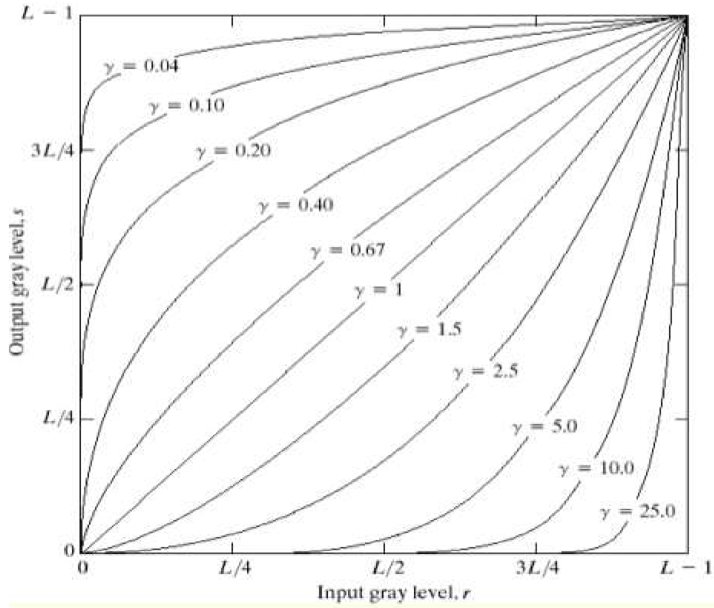
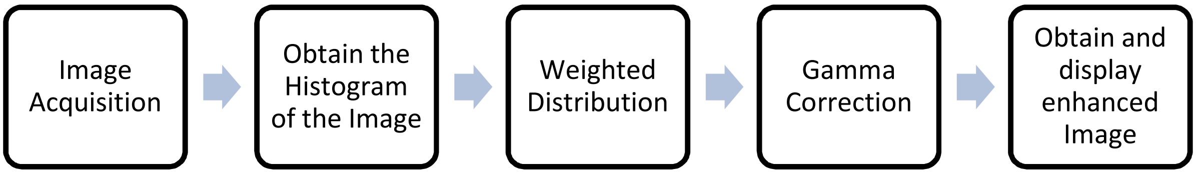


Figure 2: Plot of Input gray level vs Output gray level for Power law Transform

Variation in the value of γ varies the enhancement of the images. Different display devices / monitors have their own gamma correction, that's why they display their image at different intensity. This type of transformation is used for enhancing images for different type of display devices. The gamma of different display devices is different. For example Gamma of CRT lies in between of 1.8 to 2.5. That means the image displayed on CRT is dark.

Adaptive Gamma correction with weighted distribution

Adaptive Gamma Correction with Weighting Distribution (AGCWD) technique is based on histogram modification method [3]. This technique combines both gamma correction and histogram equalization techniques. Gamma correction method had problem that unvaried modification results for every image because a predefined value was used for all images. Histogram equalization had problem of under enhancement and over enhancement. So the AGCWD technique removed disadvantages of both gamma correction and Histogram Equalization techniques by combining both techniques and using a weighting function. The steps involved in AGCWD are as follows:



After acquisition of image, histogram of image is obtained. Weighted distribution is applied so that the image regions with high probability should not get over enhanced and image regions with less probability should not be less enhanced and no loss in important visual details must occur. Weighted Probability density function (pdf) is calculated as:

$$pdf_w = pdf_{\max}((pdf(l) - pdf_{\min}) / (pdf_{\max} - pdf_{\min}))^{\alpha} \tag{3}$$

where α is the adjusted parameter, pdf_{max} is the maximum pdf of statistical histogram, and pdf_{min} is minimum pdf. Now modified cumulative density function (cdf) is as:

$$cdf_w(l) = \sum_{l=0}^{l_{\max}} pdf(l) / (\sum pdf_w) \tag{4}$$

Where $$\sum pdf_w = \sum_{l=0}^{l_{\max}} pdf_w(\mathrm{l})$$

After weighted distribution the histogram is mapped to final histogram and gamma correction is applied. Gamma correction is done as:

$$T(l) = l_{\max}(l / l_{\max})^{\gamma} = l_{\max}(l / l_{\max})^{1-cdf(l)} \tag{5}$$

Where, gamma is calculated as:

$$\gamma = 1 - cdf_w(l) \tag{6}$$

Now final image is obtained after gamma correction.

Global Histogram equalization

Histogram equalization [1] provides a sophisticated method for modifying the dynamic range and contrast of an image by altering that image such that its intensity histogram has a desired shape. Histogram equalization employs a monotonic, non-linear mapping which re-assigns the intensity values of pixels in the input image such that the output image contains a uniform distribution of intensities (*i.e.* a flat histogram). The transformation is given by the formula

$$\begin{aligned} s_k &= T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j) \\ &= s_k = T(r_k) = \frac{L-1}{MN}\sum_{j=0}^{k} n_j \end{aligned} \tag{7}$$

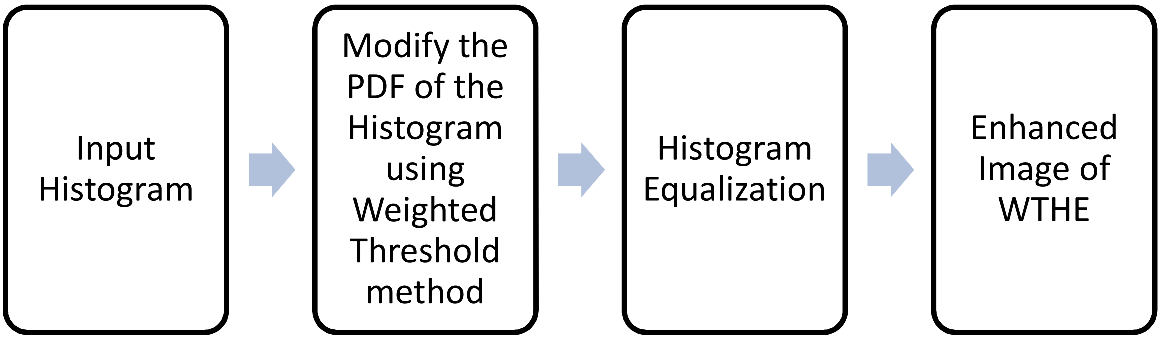
Where

$$p_r(r_k) = \frac{n_k}{MN} \tag{8}$$

Here r_k respresents the input intensity value at the kth gray level, and output intensity value is given by s_k. M and N are the number of rows and columns of the input image. L is the total number of intensity values. P_r (r_k) is the probability density function. N_j is the number of pixels in the jth intensity level.

Weighted Threshold Histogram Equalization

The general idea adopted by the WTHE method[3] is to modify the histogram before equalization is conducted. Such modifications reduce visual artefacts. Weighted Threshold Histogram Equalization is performed by modifying the histogram of an image by assigning the weight and threshold to each pixel before equalization. The steps involved in implementing WTHE are as follows.



The weighted and threshold value of probability density function $P(k_n)$ is obtained by the following equation given by,

$$p_{wt}(k_n) = \Omega(p(k_n)) = \begin{cases} p_u & \text{if } p(k_n) > p_u \\ \dfrac{p(k_n) - p_l}{p_u - p_l} r \times p_u & \text{if } p_l \le p(k_n) \le p_u \\ 0 & \text{if } p(k_n) < p \end{cases} \tag{9}$$

Where $P_{wt}(k_n)$ is the weighted and threshold parameter value of $P(k_n)$. P_u is upper threshold value, that is the PDF is clamped to maximum gray level value of $P(k_n)$.In the WTHE method the value of P_u is given by

$$p_u = v.p_{\max} \quad \text{if } 0 < v \le 1 \tag{10}$$

Where P_{max} is the peak value of the $P(k_n)$. The original PDF of $P(k_n)$ is clamped to an upper and lower thresholds value by using a normalized power law function with index r >0.

The cumulative distribution function (CDF) of original image G (i,j) is given by the equation

$$C_{wt}(k_n) = \sum_{m=0}^{k} P_{wt}(m) \quad ,\text{for } k_n = 0,1,....L-1$$

(9)

The histogram Equalization maps an input level k_n into an output level $\overline{k_n}$, given by

$$\overline{k_n} = (L-1)\times \mathrm{C}_{wt}(k_n) \tag{11}$$

2D Histogram Equalization

Two-dimensional histogram equalization (2DHE) algorithm[4] utilizes contextual information around each pixel to enhance the contrast of an input image. The algorithm is based on the observation that the contrast in an image can be improved by increasing the grey-level differences between each pixel and its neighbouring pixels. The image equalization is achieved by assuming that for a given image, the modulus of the grey-level differences between pixels and their neighbouring pixels are equally distributed.

The input image is given by X={x(i,j)|1≤i≤H, 1≤j≤W}, of size H×W pixels and its dynamic range is [x_d,x_u]. In order to consider contextual information around each pixel, a 2D histogram is created, i.e., for each grey-level of the input image, the distribution of other grey-levels in the neighbourhood of the corresponding pixel is computed. 2D histogram be expressed as

$$H_x = \{h_x(m,n) \mid 1 \le m \le K, 1 \le n \le K\} \tag{12}$$

The h_x(m,n) is computed as

$$h_x(m,n) = \sum_{vi}\sum_{vj}\sum_{k=-\lfloor w/2\rfloor}^{\lfloor w/2\rfloor}\sum_{l=-\lfloor w/2\rfloor}^{\lfloor w/2\rfloor}\phi_{m,n}(x(i,j), x(i+kj+l))(\mid \mathrm{x}_m - \mathrm{x}_n \mid +1) \tag{13}$$

here w is an odd integer number used in parametrizing a square w ×w neighbourhood around each pixel, and

$$\phi_{m,n}(x(i,j), x(i+kj+l)) = 1, \text{if } x_m = x(i,j), x_n = x(i+kj+l) \tag{14}$$

Elements of the 2D histogram h_x(m,n) are normalized according to

$$h_x(m,n) = h_x(m,n) / \sum_{i=1}^{k}\sum_{j=1}^{k} h_x(i,j) \tag{15}$$

to give a probability distribution which is summed to provide a cumulative distribution as

$$p_x = \{p_x(m) \mid m = 1,......,k\} \tag{16}$$

where,
$$p_x(m) = \sum_{i=1}^{m}\sum_{j=1}^{k} h_x(i,j)$$

An optimum 2D uniformly distributed target probability distribution function is formed as

$$H_t = \{h_t(m',n') = 1/\mathrm{L}^2 \mid 1 \le m' \le \mathrm{L}, 1 \le n' \le L\} \tag{17}$$

where L is the number of the distinct grey-levels in the range $[y_d, y_u]$ and

$$\sum_{m'=1}^{L}\sum_{n'=1}^{L} h_t(m',n') = 1 \tag{18}$$

The target cumulative distribution function formed using the target probability distribution function $h_t(m', n')$ is defined as

$$p_t = \{p_t(m') \mid m' = 1,....,L\} \tag{19}$$

Where,
$$p_t(m') = \sum_{i=1}^{m'}\sum_{j=1}^{L} h_t(i,j) = \sum_{i=1}^{m'} L\frac{1}{L^2} = \frac{m'}{L}$$

The input grey-level $\mathbf{x_m}$ is mapped to the output grey-level $\mathbf{y_{m'}}$ by finding an index **m'** for a given index **m** according to

$$m' = \underset{i \in \{1,2,....L\}}{\arg\min} \mid p_x(m) - p_t(i) \mid \tag{20}$$

Each distinct grey-level of the input image X is transformed to a corresponding output grey-level to create an enhanced output image Y.

Proposed Method:

The proposed method in this project is based on equalization of 2-D histogram conceptualized in the previous method. But instead of using the difference between the intensity value of a pixel and its neighbouring pixels, this method uses the correlation between the intensity of a pixel and the average intensity value of its neighbourhood to improve the contrast of the image.

The input image $X = \{x(i,j) \mid 1 \le i \le M, 1 \le i \le N\}$ is of size $M \times N$ pixels and dynamic range is $[x_d, x_u]$.The 2-D histogram can be defined as the distribution of intensity values or grey scale values that the pixels may assume with all the possible intensity values obtained as averages from corresponding neighbourhood. The two axes contain intensity values [0, L-1] uniformly distributed. The plot of number of pairs with a particular set of intensities gives the following 2-D histogram:

$$H_x = \{h_x(m,n) \mid 1 \le m \le L, 1 \le n \le L\} \tag{21}$$

$$m \in \{x(i,j) \mid 1 \le i \le M, 1 \le i \le N\} \tag{22}$$

$$n \in \left[\frac{1}{w \times w} \sum_{\forall i} \sum_{\forall j} \sum_{m=-k}^{k} \sum_{h=-k}^{k} x(i+m, j+n) \right] \tag{23}$$

where

k=w/2 and window size(w) is taken as 3. Here the variable m represents the original intensity values of pixels whereas n represents the average obtained from its 3×3 neighbourhood. This histogram takes into consideration the correlation or covariance existing between intensity values in a small neighbourhood of image, which the 1-D histogram ignores. An optimal distribution of dynamic range contextualized around each pixel is thus obtained.

The $h_x(m,n)$ function is normalized to obtain the probability density function given below:

$$P_{x_{(m,n)}} = \frac{h_x(m,n)}{\sum_{i=1}^{L} \sum_{j=1}^{L} h_x(i,j)} \tag{24}$$

The cumulative distribution function (cdf) is obtained from following expression:

$$CDF(m,n) = \sum_{i=1}^{m} \sum_{j=1}^{n} P_x(i,j) \tag{25}$$

Here the 2-D histogram equalized value of the intensity pairs are obtained and the original ones are mapped to the equalized ones i.e the pixel value with certain corresponding average value will be replaced by the pixel value and equalized neighbourhood average intensity. The final mapping from CDF to image produces the output image $Y = \{ y(i,j) \,|\, 1 \le i \le M, 1 \le i \le N \}$.

The dynamic range of Y is [0,L-1] same as input.

Quantitative measures:

Quantitative assessment of different methods was performed with the help of three quantitative measures EBCM (edge based contrast enhancement) [5] , AMBE (absolute mean brightness error) [6] and entropy [7] tabulated in tables 1-3.

The edge based contrast measure (CM) is based on the observation that the human perception mechanisms are very sensitive to contours (or edges). The grey level corresponding to object frontiers is obtained by computing the average value of the pixel gray levels weighted by their edge values.

Contrast c(i,j) is defined in this context is thus defined as:

$$c(i,j) = \left| \frac{x(i,j) - e(i,j)}{x(i,j) + e(i,j)} \right| \tag{20}$$

Where

$$e(i,j) = \frac{\sum_{(k,l) \in N(i,j)} g(k,l) x(k,l)}{\sum_{(k,l) \in N(i,j)} g(k,l)} \tag{21}$$

N(i,j) is the set of neighbouring pixels of pixel(i,j) and g(k,l) is the edge value at pixel (k,l). without loss of generality 3 × 3 neighbourhood and g(k,l) is the magnitude of the image gradient estimated using the sobel operators. The EBCM for an image is calculated as average contrast value, i.e

$$EBCM = \sum_{i=1}^{M}\sum_{j=1}^{N}\frac{c(i,j)}{MN} \tag{22}$$

Then comparative measure CM(m,n) is given as:

$$CM = \frac{1}{1+\dfrac{1-EBCM(Y)}{1-EBCM(X)}} \tag{23}$$

Entropy is a statistical measure of randomness that can be used to characterize the texture of the input image. Entropy measures the content in an image, where a higher value indicates an image with richer details. It is defined as

$$I = -\sum_{k=0}^{L-1} p(r_k).\log(\mathrm{p}(\mathrm{r}_k)) \tag{23}$$

Then **discrete entropy** DE(X,Y) is defined as:

$$DE = \frac{1}{1+\dfrac{\log(256)-\log(\mathrm{Y})}{\log(256)-\log(\mathrm{x})}} \tag{24}$$

An objective measurement is proposed to rate the performance in preserving the original brightness. It is stated as **Absolute Mean Brightness Error (AMBE)** and is defined as the absolute difference between the mean of the input and the output images and is proposed to rate the performance in preserving the original brightness.

$$AMBE(X,Y) = \frac{1}{1+|E(X)-E(Y)|} \tag{25}$$

Where X and Y denotes the input and output image, respectively, and E(.) denotes the expected value, i.e. the statistical mean. Lower AMBE indicates the better brightness preservation of the image.

Colour Image Enhancement

All the grey level contrast enhancement techniques described above can be extended to enhancement of colour images by isolating and processing the intensity component while preserving the chrominance or colour component. This can be done by converting the image from RGB domain to HSI domain. The HSI domain represents the image through 3 components namely, hue, saturation and intensity. Hence it can be easily used to decouple the intensity component from the colour carrying information by considering the 3rd axis, i.e. I, and applying the contrast enhancement techniques to this variable.

3. Result and Discussion:

Some examples of contrast enhancement results for grey-scale images as well as colour images are shown in Figs. 3-13.

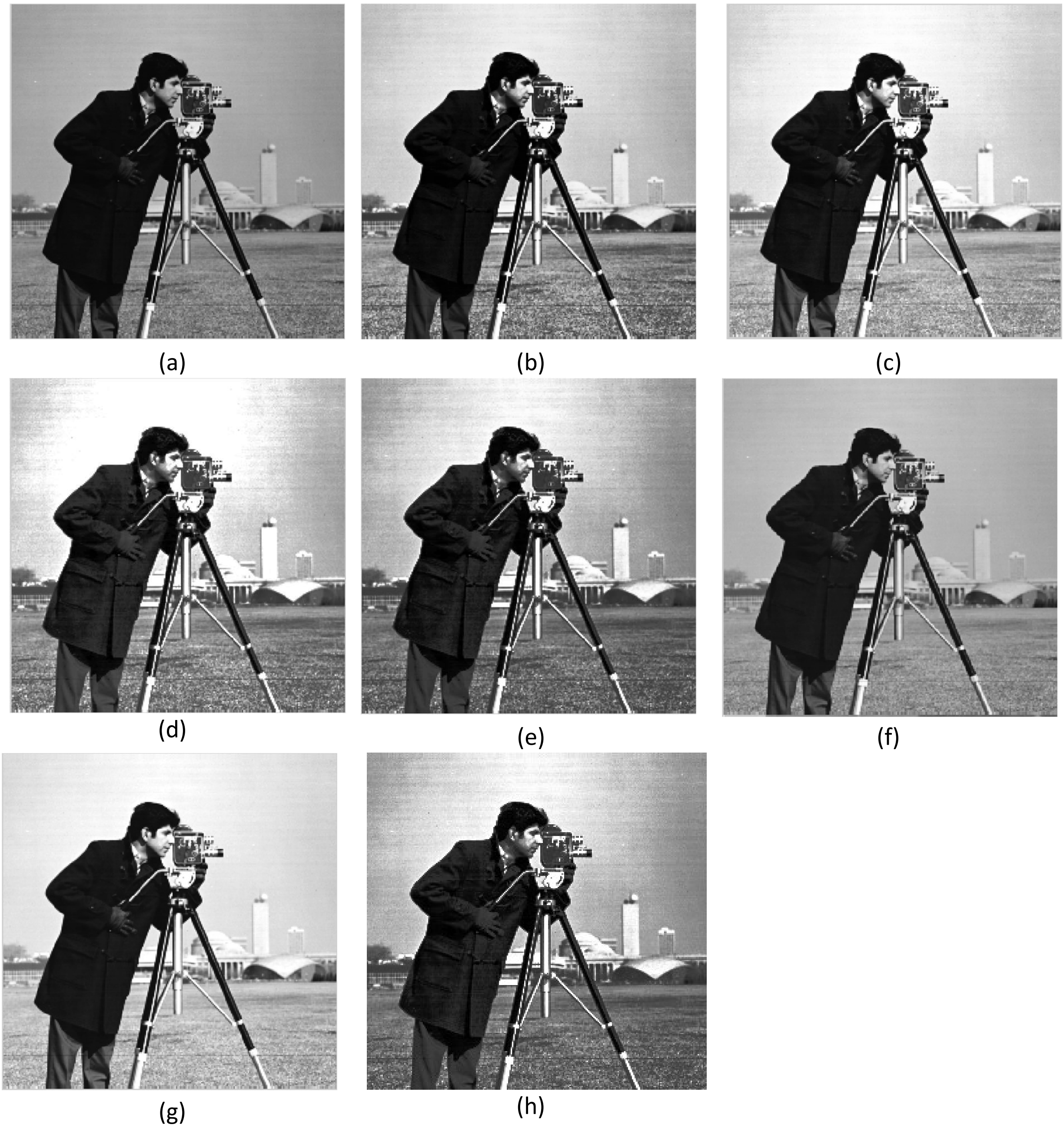


Figure. 3. Contrast enhancement results for image *cameraman.* (a) Original image. Enhanced images obtained using (b) 2-D histogram equalization, (c) adaptive gamma correction with weighted distribution, (d) weighted histogram equalization, (e) histogram equalization, (f) logarithmic correction, (g) power law transformation, (h) proposed method.

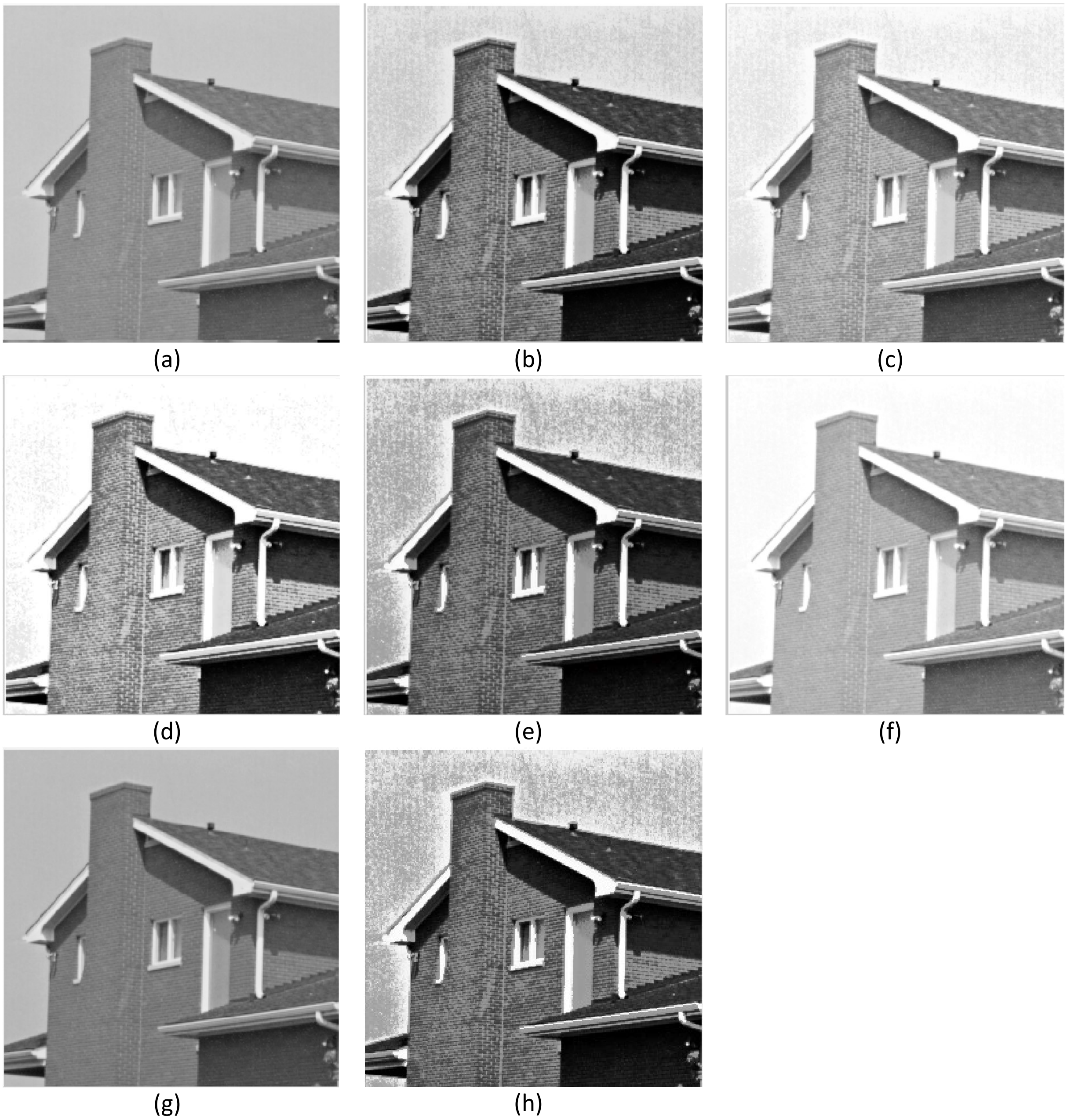
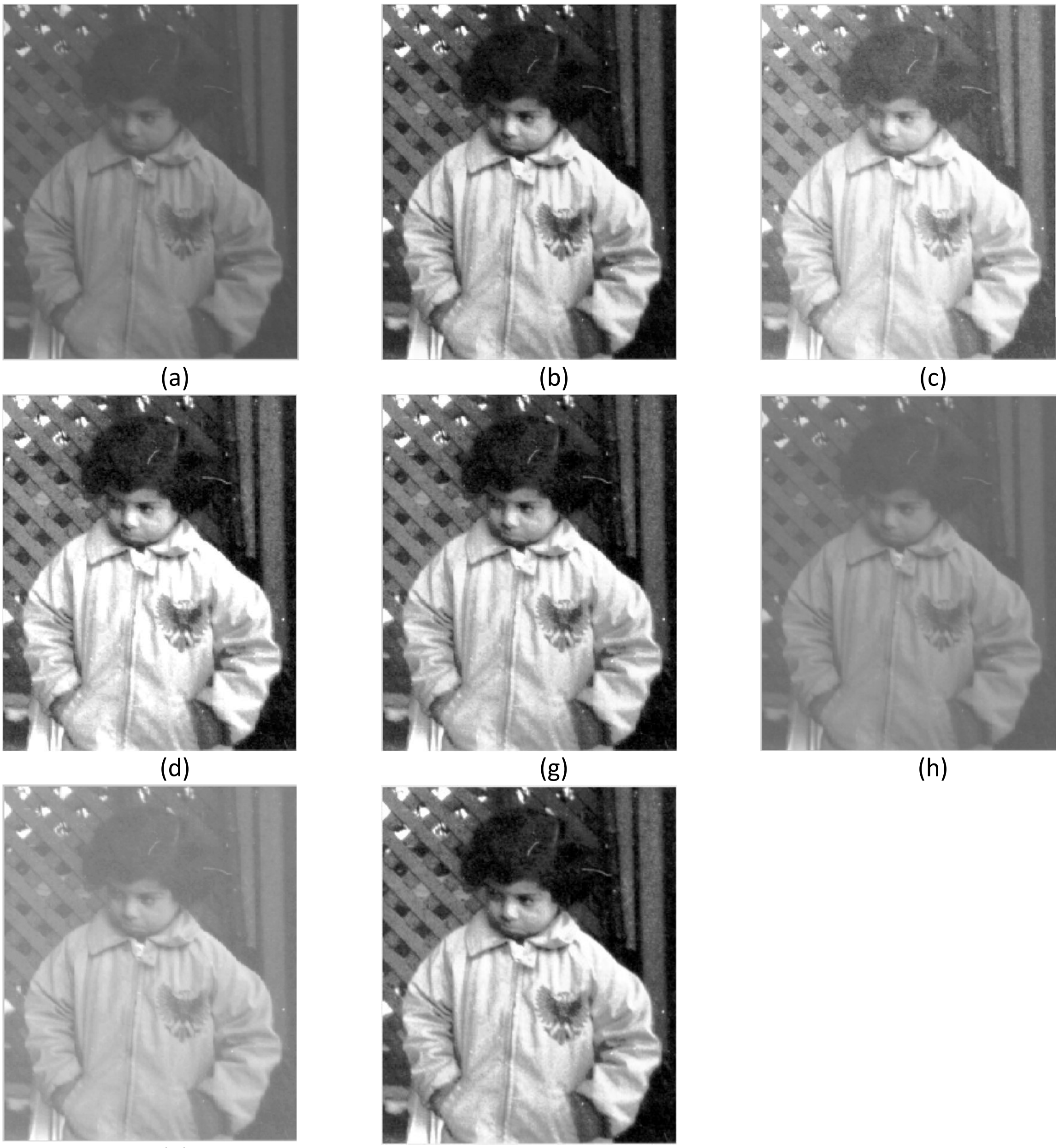


Figure. 4. Contrast enhancement results for image *house.* (a) Original image. Enhanced images obtained using (b) 2-D histogram equalization, (c) adaptive gamma correction with weighted distribution, (d) weighted histogram equalization, (e) histogram equalization, (f) logarithmic correction, (g) power law transformation, (h) proposed method.



(a) (b) (c)

(d) (g) (h)

(g) (h)

Figure. 5. Contrast enhancement results for image *pout.* (a) Original image. Enhanced images obtained using (b) 2-D histogram equalization, (c) adaptive gamma correction with weighted distribution, (d) weighted histogram equalization, (e) histogram equalization, (f) logarithmic correction, (g) power law transformation, (h) proposed method.

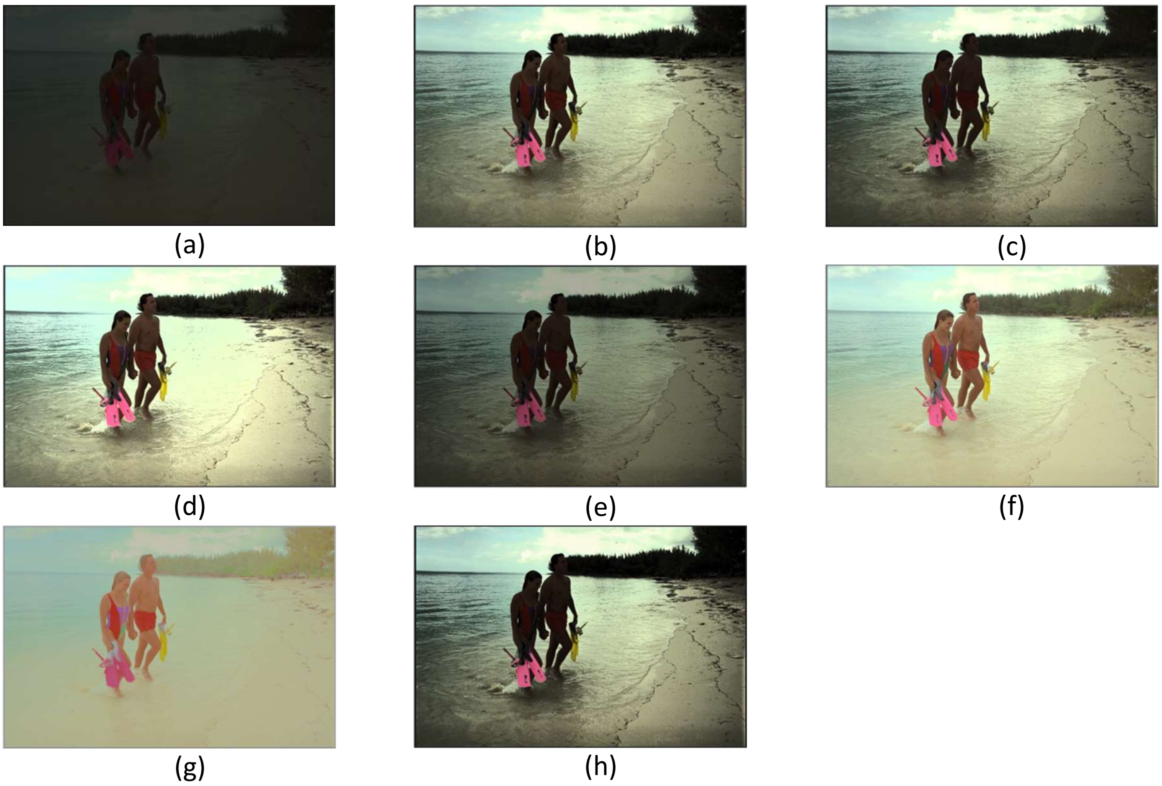


Figure. 6. Contrast enhancement results for image *Beach Level 1.* (a) Original image. Enhanced images obtained using (b) 2-D histogram equalization, (c) adaptive gamma correction with weighted distribution, (d) weighted histogram equalization, (e) histogram equalization, (f) logarithmic correction, (g) power law transformation, (h) proposed method.

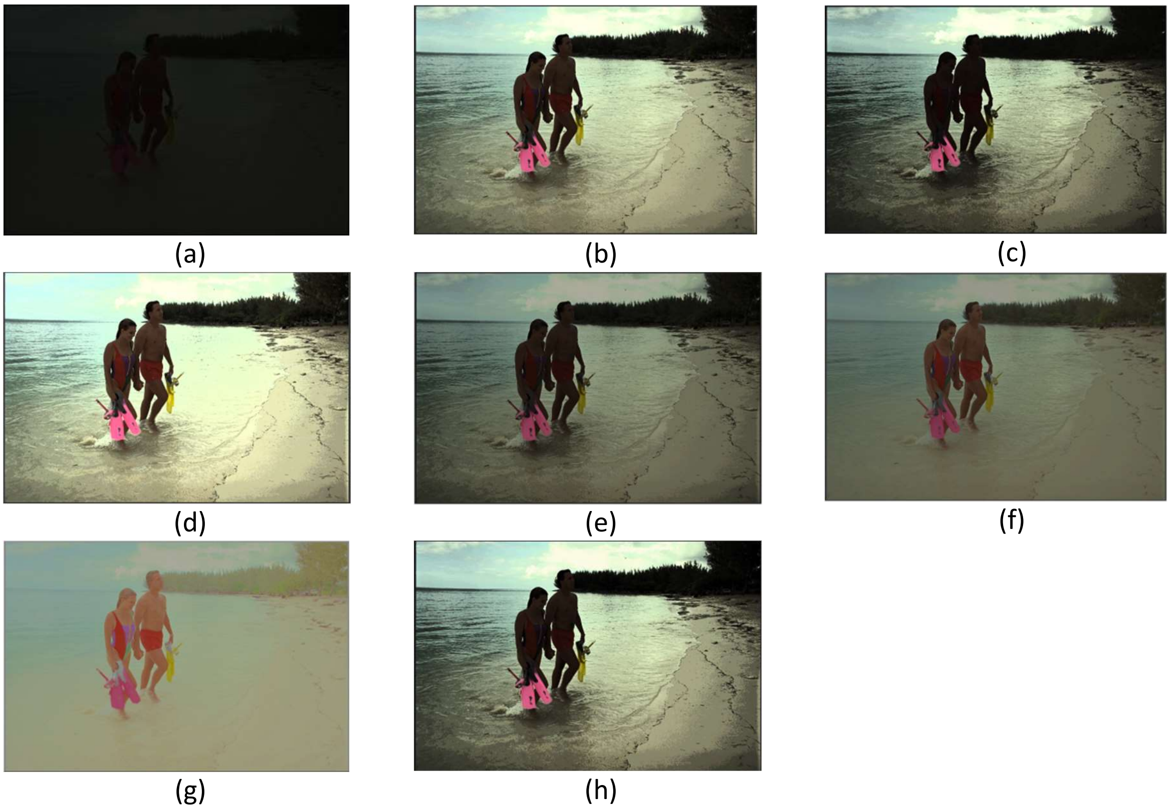


Figure. 7. Contrast enhancement results for image *Beach Level 2.* (a) Original image. Enhanced images obtained using (b) 2-D histogram equalization, (c) adaptive gamma correction with weighted distribution, (d) weighted histogram equalization, (e) histogram equalization, (f) logarithmic correction, (g) power law transformation, (h) proposed method.

Figure. 8. Contrast enhancement results for image *Lighthouse Level 1.* (a) Original image. Enhanced images obtained using (b) 2-D histogram equalization, (c) adaptive gamma correction with weighted distribution, (d) weighted histogram equalization, (e) histogram equalization, (f) logarithmic correction, (g) power law transformation, (h) proposed method.

Figure. 9. Contrast enhancement results for image *Lighthouse Level 2.* (a) Original image. Enhanced images obtained using (b) 2-D histogram equalization, (c) adaptive gamma correction with weighted distribution, (d) weighted histogram equalization, (e) histogram equalization, (f) logarithmic correction, (g) power law transformation, (h) proposed method.

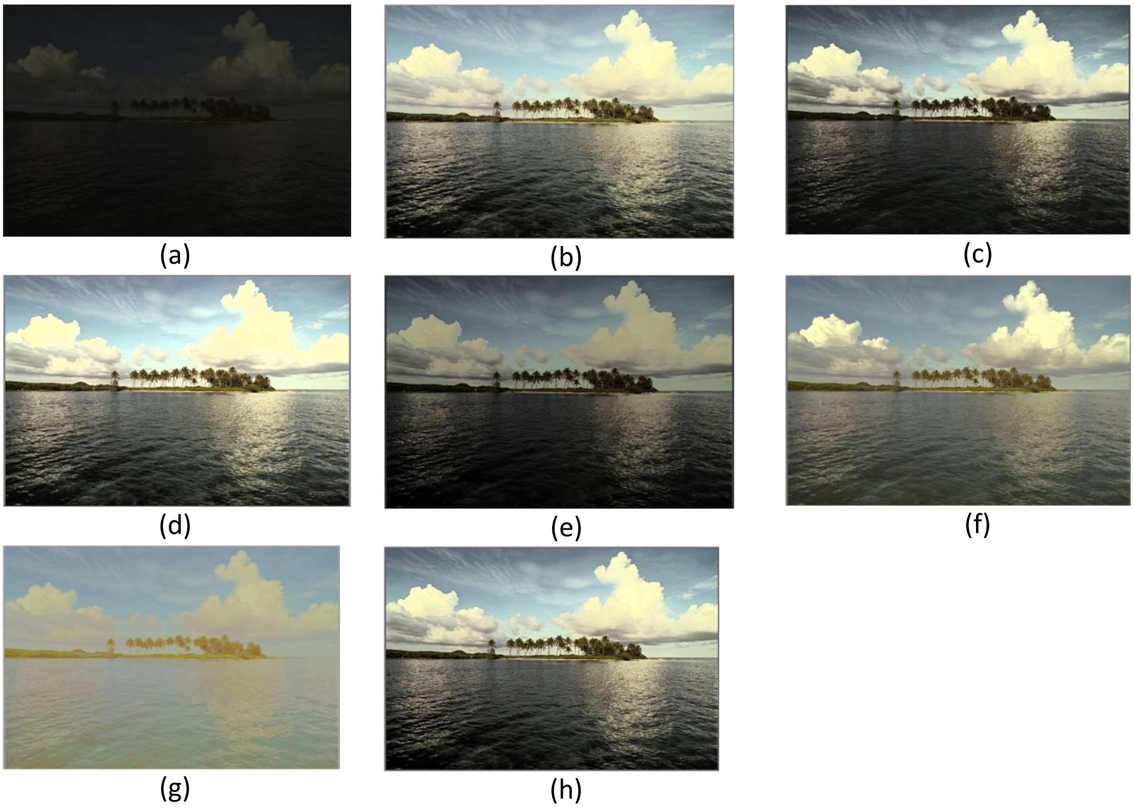


Figure. 10. Contrast enhancement results for image *Island Level 1.* (a) Original image. Enhanced images obtained using (b) 2-D histogram equalization, (c) adaptive gamma correction with weighted distribution, (d) weighted histogram equalization, (e) histogram equalization, (f) logarithmic correction, (g) power law transformation, (h) proposed method.

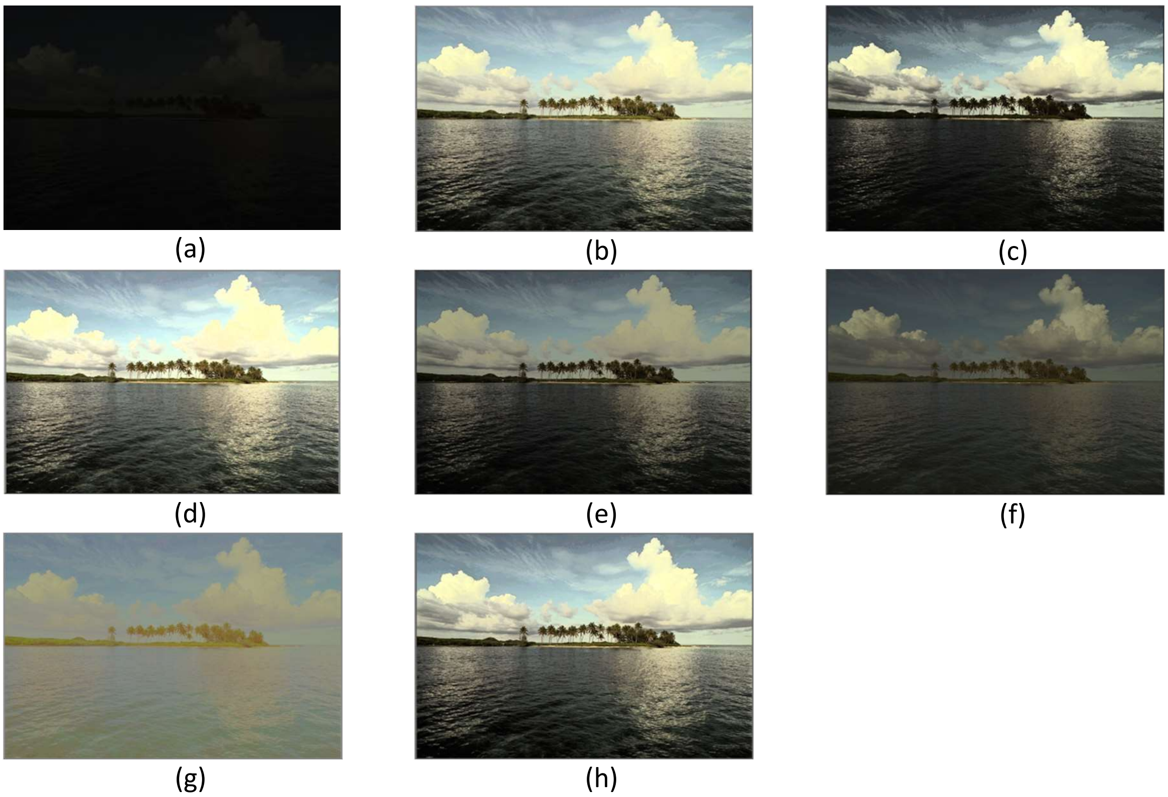


Figure. 11. Contrast enhancement results for image *Island Level 2.* (a) Original image. Enhanced images obtained using (b) 2-D histogram equalization, (c) adaptive gamma correction with weighted distribution, (d) weighted histogram equalization, (e) histogram equalization, (f) logarithmic correction, (g) power law transformation, (h) proposed method.

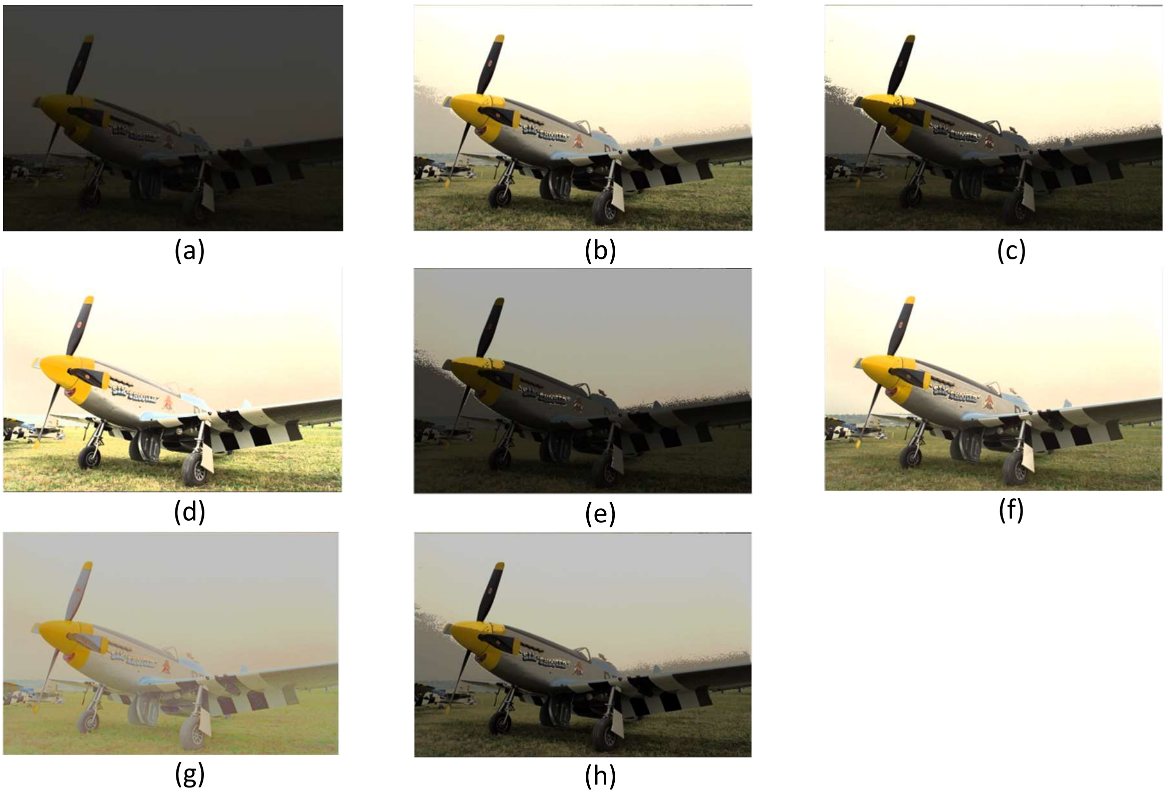


Figure. 12. Contrast enhancement results for image *Cessna Level 1.* (a) Original image. Enhanced images obtained using (b) 2-D histogram equalization, (c) adaptive gamma correction with weighted distribution, (d) weighted histogram equalization, (e) histogram equalization, (f) logarithmic correction, (g) power law transformation, (h) proposed method.

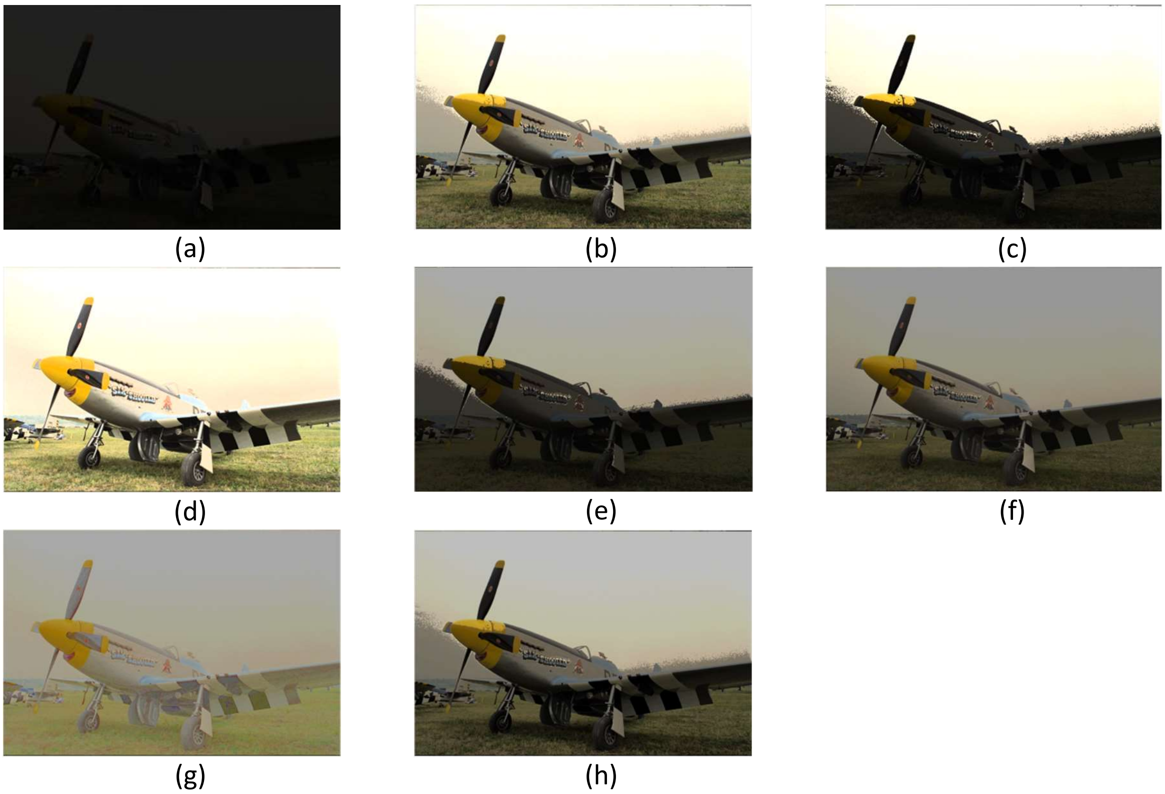


Figure. 13. Contrast enhancement results for image *Cessna Level 2.* (a) Original image. Enhanced images obtained using (b) 2-D histogram equalization, (c) adaptive gamma correction with weighted distribution, (d) weighted histogram equalization, (e) histogram equalization, (f) logarithmic correction, (g) power law transformation, (h) proposed method.

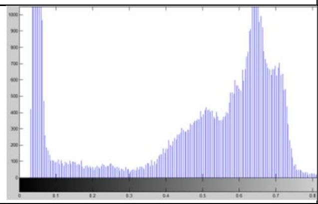
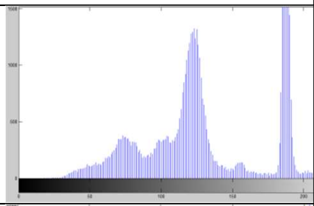
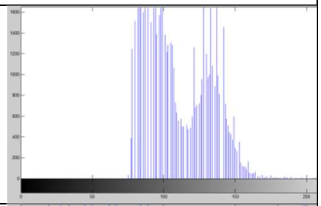
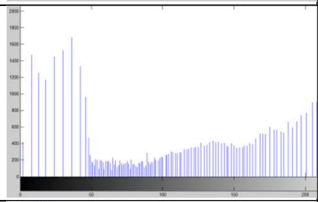
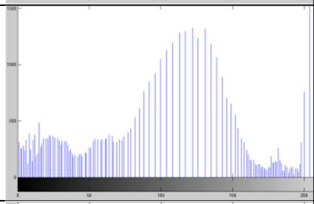
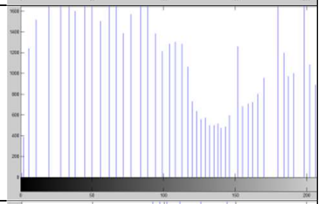
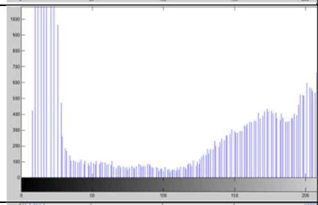
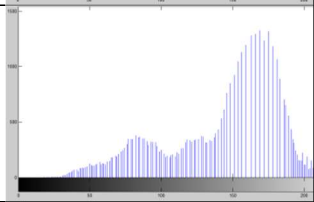
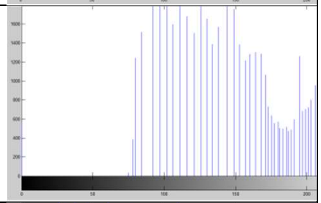
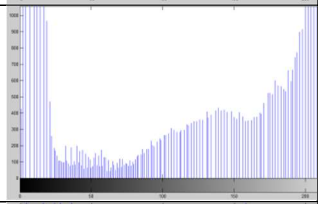
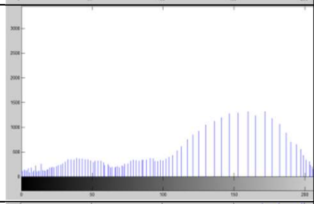
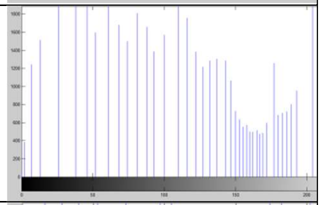
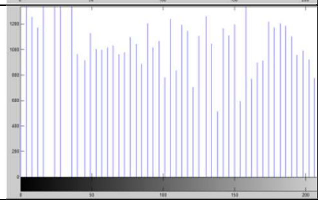
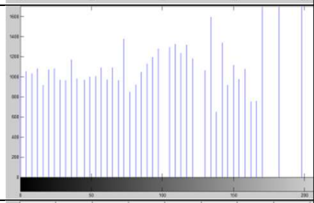
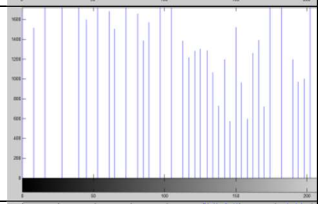
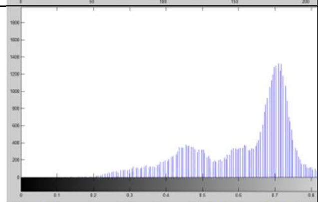
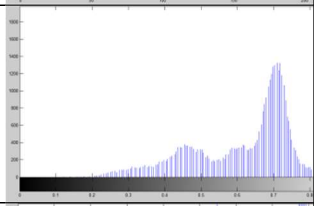
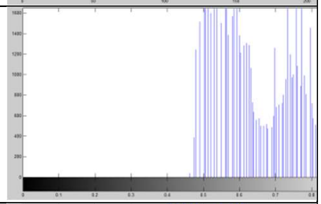
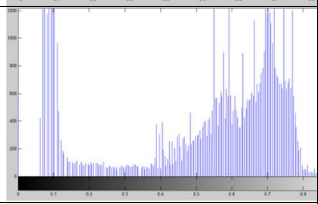
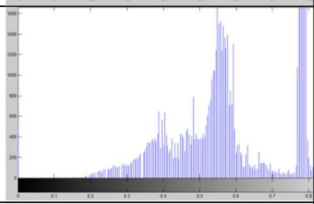
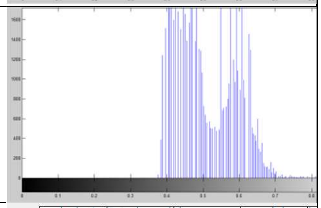
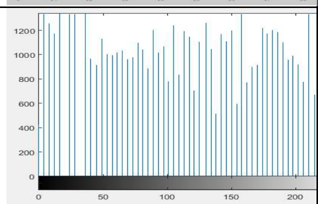
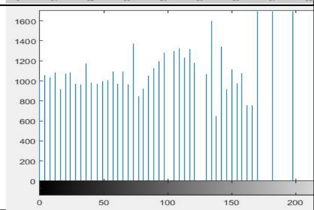
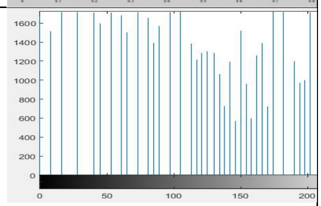
Contrast Enhancement Techniques	Cameraman	House	Pout
(a) Input Image			
(b) Power Law			
(c) Log Transformation			
(d) Adaptive Gamma			
(e) Histogram Equalization			
(f) 2DHE			
(g) WTHE			
(h) Proposed Method			

Figure 14: Histogram of input image(a) and enhanced image obtained using:(b)Power law;(c)Log transformation;(d) adaptive gamma correction;(e)HE;(f)2D HE;(g) WTHE;(h) Proposed Method.

Qualitative assessment

Qualitative assessment is the process of evaluating contrast enhancement methods on the basis how visually pleasing an image is. This process is highly subjective, but it is possible to draw some conclusions conforming to those obtained by quantitative assessments by taking into consideration a large no of evaluations.

It is evident from the images and their histograms of house and cameraman that these images have an appreciably large dynamic range but the distribution of pixels with respect to intensity levels is highly non uniform. For these images adaptive gamma, 2-D HE and WTHE and proposed 2-D HE produce better images compared to the other processes where the resultant images are dull or contain unwanted artefacts.The intensity levels of image Pout span a small portion of the greyscale. Also distribution of pixels in these levels is non uniform. Here 2-D HE and proposed method give almost identical performance which is better than the results obtained from other processes.

Among the colour images, weighted histogram equalization, 2-D HE and proposed method perform better enhancement than others. Here the level 1 and level 2 represent two levels of contrast.

From all the outputs it can be observed that the output of histogram equalization introduces artefacts or degrades the image by improving contrast between regions at the expense of contrast within the region. The 2-D histogram overcomes this problem to a great extent.

Quantitative assessment:

The following thee tables (1-3) give the values of three quantitative measures for greyscale images:

Table 1

Absolute mean brightness error calculated for different contrast enhancement technique performed on four images

Sl No.	Contrast Enhancement Technique	Cameraman	House	Pout
1.	2DHE	0.0084	0.0072	0.0090
2.	AGCWD	0.0230	0.0269	0.0162
3.	WTHE	0.0185	0.0159	0.0219
4.	HE	0.0145	0.0134	0.0260
5.	Logarithmic Trans.	0.0103	0.0087	0.0069
6.	Power Law Trans.	0.0084	0.0072	0.0091
7.	Proposed Method	0.1031	0.0799	0.0557

Table 2

Discrete Entropy calculated for different contrast enhancement technique performed on four images

Sl No.	Contrast Enhancement Technique	Cameraman	House	Pout
1.	2DHE	0.5155	0.5380	0.5388
2.	AGCWD	0.5303	0.5671	0.69520
3.	WTHE	1.3299	1.6377	0.3464
4.	HE	0.6893	0.7169	0.5090
5.	Logarithmic Trans.	0.6566	0.2299	0.0403
6.	Power Law Trans.	0.8994	2.0350	0.4416
7.	Proposed Method	0.8003	1.0671	1.6684

Table 3

Edge based contrast measure calculated for different contrast enhancement technique performed on four images

Sl No.	Contrast Enhancement Technique	Cameraman	House	Pout
1.	2DHE	0.5909	0.5906	0.4867
2.	AGCWD	0.4850	0.4189	0.2807
3.	WTHE	0.4984	0.4121	0.3261
4.	HE	0.9903	0.9903	1.0149
5.	Logarithmic Transform	0.4386	0.3436	0.2111
6.	Power Law Transform	0.5020	0.4307	0.2721
7.	Proposed Method	0.5348	0.4904	0.3646

The following three tables (4-6) give the values of quantitative measures for colour images.

Table 4:

Absolute mean brightness error calculated for different contrast enhancement technique performed on four images

Sl. No.	Contrast Enhancement Methods	Beach		Lighthouse		Island		Cessna	
		Lvl 1	Lvl 2	Lvl 1	Lvl 2	Lvl 1	Lvl 2	Lvl 1	Lvl 2
1.	2DHE	0.0102	0.0082	0.0088	0.0075	0.0085	0.0076	0.0076	0.0066
2.	AGCWD	0.0124	0.0117	0.0122	0.0109	0.0124	0.0122	0.0097	0.0084
3.	WTHE	0.0072	0.0062	0.0061	0.0056	0.0081	0.0071	0.0059	0.0054
4.	HE	0.0226	0.0135	0.0163	0.0114	0.0194	0.0137	0.0174	0.0122
5.	Logarithmic Transform	0.0065	0.0121	0.0083	0.0158	0.0098	0.0186	0.0069	0.0116
6.	Power Law Tranform	0.0231	0.0457	0.0304	0.0598	0.0361	0.0708	0.0219	0.0433
7.	Proposed Method	0.0116	0.0093	0.0104	0.0089	0.0099	0.0087	0.0119	0.0095

Table 5 :

Discrete Entropy calculated for different contrast enhancement technique performed on four images

Sl. No.	Contrast Enhancement Methods	Beach		Lighthouse		Island		Cessna	
		Lvl 1	Lvl 2	Lvl 1	Lvl 2	Lvl 1	Lvl 2	Lvl 1	Lvl 2
1.	2DHE	0.4985	0.4996	0.4967	0.4999	0.4764	0.4984	0.4998	0.4998
2.	AGCWD	0.5000	0.5000	0.4882	0.4988	0.4859	0.5000	0.5000	0.5000
3.	WTHE	0.2409	0.4021	0.2297	0.3822	0.2215	0.4158	0.3590	0.4285
4.	HE	0.4854	0.4942	0.4726	0.4956	0.4628	0.4956	0.4611	0.4781
5.	Logarithmic Transform	0.4118	0.5000	0.4866	0.5000	0.4435	0.5000	0.4537	0.5000
6.	Power Law Transform	0.3749	0.5000	0.4873	0.5000	0.4536	0.5000	0.4821	0.5000
7.	Proposed Method	0.4053	0.4904	0.4306	0.4893	0.3462	0.4820	0.4529	0.4871

Table 6:

Edge based contrast measure calculated for different contrast enhancement technique performed on four images

Sl. No.	Contrast Enhancement Methods	Beach		Lighthouse		Island		Cessna	
		Lvl 1	Lvl 2	Lvl 1	Lvl 2	Lvl 1	Lvl 2	Lvl 1	Lvl 2
1.	2DHE	0.0072	0.0076	0.0062	0.0064	0.0066	0.0068	0.0059	0.0061
2.	AGCWD	0.0099	0.0106	0.0102	0.0091	0.0105	0.0112	0.0081	0.0080
3.	WTHE	0.0058	0.0053	0.0055	0.0054	0.0066	0.0063	0.0049	0.0050
4.	HE	0.0205	0.0181	0.0102	0.0069	0.0167	0.0155	0.0079	0.0077
5.	Logarithmic Transform	0.0046	0.0265	0.0058	0.1547	0.0073	0.1719	0.0057	0.0072
6.	Power Law Transform	0.0053	0.0052	0.0065	0.0063	0.0064	0.0062	0.0054	0.0053
7.	Proposed Method	0.0083	0.0076	0.0082	0.0091	0.0077	0.0075	0.0081	0.0080

On the basis of AMBE, the image contrast enhancement technique with high value of average mean brightness error performs better. In case of grey scale images the proposed method performs better than any other method whereas for colour images adaptive gamma and the proposed method are more effective than any other method in preserving the average brightness of the error. The adaptive gamma performs better but it is quite difficult to find the optimum value of adaptive parameter which requires the use of optimization techniques. The higher value of histogram equalization is due to increase of contrast but degradation of local details.

On the basis of discrete entropy, the same principle can be followed that higher the value better is the performance. Taking into consideration the intensity images, the proposed method again performs better than any other method whereas in colour images the same observation as before can be made where the proposed method produces a value slightly less than that of adaptive gamma excluding HE .

Finally the contrast measure values of all the images are compared. For grey scale images the proposed method and 2-D HE perform better than any other method. for colour images adaptive gamma performs a little better than the proposed method.

From the comparisons it is quite evident that the proposed method is the best method of contrast enhancement according to the overall performance against the quantitative measures whereas for colour images the performance of the adaptive gamma method is slightly better than that of the proposed method. But the requirement of optimization technique further complicates the implementation of this adaptive process.

CONCLUSION:

In this thesis, a new method for contrast enhancement or grayscale as well as colour images has been proposed. Use of local information regarding contrast enhances the local as well as global contrast of the image. The quantitative and qualitative measures establish this method as one of the most effective method amongst existing and standard techniques. This method is quite simple as it is consist of small group of mathematical expressions which can be implemented and understood easily. It doesn’t require the use of optimization technique to produce a visually pleasing result which relaxes the proposed method from burden of right choice of optimization tool.

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