Image Contrast Enhancement By Using Optimal Contrast – tone Mapping Method

Ms. K. T. Chalekar	**Prof. T. S. Yengntiwar**
CSE, RTMN University	CSE, RTMN University
India	India

Abstract— This paper proposes a new image enhancement technique in framework of optimal contrast-tone mapping. It defines a measure of contrast gain and a sister measure of tone distortion for gray level transfer functions. These definitions allow us to depart from the current practice of histogram equalization and formulate contrast enhancement as a problem of maximizing contrast gain subject to a limit on tone distortion and possibly other constraints that suppress artifacts. The resulting contrast-tone optimization problem can be solved efficiently by linear programming. The proposed constrained optimization framework for contrast enhancement is general, and the user can add and fine tune the constraints to achieve desired visual effects. Experimental results are presented to illustrate the performance of the proposed method, demonstrating clearly superior performance of the new technique over histogram equalization. In addition, two locally adaptive contrast enhancement techniques by the proposed method are investigated. However, the conventional histogram equalizations methods usually reserved in excessive contrast enhancement. This paper formulates the problem of over enhancement and various techniques are identified for effective contrast enhancement.

Keywords—Contrast enhancement, CLAHE, Histogram equalization, contrast-tone optimization, tone mapping.

I. INTRODUCTION

In most image and video applications it is human viewers that make the ultimate judgment of visual quality. To human viewers, sharp contrast of edges and subtle tone of smooth surfaces in an image are often interpreted as high perceptual quality. But various conditions, such as foggy weather, poor illumination, and low grade imaging sensor, etc., can make an acquired image look faded and blurry. Therefore, since very early days of image processing many contrast enhancement techniques have been proposed and used, aiming to fully utilize the dynamic range of the raw sensor data and reproduce a visually more appealing and informative image. For improved human interpretation of image semantics and higher perceptual quality, contrast enhancement is often performed and it has been an active research topic since early days of digital image processing, consumer electronics and computer vision.

II. LITERATURE SURVEY

Contrast enhancement techniques can be classified into two approaches: context sensitive or point-wise enhancers and context-free or point enhancers. In context sensitive approach the contrast is defined in terms of the rate of change in intensity between neighboring pixels. The context-free techniques aim to increase the average difference between any two altered input gray levels. One of the earliest and most widely used contrast enhancement techniques is histogram equalization (HE), which remaps pixel values of the input image such that the processed image has as uniform a histogram as possible. Many authors proposed several approaches [1, 2, 3, 4, 5, and 6] to preserve the average intensity of the original image.

Despite more than half a century of research on contrast enhancement, most published techniques are largely ad hoc. Due to the lack of a rigorous analytical approach to contrast enhancement, histogram equalization seems to be a folklore synonym for contrast enhancement in the literature and in textbooks of image processing and computer vision. The justification of histogram equalization as a contrast enhancement technique is heuristic, catering to an intuition. Low contrast corresponds to a biased histogram and, thus, can be rectified by allocating underused dynamic range of the output device to more probable pixel values. Although this intuition is backed up by empirical observations in many cases, the relationship between histogram and contrast has not been

III. TOOLS AND TECHNOLOGY FOR IMPLEMENTATION

A. Matlab

MATLAB brings digital image processing is an extensive set of functions for processing multidimensional arrays of which images (two-dimensional numerical arrays) are a special case. The Image Processing Toolbox is a collection of functions that extend the capability of the MATLAB numeric computing environment. These functions, and the expressiveness of the MATLAB language, make image-processing operations easy to write in a compact, clear manner, thus providing an ideal software prototyping environment for the solution of image processing problems.

B. Image Quality Assessments Techniques

Measurement of image quality is important for many image processing applications. Image quality assessment is closely related to image similarity assessment in which quality is based on the differences (or similarity) between a degraded image and the original, unmodified image. There are two ways to measure image quality by subjective or objective assessment. Subjective evaluations are expensive and time-consuming. It is impossible to implement them into automatic real-time systems. Objective evaluations are automatic and mathematical defined algorithms. Subjective measurements can be used to validate the usefulness of objective measurements. Therefore objective methods have attracted more attentions in recent years. Well-known objective evaluation algorithms for measuring image quality include mean squared error (MSE), peak signal-to-noise ratio (PSNR), and structural similarity (SSIM). MSE & PSNR are very simple and easy to use.

(i) Mean Squared Error (MSE)

One obvious way of measuring this similarity is to compute an error signal by subtracting the test signal from the reference, and then computing the average energy of the error signal. The mean-squared-error (MSE) is the simplest, and the most widely used, full-reference image quality measurement. This metric is frequently used in signal processing and is defined as follows:

$$MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} (x(i,j) - y(i,j))^2$$

Where $x(i,j)$ represents the original (reference) image and $y(i,j)$ represents the distorted (modified) image and i and j are the pixel position of the M×N image.
MSE is zero when $x(i,j) = y(i,j)$.

(ii) Peak Signal to Noise Ratio (PSNR)

The PSNR is evaluated in decibels and is inversely proportional the Mean Squared Error. PSNR is most commonly used to measure the quality of reconstruction of lossy compression codecs (e.g., for image compression). The signal in this case is the original data, and the noise is the error introduced by compression. When comparing compression codecs, PSNR is an *approximation* to human perception of reconstruction quality. Although a higher PSNR generally indicates that the reconstruction is of higher quality, in some cases it may not. It is given by the equation

$$PSNR = 10 \log_{10} \frac{(2^n - 1)^2}{\sqrt{MSE}}$$

(iii) SSIM (Structural Similarity Index Metric)

The structural similarity (SSIM) index is a method for measuring the similarity between two images. The SSIM index is a full reference metric; in other words, the measuring of image quality based on an initial uncompressed or distortion-free image as reference. SSIM is designed to improve on traditional methods like peak signal-to-noise ratio (PSNR) and mean squared error (MSE), which have proven to be inconsistent with human eye perception. The difference with respect to other techniques mentioned previously such as MSE or PSNR is that these approaches estimate perceived errors; on the other hand, SSIM considers image degradation as perceived change in structural information. Structural information is the idea that the pixels have strong inter-dependencies especially when they are spatially close. These dependencies carry important information about the structure of the objects in the visual scene. The SSIM metric is calculated on various windows of an image.

IV. EXPERIMENTAL RESULTS

In this chapter, we will thoroughly present some sample images that are enhanced by the proposed OCTM in comparison with those produced by histogram equalization (HE) [1], and Contrast Limited Adaptive Histogram Equalization (CLAHE) [14] and Tone mapped method of High dynamic ranging image [18]. In order to show the versatility of our technique, some intermediate results may be employed. Figure 1 shows the main graphical user interface window. It contains Histogram equalized, CLAHE, OCTM and Tone mapped HDR output with various object quality assessment parameters.
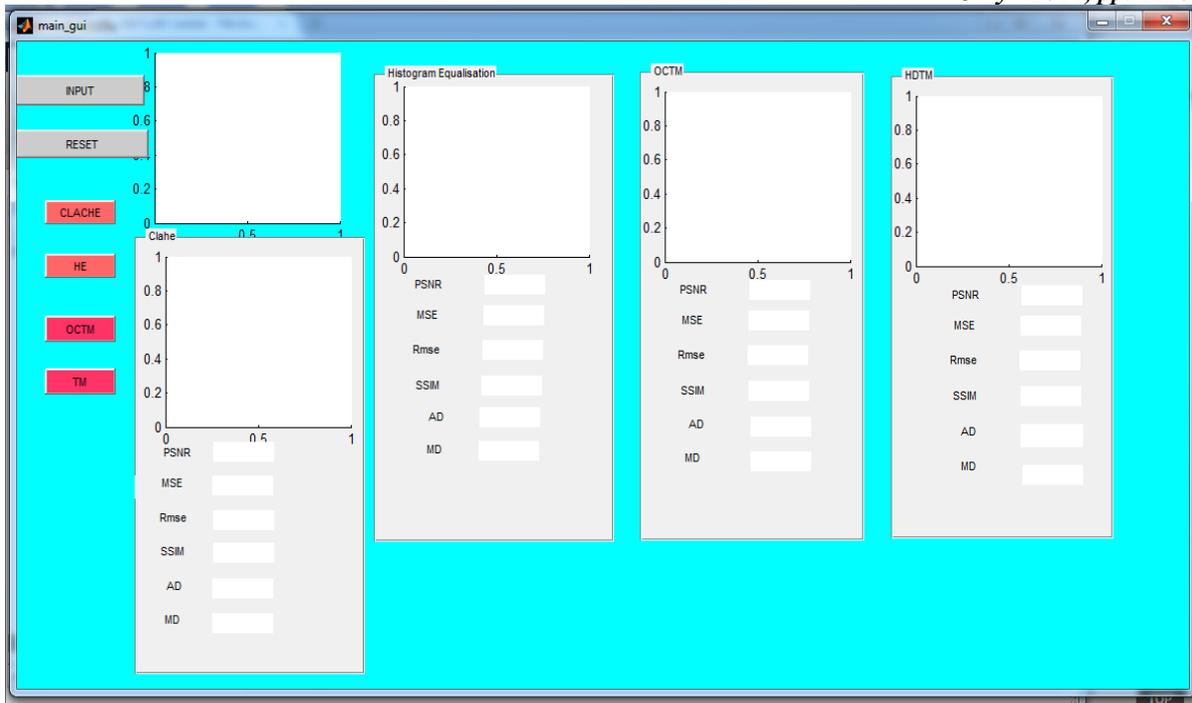
Fig.1

In Figure 2, the output of histogram equalization is too dark in overall appearance because the original histogram is skewed toward the bright range. But the contrast limited adaptive histogram equalization method enhances the original image without introducing unacceptable distortion in average intensity. This is because of the constraint that bounds the relative difference « 20%) between the average intensities of the input and output images.
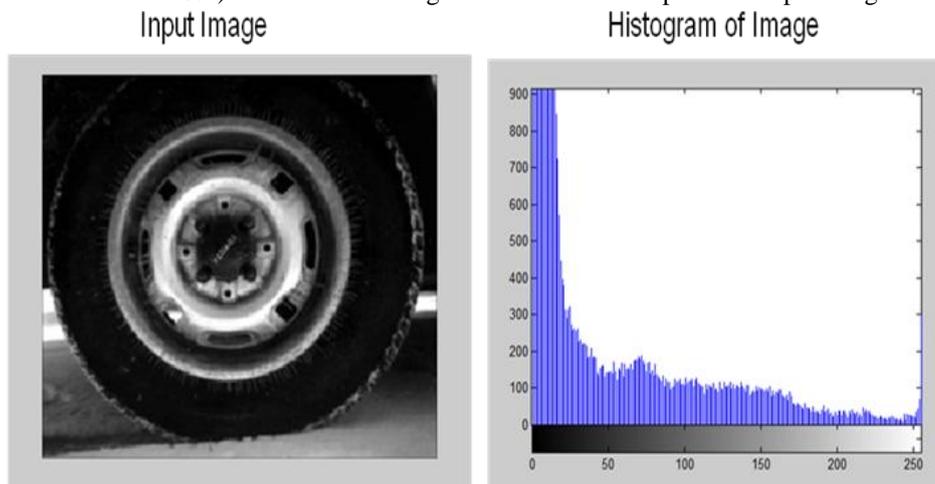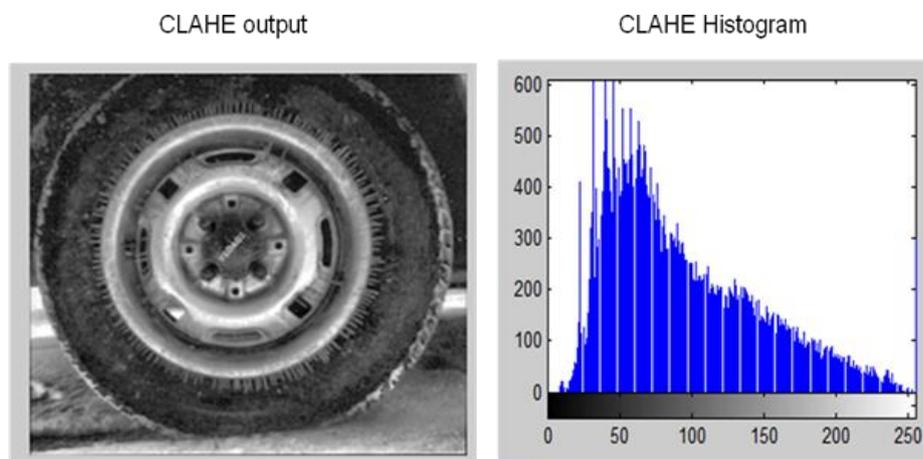

Fig. 2(a,b)

Fig.3(a,b)

We also show the histogram of enhanced CLAHE images in Figure 3 for better comparison purpose. Figure 3 shows an example when the user assigns higher weights Wj in to gray levels j, j E (a, b), where $(a, b) = (100,150)$ is a range of interest .Figure 3 compares the results of gamma corrected and the proposed method when they are applied to a typical portrait image. In this example histogram equalization overexposes the input image, causing an opposite side effect as in Figure 4(b), whereas the proposed method obtains high contrast, tone continuity and small distortion in average intensity at the same time. In Figure 4, the result of joint Gamma correction and contrast-tone optimization by the new technique is shown, and compared with those in difference stages of the separate Gamma correction and histogram equalization process. The image quality of the former is clearly superior to that of the latter. Figure 5 shows Input and output image histogram (RED channel). Figure 6 shows Input and output image histogram (GREEN channel). Figure 7 shows Input and output image histogram (BLUE channel). Figure 8 shows Pixel differences between Input and output image of Tone mapped image.
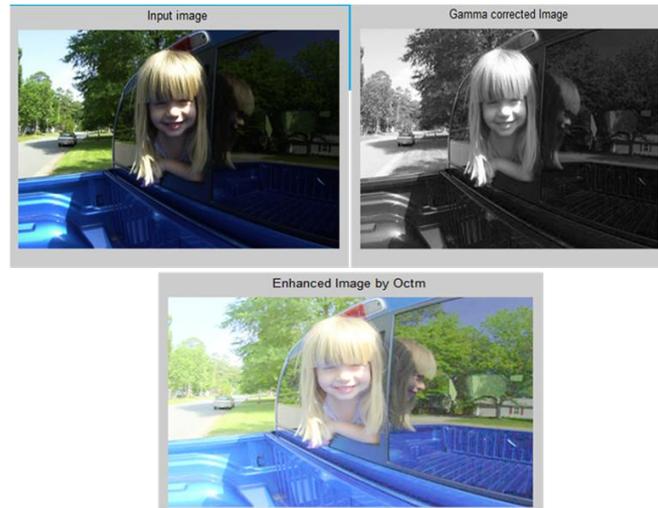

Fig.4(a,b,c)

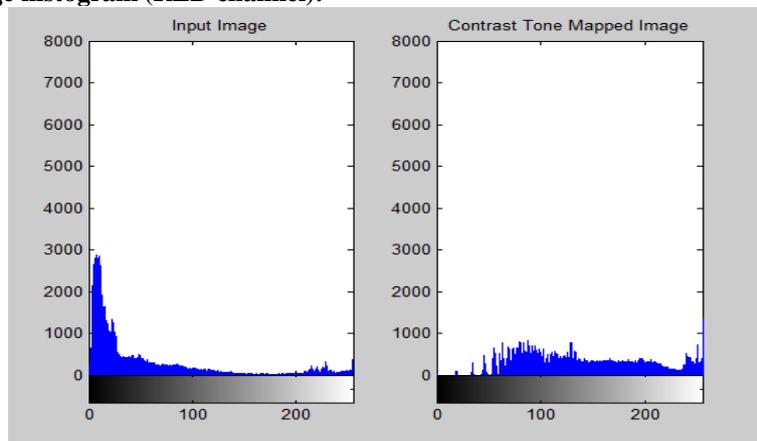**Input and output image histogram (RED channel):**

Fig.5(a,b)
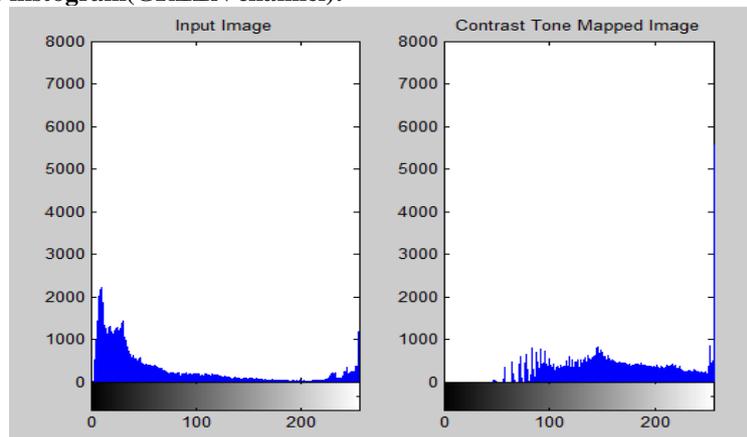
Input and output image histogram(GREEN channel):

Fig.6(a,b)

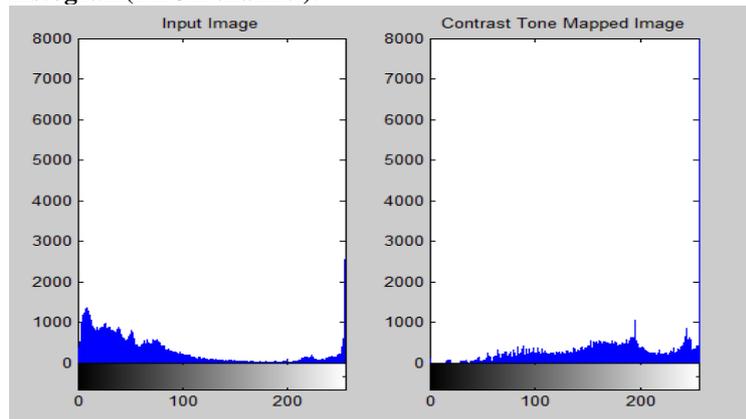**Input and output image histogram(BLUE channel):**

Fig.7(a,b)

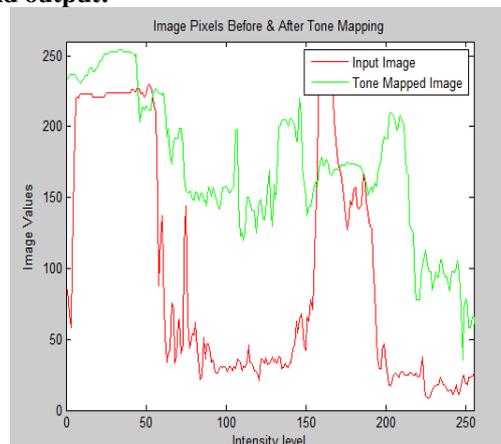**Pixel differences between Input and output:**

Fig.8(a,b)

V. CONCLUSIONS

In this Paper, a frame work for image contrast enhancement based on prior knowledge on the Histogram Equalization has been presented. The implementation of Contrast stretching, Gamma Correction and contrast limited adaptive histogram equalization is done. The output of both has been evaluated by visual perception. The resulting OCTM problem can be solved efficiently by linear programming. The OCTM solution can increase image contrast while preserving tone continuity, two conflicting quality criteria that were not handled and balanced as well in the past. There are several advantages of this method. First, the resulting contrast-tone optimization problem can be solved efficiently by linear programming in our formulation. Second, the optimization framework is general, and the constraints that are imposed by practical applications can be added to achieve desired visual effects. Second, various experiments were conducted to test OCTM. The experimental results demonstrated that OCTM clearly outperforms histogram equalization.

The OCTM output is compared with tone mapped HDR imaging using various quality assessment parameters such as MSE, PSNR, SSIM and etc. It is clearly understand with this parameter that tone mapped HDR image is better than OCTM, CLAHE and HE.

VI. FUTURE SCOPE

In OCTM, optimal transfer function is computed by linear programming, which has an *O(L3)* complexity that is too high for real-time video applications. Also, it is difficult to speed up linear programming by hardware because of the relatively complex search strategy involved in linear programming solvers. Thus, a fast algorithm to find good approximate solutions of OCTM based on machine learning and preprocessing is a future research direction.

Even though OCTM has achieved very good performance on almost all the images, we note that OCTM is not fully automatic considering some parameters have to be set manually. In addition, OCTM enhances the image contrast mainly based on the image histograms, which can not reflect all the information of the images. Therefore, computer vision aided contrast enhancement aiming to intelligently automate processing is a future research target.

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