Image Contrast Enhancement For Displaying Without Fading Under Environment Light

Yusuke Monobe
Graduate School of Science and Technology, Chiba University, Chiba-shi, Chiba, Japan
AV Core Technology Development Center, Matsushita Electric Inc., Kadoma-shi, Osaka, Japan
Haruo Yamashita
Toshiharu Kurosawa
AV Core Technology Development Center, Matsushita Electric Inc., Kadoma-shi, Osaka, Japan
Hiroaki Kotera
Graduate School of Science and Technology, Chiba University, Chiba-shi, Chiba, Japan

Abstract
This paper presents a novel contrast enhance algorithm for images displayed with bright environment light. This algorithm is designed to preserve local contrast based on the luminance ratio of the pixel to its local surround in attention. This algorithm improves image quality of projectors in a bright room.

1. Introduction
In these years, LCD and DLP projectors have become widespread rapidly. The brightness of them has been considerably improved, but the dynamic range comes to be narrowed when viewed in a bright room. In order to display without fading even under such bright environment light, a novel image contrast enhance technique has been requested.

A related work for this problem is HDR (High Dynamic Range) compression. HDR compression is a tone-mapping algorithm for displaying the wide range of the real world to display devices with LDR (Low Dynamic Range) as realistic as possible. Conventional algorithms are classified into two types [1]: spatially invariant [2]-[4] and spatially variant [5]-[7] tone mapping. Now the latter is stepping into spatial vision models. Imitating the human visual response, these approaches compress the dynamic range from HDR to LDR for displaying the realistic images.

Our proposal has a different objective from the above, which focuses attention on LDR to LDR mapping to enhance the visual contrast of displayed images. In order to display images under bright environment light as much the same contrast as seen in a dark room, this paper presents the dynamic range compression algorithm with preserving local contrast of displayed images. In follows, this algorithm is called ***LCRT*** (*Local Contrast Range Transform*).

In this paper, we introduce the total system for displaying fadeless images under bright environment light in the section 2. Next, the algorithm of ***LCRT*** and the method to apply this algorithm to color images are described in the section 3 and 4, respectively. The resultant images of this proposed algorithm are demonstrated in the section 5. Finally, conclusions and future works are described in the section 6.

2. Fadeless Image Display System
Fig.1 illustrates an overview of our proposed system. The objective of this system is to control the luminance on the screen with environment light. So in the pre-process, an original image is transformed to the displayed image on the screen in a dark room by linear scaling *RGB* components to shift zero level into the environment offset level (f_{dark}). The local contrast of this displayed image is treated as the target contrast. Next, the displayed *RGB* image is transformed into the luminance *Y* image, and the separated chroma (*C*) components are reserved. Here, a large-scaled spatial filter is convolved to the *Y* component to take a local average (***LA***) surrounding the pixel in attention. Taking the ratio of the *Y* component to ***LA***, we get a local contrast gain (***CG***) corresponding to the image detail. Thirdly, the luminance *Y* component is modulated by ***CG*** to keep the local contrast as same as the original viewed in the dark room. Finally, the modified luminance *Y'* component is combined with the chroma *C* components and inversely transformed into the corrected *R'G'B'* image. In the post-process to display the corrected image, the offset components caused by environment light is reduced from *R'G'B'* by linear scaling function to shift the environment offset level (g_{bright}) into zero level.

3. Local Contrast Range Transform
As a basically tone-mapping function to compress the input range to the output range, we introduce a popular gamma compression function. Here, we should impose two reasonable constraints on this transform.

One of the constraints is to map a minimum luminance level $f_{min}(x,y)=f_{dark}$ in a dark room to a minimum luminance level $g_{min}(x,y)=g_{bright}$ in a bright room at each pixel coordinate (x,y) in the displayed image. This constraint is described as

$$g_{bright} = f_{dark}{}^{\gamma} \tag{1}$$

where γ denotes the gamma value. From this equation, the gamma value is decided as follows,

$$\gamma = \frac{\log(g_{bright})}{\log(f_{dark})} \tag{2}$$

Another constraint is to keep the local contrast after vs. before processing. Denoting the local average of the input image $f(x,y)$ as $f_{ave}(x,y)$ and the local average of the output image $g(x,y)$ as $g_{ave}(x,y)$, this constraint is described as

$$\frac{g(x,y)}{g_{ave}(x,y)} = \frac{f(x,y)}{f_{ave}(x,y)} \tag{3}$$

Now, we assume that the local averages after and before processing approximately satisfy the following equation.

$$g_{ave}(x,y) = f_{ave}(x,y)^{\gamma} \tag{4}$$

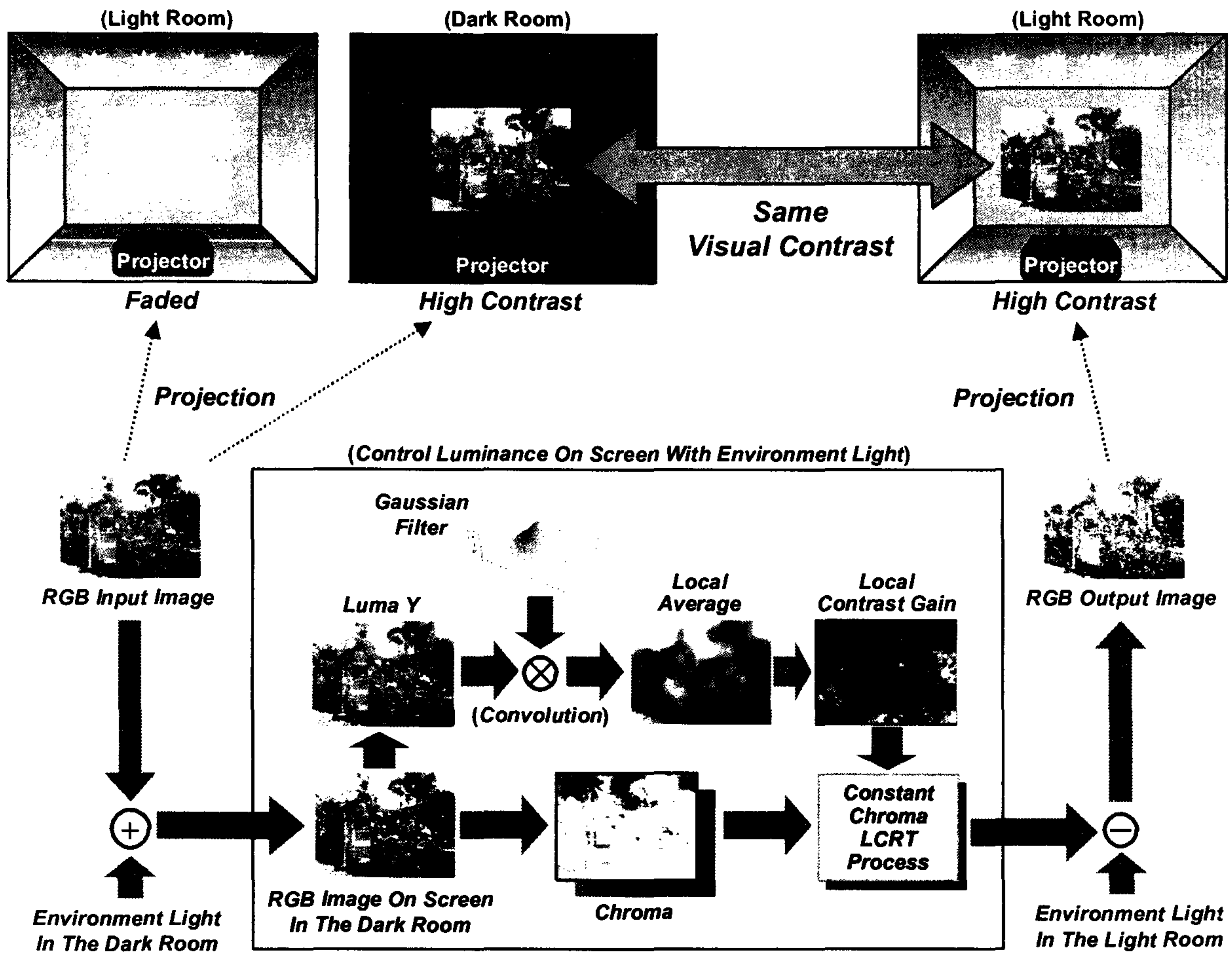

Fig.1 Overview of Fadeless Image Projection System

Replacing the output average $g_{ave}(x,y)$ by equation (4) for one of equation (3), the following equation is derived.

$$g(x,y)=\left\{\frac{g_{ave}(x,y)}{f_{ave}(x,y)}\right\}f(x,y)=\frac{f(x,y)}{f_{ave}(x,y)^{1-\gamma}} \qquad (5)$$

This equation is a basic formula of ***LCRT*** process.

Fig.2 shows the input-to-output mappings of ***LCRT*** in case of f_{dark}=0.01 and g_{bright}=0.1 which lead γ=0.5. The curving line in Fig.2 shows the relation of gamma compression for mapping the input range to the output range. When the input luminance $f(x,y)$ is equal to the local average $f_{ave}(x,y)$, the output luminance $g(x,y)$ is found on this curve as shown by dots which are located on the mapping points corresponding to $f(x,y)$=0.2, 0.4, 0.6 and 0.8, respectively. When the input luminance $f(x,y)$ is not equal to the local average $f_{ave}(x,y)$, the input luminance $f(x,y)$ is transformed along the straight line decided by the local average $f_{ave}(x,y)$ as shown by the thin dashed lines for preserving the local contrast. The thick line segments show the output luminance computed from the input luminance between $f_{ave}(x,y)$-0.1 to $f_{ave}(x,y)$+0.1 for each $f_{ave}(x,y)$.

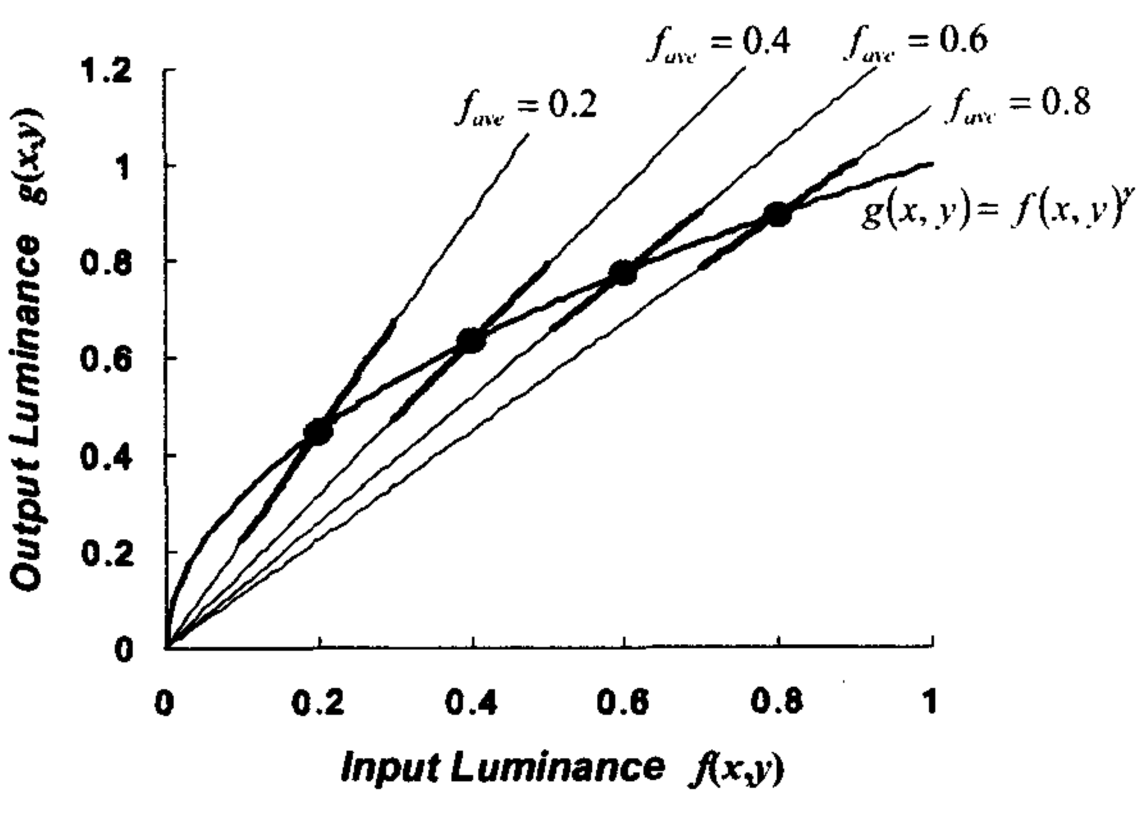

Fig.2 Input-to-Output Mappings of *LCRT*

(a) Original Images (b) Resultant Images of *LCRT*

Fig.3 Experimental Results

Here, the local average $f_{ave}(x,y)$ is calculated by taking a convolution of spatial averaging filter $G(x,y)$ and the input image $f(x,y)$ as follows,

$$f_{ave}(x,y) = \langle G(x,y) \otimes f(x,y) \rangle \tag{6}$$

In our basic model, Gaussian function is introduced as a spatial filter given by

$$G(x,y) = K \exp\left\{ \frac{-\left(x^2+y^2\right)}{\sigma^2} \right\} \tag{7}$$

$$\iint G(x,y)dxdy = 1 \tag{8}$$

where σ denotes a standard deviation which determines a kernel size M. In practice, the kernel size M=4σ+1 should be sufficient for integer value of σ taking ±2σ spread into consideration.

4. Luma-Chroma Channel Process

LCRT should be processed in a luminance component for contrast enhancement. Here, the impression of chrominance should be also preserved as same as original image seen in a dark room. To keep the impression of chrominance, we preserve a^* and b^* components in CIELAB space of an original color image.

First, RGB image is transformed to XYZ image by the linear matrix transformation. Next, a^* and b^* components in CIELAB space are calculated from *XYZ* image and reserved. Here, ***LCRT*** is applied to luminance Y component of XYZ image. Then the modified luminance Y' component is transformed to L'^* component in CIELAB space and combined with the original a^* and b^* components. Finally, $L'^*a^*b^*$ components are inversely transformed into corrected $R'G'B'$ image via $X'Y'Z'$ image.

In this process, only the lightness L'^* is changed through the modified Y' and chromatic components a^* and b^* are preserved.

5. Experimental Results

We applied the proposed algorithm to several test images with 720×480 pixels. Some of these results are shown in Fig.3. The left column shows original image and the right column shows resultant images processed by ***LCRT***. In this experiment, a minimum luminance levels in a dark room (f_{dark}) and in a bright room (g_{bright}) were set to 0.01 and 0.1, respectively. A standard deviation of Gaussian operator was set to σ=32 and a kernel size of a Gaussian filter to M=129.

These results show that the image contrast is enhanced with preserving the impression of chrominance. When these original images are displayed in a bright room, they are faded and their visibilities come to be worse, on the contrary, the resultant images are displayed with preserving as much the same contrast as original images in a dark room.

6. Discussion and Conclusion

This paper proposed a novel image contrast enhance algorithm for the purpose of displaying images without fading in a bright room. Preserving the local contrast of displayed images based on a luminance ratio of the pixel to its local surround in attention, this algorithm keeps the visual contrast of displayed images with bright environment light as much the same contrast as viewed in a dark room. Additionally, we presented the method to apply the proposed algorithm to color images with preserving the impression of chrominance. The performance of the proposed algorithm was demonstrated in the experimental results. This algorithm enables to significantly improve the image quality and visibility of projectors in a bright room.

In this paper, we introduced a basic concept of the contrast enhance algorithm. Consequently, the process costs much time when the algorithm is directly implemented. We are trying to develop a faster implementation to come into practical use.

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