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What Makes HDR the Contents More Realistic?

Peak-Luminance Enhancement Using the Loading Effect for OLED Displays

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Abstract

Recently, people, who consume digital video or image, require more realistic digital contents. That's why HDR (High Dynamic Range) device is getting popular. HDR device captures and generates high dynamic range contents and display it to make the consumer feel more realistic. But, we have still problem, how to express legacy contents, which were captured and generated by LDR (Low Dynamic Range) devices, more realistic for LDR mobile display. In this paper, we propose a new method to express LDR contents more realistic in the mobile device. We proposed to increase peak-luminance for OLED using "Loading Effect" phenomenon. Analyzing visually important regions in the contents based on human visual perception, the luminance in those regions can be controlled easily. HDR contents can be converted more realistic in OLED display by proposed method.

1. Introduction

This era is in the flood of digital contents. To watch those contents more realistic, there have been many approaches in the capturing, transmitting, and, displaying, etc. HDR devices are good solutions to capture and display the scene more realistic. As HDR contents are increased recently, the control of high luminance in the display becomes more important because higher peak-luminance makes viewer feels more realistic and immersive for the contents. There are many previous researches[1,3,4,5,6,7,8,9,10] for controlling luminance. Adjusting TMF (Tone Mapping Function) is one of the most major approaches [1,9,10] to produce realistic luminance for the viewers by mapping contents intensities to the output luminance. In this case, how to distribute the limited luminance range along with intensities in the contents is the big problem.

Another problem is there has been existed a lot of legacy contents which has been captured LDR devices, but still consumers require realistic experience when they watch the digital contents. When consumers watch LDR or HDR digital contents in the LDR display, they require having realistic experience. To make legacy LDR contents more realistic and to display them in the LDR displays more realistic are big issues in the electronics research area.

In OLED (Organic Light-Emitting Diode) Display, peak luminance has been limited along with the number of high intensity pixels, because, the amounts of driving force current are limited. If there are many pixels which have maximum intensity, the driving force current could be divided. Let's assume, there flows 100A as the driving force current, and 100 pixels have the maximum intensity, then in the each pixel there flows 1A. We can call these pixels as group A. But there are 10 pixels which have the maximum intensity, it 10A can be applied for the pixels. We can call these pixels as group B. The luminance of pixels in the group A is much brighter than the luminance of group B. This phenomenon is called as "Loading Effect". Fig. 1 shows how "Loading Effect" works in OLED display, as OPR (On Pixel Ratio) is changed in the contents. As OPR is decreasing, the physical luminance measured by the photometer is increasing.

In Fig. 2, OPR means the ratio of white pixels on the entire image, when the image is composed of W pixels in the width and H pixels in the height. The equation 1 shows, the way how to measure OPR.

$$\mathrm{OPR} = \frac{N(X)}{W \times H}, \qquad (1)$$
$$X = \{x \mid I(x) = 255\},\ I(x): \text{Intensity of pixel } x,$$
$$N(X): \text{Number of elements in set } X$$

"Loading Effect" has been regarded as the big hurdle to produce high luminance in the display, but, in this paper, a new method is proposed to use "Loading Effect" to increase peak-luminance in the display based on HVS (Human Visual System), which human always focus not entire area but salient area, mainly.

The human visual system responds high luminance easily. To make the visual contents realistic, one of the possible solutions is to increase peak luminance and the contrast. In this paper, considering the fact that when the average intensity of the visual contents is decreasing, the peak luminance is increasing by the "loading effect", we proposed a new approach to increase the visual contents' reality by controlling the average luminance while analyzing the detail of the visual contents to minimize the detail loss.

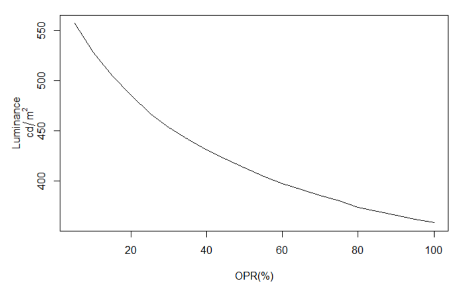

Figure 1. Peak-Luminance decreasing along with OPR

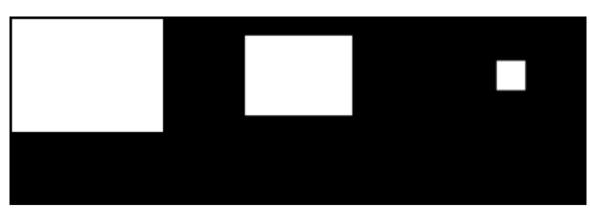

Figure. 2. OPR changes in the display device

2. Related Works

There are several approaches to increase reality in the visual contents. Figure 3 shows the visual quality difference LDR contents and HDR contents. The specular are is enhanced in HDR contents and that makes HDR contents look more realistic. Many researches have tried to distinguish image with diffuse and specular regions and enhanced specular region in the image [11,12,13]. The researches also consider the characteristics of the material to show it more realistic in Figure 4.

Other approaches are recovering shadow region and highlight region [14,15]. The gradation enhancement in the shadow and highlight region help user feel more realistic. Figure 5 shows as bit depth increased, the visual contents can express shadow and highlight region in detail. But the problem is to recover shadow or highlight region without any bit depth increase.

Figure 6 shows the process of estimating illumination [16,17]. Estimating the illumination is also one of the ways to increase the reality in the visual contents. Estimating the illumination means to recognize the category of illumination and the location of the illumination. If the characteristics and the location of the illumination are known, then, the shadow region and highlight region could be controlled very easily.

But, those methods require too much computational power, so there is problem to implement those algorithms in current devices. Those still remain in the hot research topic in the academic area.

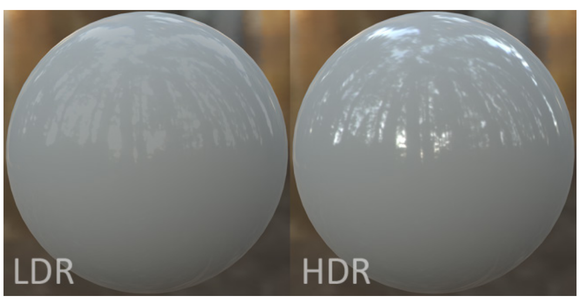

Figure. 3. The effect of HDR

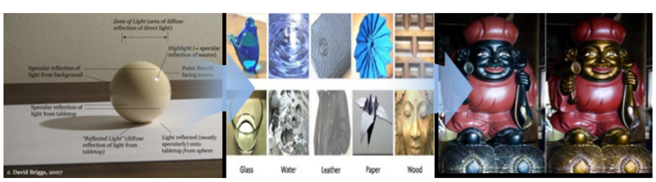

Figure. 4. Specular region enhancement

Figure. 5. Shadow region recovery (Left) and Highlight region recovery (right)

Figure. 6. Illumination Estimation for reality

3. Problem Definition

There are 4 possible combinations between LDR/HDR contents and LDR/HDR devices. In the case of displaying any kinds of contents on HDR devices, there are many researches about tone mapping functions. LDR or HDR contents can be converted by the tone mapping function to display in the HDR device. When HDR contents are displayed in LDR device, special tone mapping function for compressing dynamic range can be considered. So, in this paper we focus on only 1 case which is displaying LDR contents on LDR device.

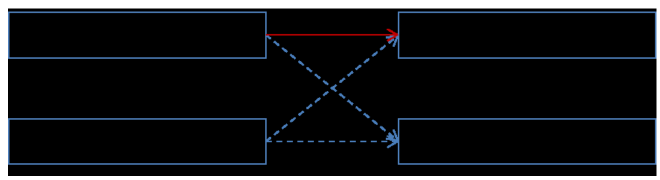

Figure. 7. All possible combination between LDR/HDR contents and devices

As peak luminance in OLED display increases along with OPR's decreasing, our main idea is to reduce average OPR of the contents by adjusting proposed TMF which is based on Kuo's TMF (Figure. 8) [1]. Kuo's TMF [1] decreases all the intensities under high intensity area and increase them in the high intensity (Figure. 8). The intensity difference between input and output (Blue line in Figure. 8) is fixed for every pixel.

Our research problem is to control the difference between linear model and Kuo's TMF[1] (Blue line in Figure. 8) by pixels' saliency. We add not only intensity feature but also structure-ness around each pixel and its location as important features based on HVS analysis. Finally, the average OPR could be decreased by decreasing non-salient pixels' intensity.

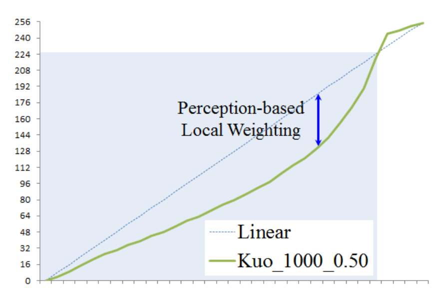

Figure. 8. Tone Mapping Function and Linear Model

Shortly, we formulated this problem to decrease average intensity and increase the intensity in the local salient region in the visual contents by analyzing the contents. Figure 9 shows simple example for our problem definition. Automatically, we detect the area around moon and increase the physical brightness of the region by decreasing average intensity of the visual contents. By deciding which area is salient or not, then the intensity in the non-salient region can be reduced. Non-salient region is bigger than salient region, so it makes average intensity of the visual contents decreased.

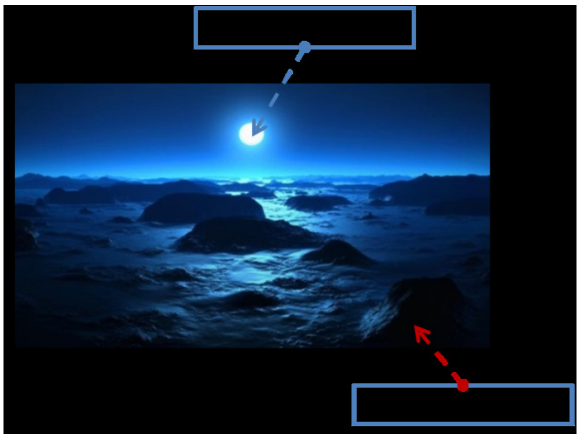

Figure. 9. Region Detection for increasing reality in the image

4. Proposed Algorithm

Proposed algorithm is composed of 3 stages. Figure 10 shows the flow chart of the proposed algorithm. At the first, we analysis contents and categorize it several modes to select optimal tone mapping function for each mode by histogram analysis. The second stage is generation of saliency map. To control the gain of tone mapping function, we designed salient map based on HVS characteristics. Finally, at the third stage, we can increase or decrease the intensity proportional to the saliency.

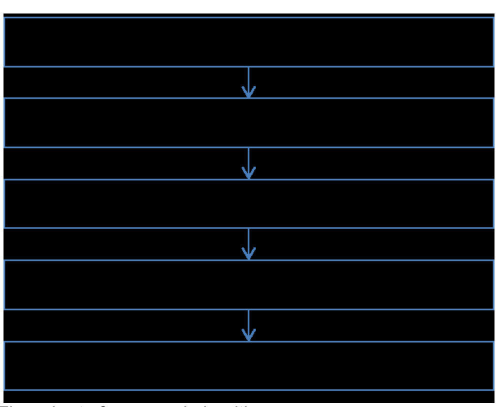

Figure. 10. Flow chart of proposed algorithm

4.1. Contents Analysis

The contents are categorized 4 modes by histogram analysis. The 4 modes are composed of night scene, high intensity scene, low intensity scene, and User Interface pattern. The analysis process and tone mapping function is introduced our previous research paper.

4.2. Saliency Map Generation

We design the level of saliency in each pixel using 3 criterions based on HVS characteristics. Those 3 criterions are introduced below. And the saliency can be decided by linear combination of those 3 categories.

(i) Salient regions are located in the center of image
(ii) Salient regions are composed of complex structure
(iii) Salient regions are high intensity area

To classify the saliency-ness in the pixel, 3 major features are combined and saliency map is used in Fig. 12 and (3) because human considers the center of image, the complex structured area and bright region. Equation (3) shows saliency-ness in one pixel is weighted summation of 3 features.

All features are designed for hardware implementation considering low cost for computation and memory efficiency. Equation (4) explains how to measure the center priori based on the distance from center. As far from the center of image the attention-ness is decreased. Structure-ness means the complexity or texture-ness around the pixel. Simple edge detector or gradient could be used for measuring it in (4). We compare original structure difference with our approximated simple edge detector in Figure 14. Figure 13 shows the result by proposed algorithm. In Figure 13, white rectangle shows non-saliency area and yellow rectangle shows salient area.

$$f_{saliency}(x,y) = W_\alpha \times f_{Center}(x,y) + W_\beta \times f_{Structure}(x,y) + W_\gamma \times I(x,y) \quad (2)$$

$$f_{Center}(x,y) = e^{-\alpha \times \sqrt{(x-\frac{width}{2})^2+(y-\frac{height}{2})^2}} \quad (3)$$

$$f_{Structure}(x,y) = \sum_{k=-n}^{k=n} \sum_{k=-n}^{k=n} \delta_n \times \sqrt{(I(x+n,y+n) - I(x,y))^2} \quad (4)$$

Figure. 11. Original Image

Figure. 12. Saliency Map

Figure. 13. Adjusting Proposed TMF

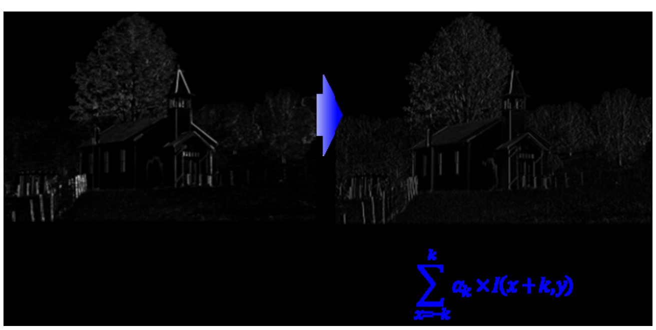

Figure. 14. The approximation of Structural Difference with simple edge filter

5. Experimental Result

We evaluate proposed algorithm with both quantitative measure and qualitative measure. Figure 15 shows experimental results for 4 image dataset. For quantitative measurement, display peak-luminance is measured by luminance meter (CS-200 Minolta) and for qualitative measurement MOS (Mean Opinion Score) is used for 10 ordinary people. Table 1. shows experimental result. Without any device change or driving current increasing, OLED display increases its peak-luminance 7.2%. Peak-luminance increasing shows MOS increasing by 4.03, when original images have 3.0 as their MOS.

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TABLE 1. PEAK-LUMINANCE INCREASE AND ITS MOS

Test data	Original	Proposed	Inc.Rate(%)	MOS
No.1	473.6	476.9	0.6	4.01
No.2	396.7	444.7	12.10	4.02
No.3	349.2	396.3	13.49	4.06
No.4	415.2	441.1	6.24	4.03
No.5	398.3	412.9	3.67	4.03
Average			**7.24**	**4.03/5.00**

6. Conclusion

In this paper, we proposed a new method to increase peak-luminance by applying TMF based on HVS characteristics with simple computational power. For implementing HVS characteristics, we have selected 3 features and made mathematical model to combine them. Proposed algorithm is evaluated by both quantitative and qualitative methods. High peak luminance makes viewers feel more realistic. By controlling weight parameters in Equation 1, saliency-ness in a certain pixel could be controlled. The optimization of those parameters and adding more features which explain HVS characteristics is remained as further work. Recent machine learning technology could be used parameter optimization.

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Author Biography

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Figure. 15. Experimental Result for Dataset (Left: Original Image, Right: Proposed Algorithm)