Hierarchical Logo Detection and Image Processing Algorithm for Preventing OLED Image Sticking

Euiyeol Oh *, Jeisung Lee *, Jinyoung Oh *, JiHoon Park *, JongSang Baek *, Yoonsik Choe **

*** LG Display, Seoul, Korea**

**** Yonsei University, Seoul, Korea**

Abstract

The OLED display has been known to have excellent display characteristics such as high response speed, wide viewing angle and color rendering capabilities. However, OLED devices require sustained efforts to improve the OLED lifetime due to a characteristic that the luminance decreases according to elapsed time. In this paper, we proposed hierarchical logo detection and brightness control method to prevent image sticking on OLED TV. We have experimented with this method in FPGA and We prove that the proposed algorithm can increase the lifetime of OLED TV.

Author Keywords

Segmentation; Logo detection; OLED burn-in; burn-in detection; image sticking.

1. Introduction

The OLED display has been known to have excellent display characteristics such as high response speed, wide viewing angle and color rendering capabilities. In addition, OLED displays will be emerging as the most prominent devices in the future due to the possibility of flexible display and transparent display [1-2]. However, OLED devices require sustained efforts to improve the OLED lifetime due to a characteristic that the luminance decreases according to elapsed time. OLED devices have luminous degradation that is accelerated by current density and temperature [3]. In order to increase the lifetime of OLED TV, it is necessary to lower the stress of OLED pixel that is continuously used with high current. The TV logo usually has a feature of high brightness and continuous appearance in same place. It has high power consumption with high temperature. These features can accelerate the lifetime reduction of OLED TV. In fact, when we test the OLED TV with general videos for a long time, image sticking is mainly occurred in logo area. For this reason, logo detection and luminance control method is critical to increase OLED lifetime. TV logo recognition has been widely used in various fields, such as video analysis, program classification, copyright protection and so on. Katrin[4] proposed a probabilistic detection method of the logo region by applying Maximum a Posteriori Estimation(MAP). This method assumes that there is no image change in the logo area. He et al.[5] applied Otsu algorithm to the result of image difference to extract the logo region and classified the kind of logo by using SURF feature, k-means clustering and Support Vector Machine(SVM). Yueuing et al.[6] proposed a deep learning network to extract logo. They used CNN for extracting ROI region of logo and applied Fast RCNN[7] to classify the kind of logo. Ersin et al.[8] proposed a method to extract animated logo. They used boundary data of logo and multi-frame data. Recently, these logo detection methods have been mainly focused on exact segmentation and classification of logo. However, these algorithms are not suitable for real applications such as FPGAs, because of high computational cost and memory usage. Pixel-based logo extraction methods may be more accurate, but it requires too much memory size and computational cost. Especially, the animated logo needs multiple video frames to segment the logo. In this paper, we have proposed a way to increase the lifetime of OLED TV with fewer resources. The proposed method can detect most of the logo with fewer resources and it can reduce the stress of OLED TV by adjusting the brightness of the logo in real time. We used block based extraction method with hierarchical structure to detect all kinds of logo such as opaque logo, translucent logo and animated logo and so on. Figure 1 shows an example of the logo types. We tested the algorithm performance in the OLED FPGA board and we proved that our algorithm is effective to increase lifetime of OLED TV.

Figure 1. An example of the logo types: (a) opaque logo, (b) translucent logo, (c) animated logo.

2. OLED Stress Based Logo ROI Detection

In this paper, we propose a method to detect all kinds of logo and effectively reduce the logo image sticking problem using hierarchical structure of block unit with small resources. Our proposed method has three steps. Figure 2 shows the structure of

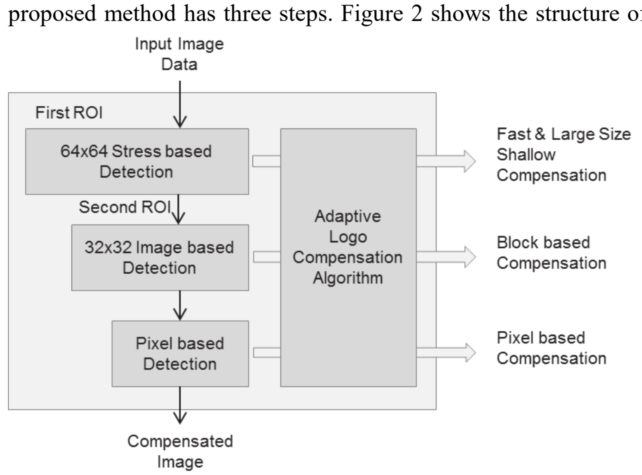

Figure 2. The structure of the proposed logo detection and compensation method.

the proposed algorithm. The first detection step is the stress based detection. This step quickly detects the most stressed areas in the OLED TV and it is possible to detect almost the logo area regardless of the logo types: opaque logo, translucent logo and animated logo and so on. It is very difficult to extract the exact logo shapes with small resources. Especially, the animated logo extraction requires at least many frames data. Our approach is not focused on extracting logo exactly, but we only have interest in how to reduce the OLED stress in logo area within restricted resource. So, we used stress accumulation method with IIR filter in 64x64 block size unit. We calculated the stress value that the OLED receives based on the OLED degradation model [3] and we resized the stress data image by dividing it by the block size of 64x64 units. Equation 1 shows the OLED degradation model. L_0, L_t and t are the initial luminance, luminance at time t, and the elapsed time. τ, J, and T_{EL} are the timescale, current density, and temperature. A is a constant and k is the Boltzmann constant.

$$\begin{cases} L_t = L_0 \times e^{-\left(t/\tau\right)^{\beta}} \\ 1/\tau = A \times J^{\gamma} \times e^{-\frac{Ea}{kT_{EL}}} \end{cases} \tag{1}$$

In the Equation 1, it can be seen that the smaller the timescale value, the larger the OLED luminance reduction. The main factor of timescale is current consumption and temperature. Stress value can be simplified as Equation 2 because current is more directly related to image input data. 2.2 Gamma is applied to extract the simple current value from the input data. The actual current value includes additional calculation processes, but relative current is enough to detect the logo.

$$\begin{cases} Mimg(x,y) = \max_{d=r,g,b} img(x,y,d) \\ I_s(x,y) = A \times Mimg(x,y)^{2.2\times\gamma} \end{cases} \tag{2}$$

In Equation 2, *img* means input data and I_s is estimated stress value. The input frame has three-dimensional data with *R, G, B* and it is replaced by one-dimensional max value *Mimg*. If we divide the stress data by 64x64 block units, we can get a 60x34 sized stress map from UHD size image and IIR filter was applied to the 64x64 block based mean stress data every frame. We added the edge strength value on the final OLED stress value, because most of the image sticking occurs in strong edge area. The final stress map can be defined as follows:

$$\begin{cases} S_t(x,y) = S_{t-1}(x,y) \times (1-\alpha) + \alpha \times I_{bs}(x,y) \\ E_t(x,y) = E_{t-1}(x,y) \times (1-\alpha) + \alpha \times e_{bs}(x,y) \\ F_t(x,y) = S_t(x,y) \times E_t(x,y) \end{cases} \tag{3}$$

where $S_t(x,y)$ is the image stress value at time *t*, $E_t(x,y)$ is the edge stress value. α is a constant less than one. F_t is the final stress value at time *t*. I_{bs} means block based average map of I_s and e_{bs} means block based edge map. We used the inflection point proposed by C.C.chui et al.[9] as a threshold in the final stress histogram data to extract logo region. When defining the ROI area after applying the method of C.C.chui, the threshold is limited so that the logo area can be detected within 3~7% of the entire area, because adjusting the brightness of an excessively wide area may affect the overall image quality. Finally, we applied 3x3 dilation to 64x34 stress map around three times to get the final logo ROI region, $Fr_t(x,y)$. Since it is impossible to detect an accurate logo area, it is necessary to set a larger area. When making compensation data for lowering the stress of OLED, 7x9 LPF is applied to $Fr_t(x,y)$ so that the luminance change in the video is not well recognized. Interpolation is also used to matching the 60x32 size stress data to input video size.

3. Block Image based Logo Detection

The second detection step is an block image based extraction. In this step, we focused on more accurately detecting the logo area with a small resource. In particular, this step aims to detect opaque logo and translucent logo, which have the greatest impact on OLED degradation. The static logo has a characteristic that brightness value is higher than average image and the image change is small. As an example, Cózar, Julián Ramos, et al.[10] used the luminance variance image(LVI) to extract logo region. LVI is represented by the difference between the maximum and minimum luminance values in the corresponding pixel location along the sequence of frames. If you look at the LVI in the logo area, the opaque logo is almost unchanged, and the variance of the translucent logo is not greater than a certain value. In the second detection step, we define the logo as a region where the luminance is larger than a certain value and the image difference is smaller than a specific value. To estimate the logo region based on the luminance, we divided the input frame data by 32x32 block units, and we obtained block based average map that has 120x68 size from UHD size image. IIR filter was applied to the 32x32 block based average map every frame.

$$D_t(x,y) = D_{t-1}(x,y) \times (1-\alpha) + \beta \times Mimg_b(x,y) \tag{4}$$

where $Mimg_b(x,y)$ is the 120x68 sized block average map and $D_t(x,y)$ is the IIR filtered out of the block map. The estimated logo region can be obtained as follows:

$$Lu_t(x,y) = \begin{cases} 1 & if\ D_t(x,y) > th\_lu \\ 0 & otherwise \end{cases} \tag{5}$$

$Lu_t(x,y)$ means estimated logo region based on luminance. There is a strong possibility that a logo exists in a region where the luminance is continuously high. So, we applied a threshold *th_lu* to $D_t(x,y)$. If $D_t(x,y)$ is larger than *th_lu*, we can estimate that logo is located in the point (*x*, *y*). The threshold *th_lu* was set as about 120 gray values. Because most of the logo region has higher luminance than 120 gray values, and if the logo luminance is too low, it is not significant to the OLED degradation. To estimate logo region based on luminance variance, we used the block frame difference. Calculating the image difference in block units can degrade the logo detection accuracy, but using appropriate thresholds is sufficient to detect a typical static logo.

$$df_t(x,y) = Mimg_{b,t}(x,y) - Mimg_{b,t-1}(x,y) \tag{6}$$

$$Df_t(x,y) = \begin{cases} 1 & if\ df_t(x,y) < th\_df \\ 0 & otherwise \end{cases} \tag{7}$$

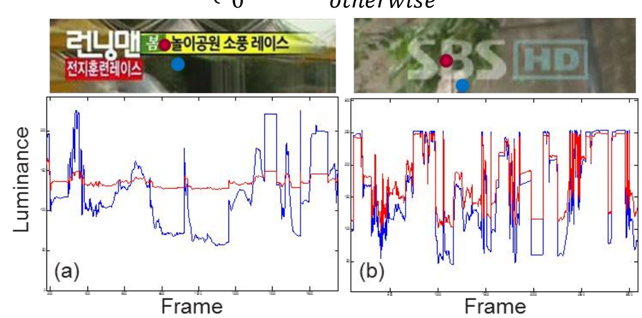

Figure 3. Comparison of characteristics of the opaque logo and the translucent logo according to the change of the surrounding luminance. (a) is opaque logo and (b) is translucent logo. The red line represents the sequence data of the red dot and the blue line represents the sequence data of the blue dot.

Therefore, the threshold *th_df* should be set low value under about 30. The estimated logo region EL_t can be detected as follows:

$$EL_t(x,y) = Lu_t(x,y)\ \&\ Df_t(x,y) \& Fr_t(x,y) \qquad (8)$$

Additionally, we used data count of $EL_t(x,y)$ for stable logo detection. If $EL_t(x,y)$ is one, data count is increased. Otherwise, data count is decreased.

$$DC_t(x,y) = \begin{cases} DC_{t-1}(x,y)+1 & if\ EL_t(x,y)=1 \\ DC_{t-1}(x,y)-1 & otherwise \end{cases} \qquad (9)$$

The range of $DC_t(x,y)$ is from 0 to 1024, and the data count is used as a luminance gain. The final luminance gain $Lg_t(x,y)$ can be calculated as follows:

$$Lg_t(x,y) = MaxGain \times (DC_t(x,y)/\,1024) \qquad (10)$$

where, *MaxGain* means maximum luminance reduction. If *MaxGain* is 20% and $Lg_t(x,y)$ is 512, then the current luminance reduction of region (*x, y*) is 10%. Next, we applied 3x3 dilation twice to $Lg_t(x,y)$, and we applied 3x3 LPF to obtain logo compensation data. Finally, interpolation is also used.

4. Logo Region Refine method

The third step is the pixel based detection that refines the logo region from the block based detection region. The opaque logo or translucent logo has the feature that their brightness does not fall below a certain value regardless of which video image appears. Figure 3 shows an example of sequence data characteristic of the opaque logo and the translucent logo according to the change of the surrounding luminance. In the figure, it can be seen that the opaque logo has a constant value irrespective of the change of the surrounding brightness. In the case of translucent logos, it can be seen that the brightness of the logo is largely changed according to the surrounding brightness but does not fall below a certain value. It means that it is possible to extract pixel based logo, if the surrounding brightness falls below a certain value. We define the threshold as *th_ln* and set it to about 80. The logo surrounding area can be defined as the remaining area after subtracting from the area where three dilation is applied in the $Lg_t(x,y)$ to the area where two dilation is applied in the $Lg_t(x,y)$. If the brightness around the logo is lower than *th_ln*, an area larger than *th_ln* is defined as logo area, and the other area is defined as background. Figure 4 shows an example of the pixel based logo extraction. If we lower the brightness of the logo area with the block based detection result, the surrounding of the logo becomes dark and it affects image quality. So, we need a method to avoid this problem and adaptive control method is applied according to input image. When the brightness around the logo is more than a certain value, the luminance reduction of the block unit is lowered. If the brightness around the logo is less than a certain value, the brightness of the logo pixel area is lowered and the logo around region is not changed or little lowered. This method can solve the problem of darkening the logo around region and can increase the luminance reduction amount of the logo region.

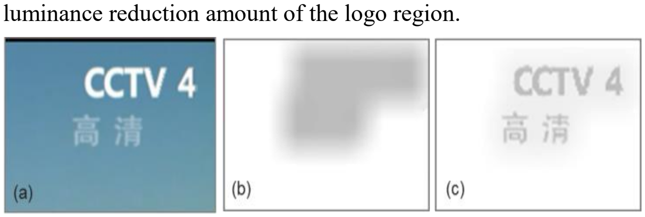

Figure 4. An Example of the pixel refinement: (a) input image, (b) the region of block based detection, (c) pixel refinement result.

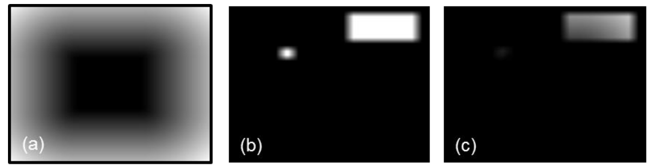

Figure 5. An example of limiting the detection area: (a) An example of local gain, (b) an example of compensation gain before applying the local gain, (c) an example of final compensation gain after applying the local gain.

5. Logo Compensation method

The method proposed in this paper is a method to detect the logo region as a minimum resource applicable to H / W FPGA. Rather than accurately detecting the logo area in real time, the main purpose is to alleviate the image sticking problem of logo area, which is a major issue of OLED TV. After detecting the logo, several compensation methods are applied to mitigate the image sticking problem of the OLED TV through adjusting the brightness of the logo region. The first method is to limit the detection region. The logo usually appears in the corner of the TV screen. In the proposed algorithm, the compensation gain for each position is applied differently in order to increase the detection accuracy of the logo region and to minimize the degradation in image quality that may occur due to the luminance change of the screen. Figure 5 shows an example of how to limit the detection area and the results when the compensation method is applied to the logo detection result. In Figure 5, (a) shows an example of local gain map. (b) is an example of a compensation gain that can be displayed when a logo is detected. There is a small rounded type point that is a erroneously detected point which is shown close to the center of the screen. (c) shows an example of the final gain map when the local gain is applied to the detected region. By using this method, it is possible to prevent that the logo is erroneously detected. The second method is to adjust the gain value applied to the logo according to the brightness around the logo. The proposed algorithm uses a block based detection method. If a constant gain value is applied to the detected logo regardless of the brightness around the logo, the TV user can easily detect the brightness change of the logo area. In order to solve this problem, adaptive gain according to the surrounding luminance of logo is applied. The maximum luminance reduction amount is adjusted so that the luminance of the logo region is equal to or higher than the luminance around the logo. In order to improve the average luminance reduction of the logo region, the adaptive control of luminance is applied only to the image based detection method. Even if there is no adaptive control, the stress based algorithm is not well recognized to the user because it reduces the brightness to maximum 20% in a wide range smoothly. In case of the image based detection method, the luminance is lowered up to 25%, and it may be adaptively changed according to the image environment.

6. Experimental Result

One video was made by combining twenty videos, and the MOS evaluation and the average luminance reduction of the logo region were measured in the video. The proposed algorithm is implemented in FPGA and the luminance is measured through the measuring equipment in actual OLED panel. The proposed algorithm can reduce the brightness of opaque logos by about 30% and reduce the brightness by about 23% for translucent logos. Figure 6 shows Mean Opinion Score (MOS) evaluation result. The MOS result is about 4.3 and it show that our algorithm

Table 1. MOS Evaluation Check List and Score

Score	*Evaluation Check List*
5	It is like the original
4	It is close to the original but it feels a little dark.
3	The darkness is clearly perceived.
2	It became dark enough to interfere with watching TV.
1	It is difficult to watch TV.

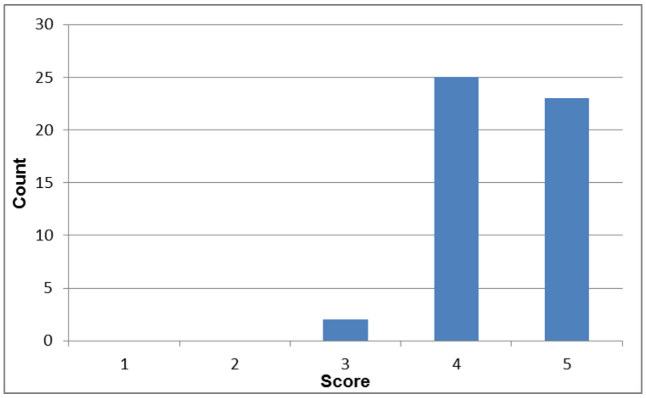

Figure 6. MOS evaluation of TV picture quality with our algorithm

does not significantly affect image quality degradation. Table 1 shows MOS evaluation check list. Figure 7 shows an example of the algorithm result. (a) shows the original video. (c) is the final result of the proposed algorithm, and the logo region appears a little darker than the original image.

7. Conclusion

Previous Logo detection methods focused on correctly detecting logo, so it requires a large amount of computational resource and memory to apply these methods on actual H/W. The amount of memory space required to store one frame of UHD image is about 200Mbit, so the pixel based approaches required more than 200Mbit to extract logo. In this paper, we proposed the algorithm that is able to detect the logo and to control the brightness according to the image environment by using only 2Mbit of computational resource, when it applied to the FPGA H/W system. We proved that our method can improve the lifetime of the OLED TV. Though it may vary depending on the characteristics of the OLED device, the luminance reduction of 30% on the average can be regarded as a result of doubling the OLED TV lifetime assuming that the current coefficient γ is 2 in the OLED degradation model of equation 1. The proposed method is not focused on exactly detecting logo. False detection can be occur, because the main purpose of the algorithm is to detect high stressed area. Only the logo is the most stressed area. Image quality problem caused by false detection can be avoided by

Figure 7. An Example of algorithm result: (a) input image, (b) stress based logo detection result, (c) Image based logo detection result.

limiting the area and widely smoothing the compensation data. Our proposed method has been applied to OLED TV for years and the algorithm effect was proved in the market field.

8. References

[1] Sugimoto, Akira, et al. "Flexible OLED displays using plastic substrates." IEEE Journal of selected topics in quantum electronics 10.1 (2004): 107-114.

[2] Görrn, Patrick, et al. "Towards see-through displays: fully transparent thin-film transistors driving transparent organic light-emitting diodes." Advanced materials 18.6 (2006): 738-741.

[3] Yoshioka, Toshihiro, et al. "P-129: Comprehensive Analysis of Luminous Decay Curves for Accelerated Lifetime Testing of OLEDs." SID Symposium Digest of Technical Papers. Vol. 46. No. 1. 2015.

[4] Meisinger, Katrin, et al. "Automatic tv logo removal using statistical based logo detection and frequency selective inpainting." Signal Processing Conference, 2005 13th European. IEEE, 2005.

[5] Jingmeng, He, et al. "A TV logo detection and recognition method based on SURF feature and bag-of-words model." Computer and Communications (ICCC), 2016 2nd IEEE International Conference on. IEEE, 2016.

[6] Zhang, Yueying, et al. "Weakly-supervised TV logo detection." Automation (YAC), 2017 32nd Youth Academic Annual Conference of Chinese Association of. IEEE, 2017.

[7] Girshick, Ross. "Fast r-cnn." Proceedings of the IEEE international conference on computer vision. 2015.

[8] Esen, Ersin, et al. "A fast method for animated TV logo detection." Content-Based Multimedia Indexing, 2008. CBMI 2008. International Workshop on. IEEE, 2008.

[9] Chiu, Chung-Cheng, Min-Yu Ku, and Li-Wey Liang. "A robust object segmentation system using a probability-based background extraction algorithm." IEEE Transactions on circuits and systems for video technology 20.4 (2010): 518-528.

[10] Cózar, Julián Ramos, et al. "Logotype detection to support semantic-based video annotation." Signal Processing: Image Communication 22.7-8 (2007): 669-679.