# Image Contrast Enhancement Based on Tone Curve Control for LCD TV

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**Abstract**

In this paper, we propose an image contrast enhancement algorithm for an LCD TV. The proposed algorithm consists of two processes: the image segmentation process and the tone curve control process. The first process uses an automatic threshold technique to decompose an input image into two regions and then utilizes a hierarchical structure for real-time processing. The second process generates a gray level tone curve for contrast enhancement using a weighted sum of average tone curves for two segmented regions. Experimental result shows that the proposed algorithm outperforms the conventional contrast enhancement methods for an LCD TV.

## 1. Introduction

Due to the characteristics of the liquid crystal displays (LCD), such as thin appearance, light weight, low power consumption, and high resolution, it extends market share among visual displays. However, motion image blur caused by characteristics of the LCD, such as slow response time and hold type driving, is still weak point. Also, as the size of the LCD panel becomes larger, image enhancement method for the LCD is becoming very important in order to offer high quality and resolution images.

Generally, the image enhancement methods typically applied for the flat panel display (FPD) can be categorized into four classes: contrast enhancement, edge enhancement, noise reduction, and edge restorations [6]. In this study we would like to focus on the contrast enhancement method. First of all, the histogram equalization (HE) is the most common method because of its simplicity and effectiveness. However, such method is less effective when the contrast characteristics vary across the image or the image has low contrast [8]. To overcome this limitation, a local histogram equalization (LHE) has been proposed, such as block overlapped histogram equalization (BOHE) [9] and partially overlapped sub-block histogram equalization (POSHE) [10]. However, such methods also suffer from the high computational cost and the blocking effect.

In this paper, we propose an image contrast enhancement algorithm based on tone curve control for an LCD TV. The algorithm consists of two processes: the image segmentation process and the tone curve control process. The first process decomposes an input image into two regions, which employs an automatic threshold technique and uses a hierarchical structure for a real-time processing. In the second process, an improved tone curve is generated by using weighted sum of average tone curves for two regions.

This paper consists of several sections as follows. In section 2, the proposed enhancement method is presented. Result of experiments for contrast enhancement is reported in section 3. Finally, conclusions and future work will be mentioned in section 4.

## 2. Image Contrast Enhancement

Figure 1 shows a block diagram of the proposed algorithm, which consists of two processes, an image segmentation block and a tone curve control process. There are 4 steps about the each process, respectively. In the image segmentation process,

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step 1 is to resize an input image and convert it into gray scale. Step 2 is to blur it using Gaussian filter, and step 3 is to find a threshold automatically. Step 4 is to de-compose the image into two regions, one is the pixels above the threshold, and the other is the pixels below the threshold, and to restore it to the original size. The tone curve control process also consists of 4 steps and takes the decomposed image as an input. Step 1 is to transform the decomposed regions by histogram equalization and get tone curves of them. Step 2 is to get average tone curves of the each region and weighted sum of them is got in step 3. Finally, by using the result of weighted sum, we correct the original tone curve in step 4 and apply it to the input image.

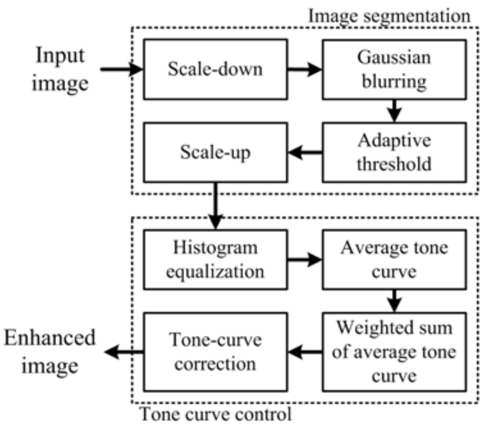



Fig. 1. Block diagram of the proposed method

### 2.1 Image Segmentation

Our target platform is a 42-inch diagonal LCD HDTV, of which resolution is 1920x1080. Since the high resolution affects heavy computational cost, we resize the high resolution image to 160x90 pixels and convert it into gray scale as shown in figure 2(b), (c). And then, we apply Gaussian filter to blur the image for reducing effect of detail as shown in figure 2(d).

There are many automatic thresholding techniques to gray scale images [1-5,12], but we use a method based on average and variance of an image, which is simple and easy to hardware implementation. The average of the image, $m$ is given by equation 1, and the variance, $v$ is given by equation 2.

$$m = \frac{\sum_{x=1}^{w}\sum_{y=1}^{h} I(x,y)}{w*h} \tag{1}$$

$$v = \frac{\sum_{x=1}^{w}\sum_{y=1}^{h} \left| I(x,y) - m \right|}{w*h} \tag{2}$$

where $I(x,y)$ is intensity of the image, $w$ and $h$ are width and height size of the image, respectively. We determine the threshold, $\varepsilon$ as follows:

$$\varepsilon = m + v \tag{3}$$

We decompose the image into a positive and negative region by whether a pixel of the image is above or below the threshold given by equation 3. The decomposed region is shown as figure 2(e). Finally, we restore the decomposed image to the original size by nearest-neighborhood interpolation method[7]. The restored image is shown as figure 2(f). Figure 3 shows some examples of the proposed segmentation method.

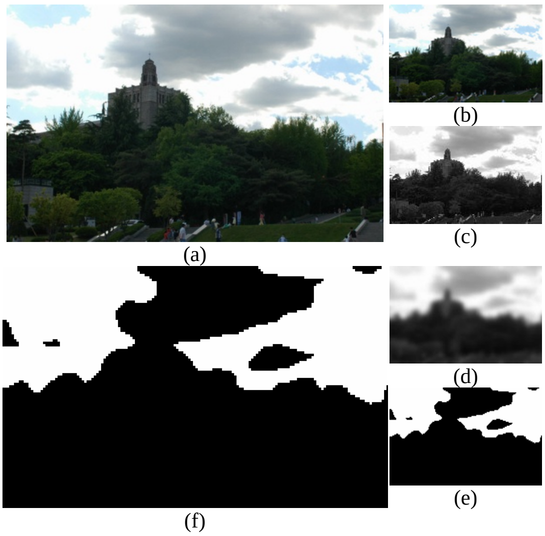



Fig. 2. Sequences of image segmentation;
(a) input image (b) resized image (c) gray scale image
(d) Gaussian blurring (e) decomposed image by automatic thresholding (f) restored image;
(a) and (f) are 1920x1080 pixels.
(b)~(e) are 160x90 pixels.

### 2.2 Tone Curve Control

The image histogram is a useful method to analyze an image, because the histogram provides information for the contrast and overall intensity distribution of an image.

Contrast of an image is determined by its dynamic range, which is defined as the ratio between the brightest and the darkest pixel intensities. An image with low contrast has a histogram that will be narrow and will be centered toward the middle of the gray scale. In case of an image with high contrast, the components of the histogram cover a broad range of the gray scale. Intuitively, it is reasonable to conclude that an image whose pixels tend to occupy the entire range of possible gray levels [6, 7].

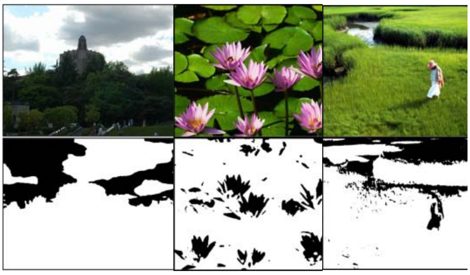


Fig. 3. Results of the proposed segmentation method

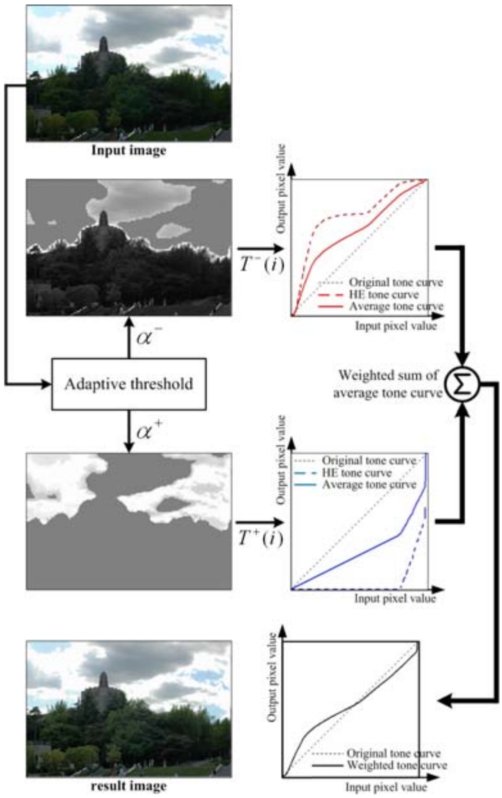



Fig. 4. The proposed tone curve control algorithm

Histogram equalization is one of the most popular methods for image enhancement. However the histogram equalization is less effective when the contrast characteristics vary across the image or the image has low contrast [8]. To overcome this problem, we propose a contrast enhancement algorithm based on the tone curve control. The tone curve means a gray level transformation between input pixel value and output pixel value.

Figure 4 show an overall sequence of the proposed algorithm. The algorithm takes the decomposed image in the previous section as an input. First, we transform the each region by histogram equalization and get two tone curves of them, which is defined as $T^+(i)$, $T^-(i)$, respectively. In case of an image with low contrast, the tone curve of it will have steep slope. To correct the drawback, the algorithm takes average tone curves between tone curves of the original images and $T^+(i)$, $T^-(i)$, and define them as $T_m^+(i)$, $T_m^-(i)$, respectively. The aim of weighting function, $f_w$ is generating a tone curve to keep the shape of the curve to monotone increasing. The coefficients of the weighting function mean ratios of each size of the decomposed regions to a whole size of the input image. The weighting function is as follows:

$$\hat{T}(i) = f_w\left(T_m^+(i), T_m^-(i)\right) = \frac{\alpha^+ T_m^+(i) + \alpha^- T_m^-(i)}{\alpha^+ + \alpha^-} \tag{4}$$

where $\alpha^+$, $\alpha^-$ are sizes of the positive and negative region, respectively.

The tone curve given by the equation 4 shows feasible performance compared to a conventional method, but in case of an image that has mostly one color, it also shows bad result.

To solve this problem, we correct the original tone curve by using the equation 4 as follows:

$$\gamma = 1 - \frac{\left|\alpha^{+} - \alpha^{-}\right|}{\alpha^{+} + \alpha^{-}} \qquad (5)$$

$$\overline{T}(i) = \frac{1}{\gamma + \beta}\left(\gamma \cdot \hat{T}(i) + \beta \cdot i\right) \qquad (6)$$

where $\gamma$ is normalization term, $\beta$ is contrast decreasing rate, which is positive constant value, and $i$ is pixel value of an input image, respectively. If an image consists of mostly one color, that is $\alpha^{+} >> \alpha^{-}$ or $\alpha^{+} << \alpha^{-}$, the n the normalization term decreases and the factor of $\hat{T}(i)$ also decreases. The more $\beta$ becomes larger, the more factor of $i$ increases. We set $\beta$ as 0.4 in our application.

## 3. Experiments

Figure 6 and 7 shows the mean, standard deviation (SD) and median value changes according to the variations of $\beta$ for 'Lena image' and 'foreman image'.[13] Because the higher SD means the higher contrast, the results clearly show that the proposed algorithm enhance the image contrast. By using $\beta$, we can control the SD without affecting the mean and deviation value as shown in figure 6 and 7.

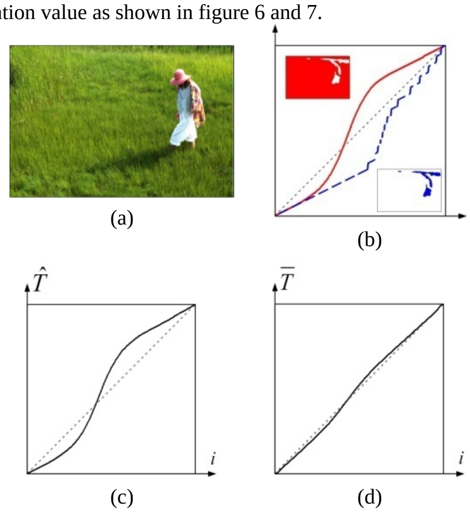
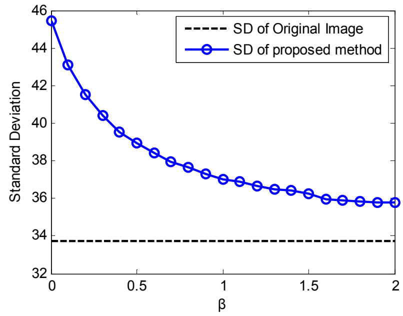



Fig. 3. Tone curve correction
(a) original image (b) average tone curves
(c) weighted sum of the average tone curves
(d) corrected tone curve

Also, we compared the performance between three image contrast enhancement algorithms such as the contrast stretching, the histogram equalization, the proposed algorithm without the tone curve correction, and the proposed algorithm with the tone curve correction. The experiments were performed on four standard CIF-format image sequences (352x240 pixels, 24 bit/pixel) such as 'football', 'table-tennis', 'flower garden', and 'foreman', respectively.[13] The results are summarized in figure 8, 9, 10, and 11. The results show that the SD of the proposed algorithm is smaller than that of the histogram equalization.

| | | Mean | SD | Median |
|---|---|---|---|---|
| Factor | 0 | 106.25 | 45.43 | 101 |
| | 0.2 | 105.66 | 41.5 | 101 |
| | 0.4 | 105.31 | 39.54 | 101 |
| | 0.6 | 105.07 | 38.39 | 100 |
| | 0.8 | 104.92 | 37.67 | 100 |
| | 1 | 104.91 | 37.03 | 100 |
| original image | | 105.43 | 33.74 | 101 |

(a) mean, SD, median values of Lena image

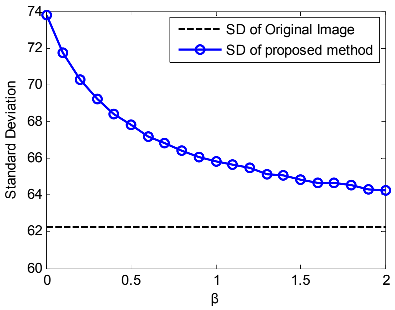



(b) SD with respect to $\beta$ of Lena image

Fig. 4. Comparison of the mean, SD, and median values of Lena image

| | | Mean | SD | Median |
|---|---|---|---|---|
| Factor | 0 | 126.78 | 73.79 | 135 |
| | 0.2 | 131.57 | 70.3 | 142 |
| | 0.4 | 134.13 | 68.43 | 146 |
| | 0.6 | 135.85 | 67.2 | 148 |
| | 0.8 | 137.06 | 66.44 | 150 |
| | 1 | 137.86 | 65.81 | 151 |
| original image | | 144.54 | 62.25 | 160 |

(a) mean, SD, median values of foreman image




(b) mean, SD, median values of foreman image

Fig. 5. Comparison of the mean, SD, and median values of foreman image

We made another experiments to evaluate the performance of the proposed algorithm. The experiments were performed on four full-HD images of which resolution is 1920x1080 and bit rate is 24 bit/pixel, as shown in figure 12. Figure 13, 14, 15, and 16 show the mean, SD, and median value changes according to the variations of $\beta$, respectively. In case of the full-HD images of #1, 2, and 3, the SDs of the result images are smaller than that of the original images. On the other hand, in case of the full-HD image of #4, the SD of the result image is larger than that of the original image. These effects are caused by the contrast of the original image. Thus, the result of SD is changed according to an image characteristic by the proposed algorithm. Therefore, the proposed algorithm makes it possible to control SD of an image and enhances the contrast effectively.

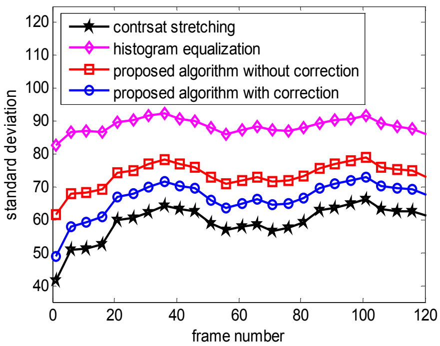



Fig. 6. SDs of the “football” image sequences

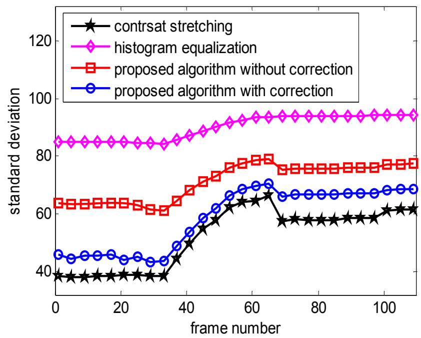



Fig. 7. SDs of the “table-tennis” image sequences

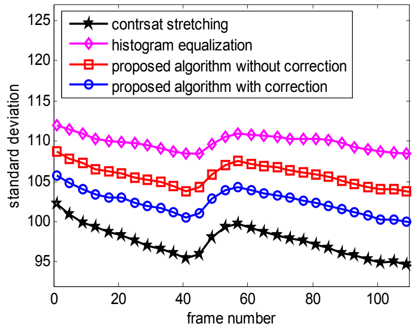



Fig. 8. SDs of the “flower garden” image sequences

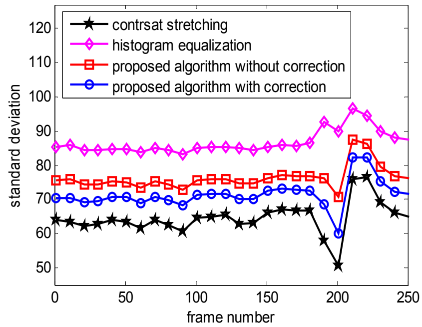



Fig. 9. SDs of the “foreman” image sequences

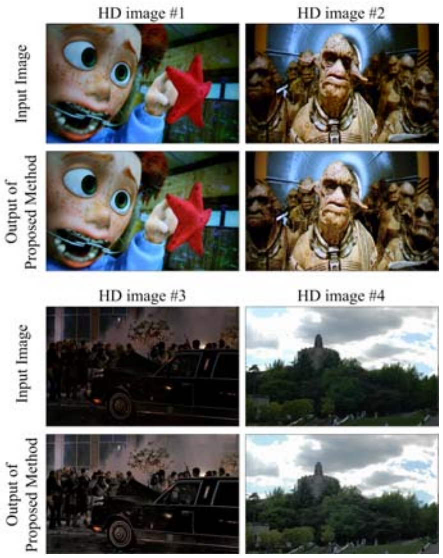
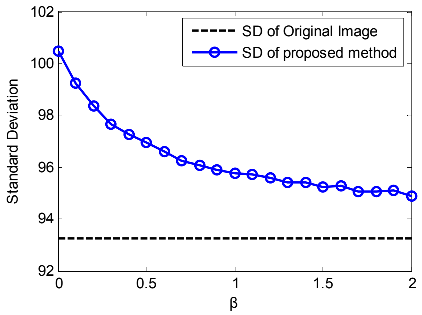



Fig. 10. Full-HD images and result images

| | | Mean | SD | Median |
|---|---|---|---|---|
| factor | 0 | 95.09 | 100.49 | 76 |
| | 0.2 | 87.48 | 98.37 | 67 |
| | 0.4 | 83.43 | 97.27 | 61 |
| | 0.6 | 80.94 | 96.6 | 58 |
| | 0.8 | 79.19 | 96.08 | 56 |
| | 1 | 77.89 | 95.75 | 54 |
| original image | | 71.28 | 93.24 | 46 |

(a) mean, SD, median values

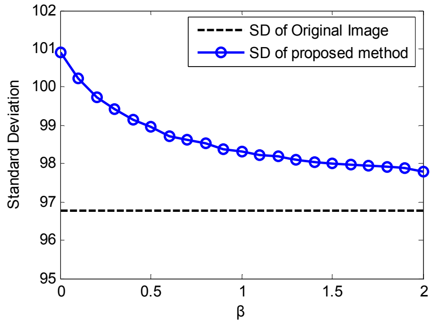



(b) SD with respect to $\beta$

Fig. 11. Comparison of the mean, SD, and median values of the full-HD image of #1

| | | Mean | SD | Median |
|---|---|---|---|---|
| fac | 0 | 84.3 | 100.9 | 45 |
| | 0.2 | 76.85 | 99.74 | 35 |
| | 0.4 | 72.8 | 99.14 | 29 |
| | 0.6 | 70.25 | 98.72 | 26 |
| | 0.8 | 68.55 | 98.53 | 24 |
| | 1 | 67.32 | 98.3 | 22 |
| original image | | 60.31 | 96.78 | 13 |

(a) mean, SD, median values

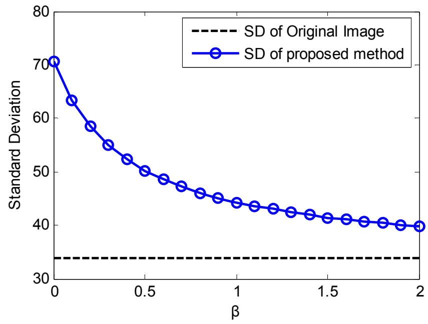



(b) SD with respect to $\beta$

Fig. 12. Comparison of the mean, SD, and median values of the full-HD image of #2

| | | Mean | SD | Median |
|---|---|---|---|---|
| factor | 0 | 58.27 | 70.56 | 44 |
| | 0.2 | 45.97 | 58.5 | 32 |
| | 0.4 | 39.43 | 52.36 | 25 |
| | 0.6 | 35.45 | 48.64 | 21 |
| | 0.8 | 32.79 | 46.07 | 18 |
| | 1 | 30.81 | 44.28 | 16 |
| original image | | 20.01 | 33.83 | 4 |

(a) mean, SD, median values

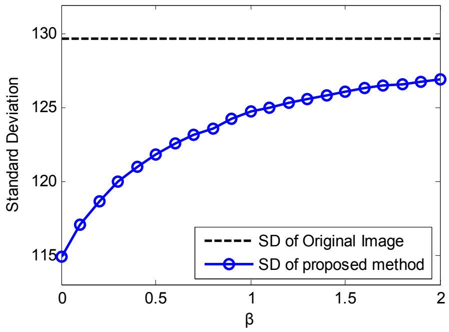



(b) SD with respect to $\beta$

Fig. 13. Comparison of the mean, SD, and median values of the full-HD image of #3

| | | Mean | SD | Median |
|---|---|---|---|---|
| factor | 0 | 123.7 | 114.9 | 95 |
| | 0.2 | 122.2 | 118.6 | 87 |
| | 0.4 | 121.4 | 120.9 | 83 |
| | 0.6 | 120.8 | 122.5 | 80 |
| | 0.8 | 120.4 | 123.5 | 78 |
| | 1 | 120.2 | 124.7 | 76 |
| original image | | 119 | 129.7 | 66 |

(a) mean, SD, median values




(b) SD with respect to $\beta$

Fig. 14. Comparison of the mean, SD, and median values of the full-HD image of #3

Table 1 shows the average processing times of each process of the proposed algorithm, image segmentation process and tone curve control process. It was performed on Pentium IV 2.4Ghz PC with the full-HD images shown in figure 8. The average processing times required to perform the each process are 4ms and 12ms, respectively.

Table. 1. The average processing time of each process

| | Processing time (ms) |
|---|---|
| Image Segmentation | 4 |
| Tone curve control | 12 |

## 4. Conclusion

We present an image contrast enhancement algorithm based on tone curve control. The proposed algorithm consists of two processes, image segmentation process and tone curve control process. The first process employs an automatic threshold technique and a hierarchical structure, and the second process enhances the contrast of an image by using tone curve based method. The goal of our method was to enhance the contrast of an image with full-HD resolution partially. Reducing computational cost was also another goal of our method. The proposed algorithm could enhance the contrast of an image according to the image characteristic. As shown in experimental results, the proposed algorithm has better performance compared to a conventional method and feasible computational cost for real time processing.

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