Low Cost, High Performance, and Effective Overdrive Implementation Method for LCD Systems

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Abstract

We propose a low cost, high performance, effective overdrive implementation method for liquid crystal display systems. The technique can calculate all overdrive values using higher order approximation algorithm by only three measurements. We find that our technique can be applied regardless of LCD panels. Due to its simplicity, we can also tune motion performance of the LCD systems without measurements.

1. Introduction

Overdrive (OD) technologies have been developed since the beginning of 1990s [1, 2] in order to reduce the motion blur artifacts of liquid crystal displays (LCDs) due to the slow response times of LC molecules. These days, the OD technologies have been adopted in most LCD television (TV) applications. The applications of these technologies have also been expanded to monitor panels, mobile displays.

Moving image quality of LCD is becoming more important than ever as the number of multi-media contents is exploding. Thus, the OD technology is indispensable in TVs and is being adopted in monitors. Furthermore, multimedia contents in mobile devices have been increased significantly than before, which means market is requesting faster mobile displays. To apply the OD technology to mobile displays, power consumption should be reduced. Low cost and efficient overdrive technology for high resolution panels becomes a challenging issue [3-8].

A conventional OD technology requires several look-up tables (LUTs) and interpolation logics to calculate OD values depending on transitions. The size of LUTs is as large as 55,488 bits ($17\times17\times6\times32$) when the dimension of an LUT is 17×17 and the stored data are 32 bits. 32-bit data are composed of an overdrive value and interpolation parameters. The increased power consumption due to an additional frame memory and the huge LUT operation has prevented panel makers from adopting the OD technology in laptop panels. There is another way to adopt the OD technology in laptop computer. Intel proposed a new method to implement the OD technology inside a graphic chipset. This makes it possible to implement OD technology in laptop computer without any increase of power consumption. However, PC makers need to find out LUT values by themselves. It is a time-consuming job. It needs deep understanding of LCDs and very expensive equipment. Thus, more practical implementation method is necessary.

2. Overdrive Implementation

We propose an overdrive implementation method for set maker and users to find out OD LUTs easily in a short time without an expensive measurement tool. This method is applicable to all the panels for laptop computer, monitors and mobile devices.

2-1 How to Find out OD values

We can fit the relations between (D_{OD}-D_{PF}) and D_{CF} when D_{PF} is fixed, where D_{OD}, D_{PF} and D_{CF} are OD data, previous frame data and current frame data, respectively. In 2008, we presented a third order approximation method where we used a base line with D_{PF}=0 and we shifted it to obtain OD values of other transitions with different D_{PF} [9]. However, we found that it needs more accuracy.

Therefore, we propose a combination of linear and third-order approximations for better results over all transitions. We propose the previous frame data of the base lines for rising and falling transitions to be 64 and 192, respectively. After extracting base lines, they are shifted to get OD values of other transitions as illustrated by a red dotted line in Fig. 1. For better accuracy, we apply linear approximation to some specified transitions. The linear approximation regions are illustrated by blue solid lines as shown in Fig. 1. We apply linear approximation when D_{CF} ranges from D_{PF} to D_{PF}+32 and from 224 to 255 for rising transitions.

A third-order line can be expressed as follows,

$$y = \alpha x^3 + \beta x^2 + \gamma x + C - D_{PF} \qquad (1)$$

In Eq. (1), x=D_{CF} and y=D_{OD}-D_{PF}. The value of α, β, γ and C can be obtained if we know four different points (x, y).

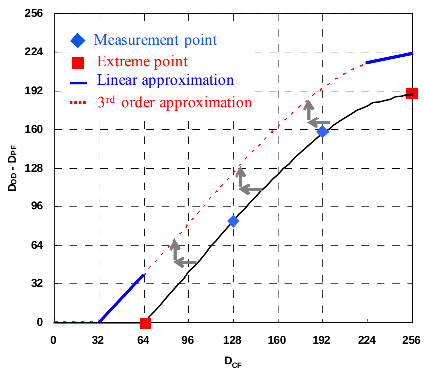


Figure 1. How to create a base line using a third order approximation and how to shift it. We propose linear approximation regions.

We assume the four parameters are determined when D_{PF} = 64. We expect that an equation for D_{PF} = 32 can be obtained by shifting the base line both to x- and y-directions. Then, the equation for different D_{PF} can be written as follows:

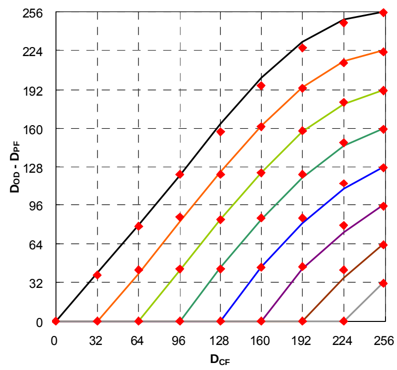
$$y = \alpha(x-\Delta x)^3 + \beta(x-\Delta x)^2 + \gamma(x-\Delta x) + C - D_{PF} \quad (2)$$

The x-shift, Δx, changes with D_{PF}. After measuring nine panels, we found that the relation among the shifting values. Thus, Δx of rising transitions, Δx_R, can be expressed as follows:

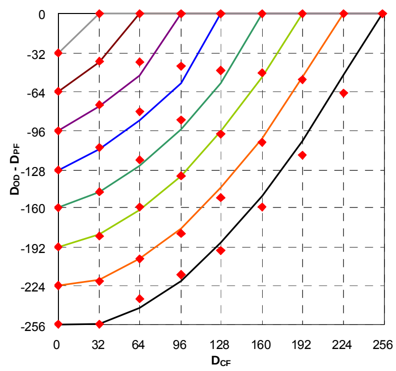
$$\Delta x_R = \left(\frac{s_R}{255}\right) \times (D_{PF} - D_{PF0}) \qquad (3)$$

where D_{PF0} is the previous frame data of the base line selected by users, Δx of falling transitions, Δx_F, is as follows:

$$\Delta x_F = \left(\frac{-s_F}{255}\right) \times (D_{PF} - (255 - D_{PF0})) \qquad (4)$$



(a) rising responses



(b) falling responses

Figure 2. Comparison between the proposed approximation and original overdrive values of laptop panel for (a) rising and (b) falling responses

As you know, Δx_R is different from Δx_F. We found that s_R = 48 is the best for Samsung's laptop panel (LTN154X3-L03). In addition, the best choice of s_F is 48 or 96 when D_{PF} is smaller than D_{PF0} or D_{PF} is larger than D_{PF0}, respectively. Figure 2 shows comparison between the proposed approximation and original overdrive values of laptop panel for rising and falling responses. We can see that the proposed approximation method matches actual OD values very well.

2-2 How to apply approximation method easily regardless of LCD panels

Table 1 shows optimum coefficients of the proposed approximation for rising transitions of nine different models from different makers. As shown in Table 1, we can find a bigger variation of coefficient γ and C-D_{PF} than coefficient α and β . In addition, if α or β is changed, there would be a big change because α and β are multiplied by much higher values. Thus, we decided to fix coefficient α and β. We can express all the OD values of all LCD panels using,

$$y = \alpha x^3 + \beta x^2 + (\gamma + A)x + (C - D_{PF} + B) \,. \, (5)$$

Here, A and B are parameters among different panels. According to our analysis, variation B is almost ten times of A. Thus, Eq. (5) is converted to

$$y = \alpha x^3 + \beta x^2 + (\gamma + 0.1\Delta)x + (C - D_{PF} + \Delta) \,.(6)$$

Here, Δ is an adjusting parameter among different panels. If we know parameters *α*, *β*, *γ*, and C of one panel, we can get OD values of another panel using the parameters. In other words, we can tune optimum OD values by changing only one variable.

Table 1. Optimum coefficients of the proposed approximation

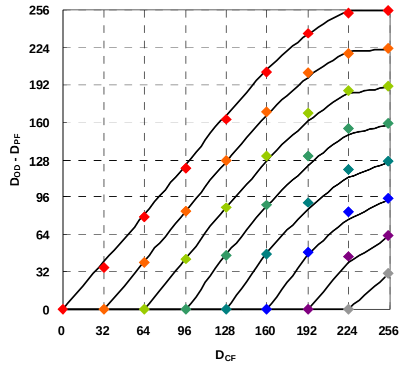
Panel		Coefficient			
		α	β	γ	$C\text{-}D_{PF}$
AUO	B154EW03	-1.85E-05	6.77E-03	4.15E-01	-4.91E+01
CMO	N154C6-L01	-2.38E-05	8.20E-03	4.14E-01	-5.37E+01
CMO	N154I1-L0A	-2.90E-05	1.06E-02	1.07E-01	-4.20E+01
CMO	N154I2-L02	-2.99E-05	1.06E-02	1.66E-01	-4.60E+01
CMO	N154I4-L02	-2.02E-05	7.27E-03	4.06E-01	-5.03E+01
CMO	N154I5-L01	-2.91E-05	1.01E-02	2.73E-01	-5.09E+01
SAMSUNG	LTN154X3-L03	-1.77E-05	5.45E-03	7.74E-01	-6.68E+01
SAMSUNG	LTN154XB-L01	-2.02E-05	7.67E-03	2.75E-01	-4.40E+01
TMD	D2PO12.1	-3.33E-05	1.25E-02	-1.39E-01	-3.32E+01

3. Results and Discussion

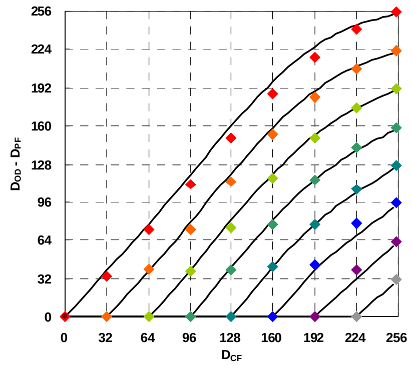
We extracted OD values from Samsung's laptop panel (LTN154X3-L03). As we proposed in the previous section, we extracted *α*, *β*, *γ*, and C. We applied the equation to two different panels, by modifying Δ, such as CMO (N154I5-L01) and AUO (B154EW03) panels. Figure 3 shows the application results of the proposed method to two different panels. Here, the adjusting parameters Δ for CMO and AUO panels are 0.2, -0.23, respectively. Symbols and solid lines are actual and calculated OD values, respectively.

We can see that the proposed approximation method matches actual OD values very well. Table 2 shows error rate between actual and approximated OD values using individual and Samsung coefficients. As shown in Table 2, the proposed method is almost similar to third order approximation using individual parameters. Error rate is very low in all panels using any method. Therefore, the proposed method have high performance and we can find OD value easily.

The error rate was defined as the average of (actual OD-approximated OD)/(actual OD) for 28 transitions.



(a) CMO panel (N154I5-L01)



(b) AUO panel (B154EW03)

Figure 3. The proposed approximation for (a) CMO panel (N154I5-L01), (b) AUO panel (B154EW03) using parameters of Samsung panel (LTN154X3-L03).

Table 2. Error rate between actual and approximated OD value using individual and Samsung coefficients

Panel		Using individual coefficient	Using SAMSUNG coefficient
AUO	B154EW03	6.29%	5.09%
CMO	N154C6-L01	3.53%	4.61%
CMO	N154I1-L0A	3.31%	3.83%
CMO	N154I2-L02	2.87%	3.77%
CMO	N154I4-L02	4.79%	5.30%
CMO	N154I5-L01	2.32%	3.29%
SAMSUNG	LTN154X3-L03	2.93%	2.93%
SAMSUNG	LTN154XB-L01	6.62%	5.58%
TMD	D2PO12.1	3.81%	6.06%
Overall average		4.05%	4.50%

If set makers implement the OD technology inside a graphic chipset, set makers or users must find optimum OD values. If they get three OD values of three transitions with a fixed start level, they can obtain all the other OD values based on our approach. Without the help of an expensive equipment, they can find the OD values using human eyes. Figure 4 shows how to extract overdrive values using human eyes. Set makers or users can select three transitions with fixed D_{PF} and three D_{CF} for three transitions and can control overdrive values with OD control areas (red dotted box).

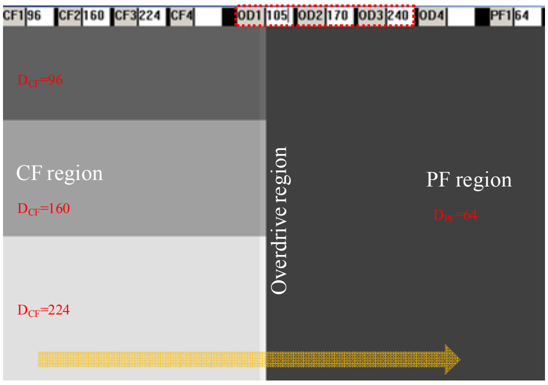


Figure 4. Software to get three OD values

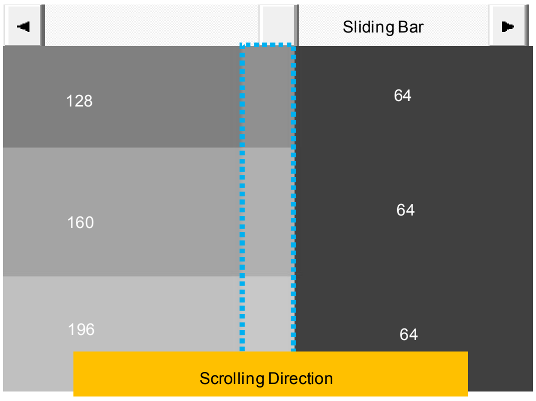


Figure 5. How to extract overdrive values using prefixed parameters

If set makers prefix parameters α, β, γ, and C, we can change OD values regardless of LCD panels by controlling only the adjusting parameter, Δ. Figure 5 shows how to extract overdrive values using prefixed parameters. We add only one sliding bar representing the adjusting parameter Δ . If we move the sliding bar back and forth, three OD values (blue dotted box) can be changed at the same time. After selecting OD values, OD values at all transitions can be calculated automatically using our method. We can find out optimum OD values by observing the scrolling pattern as shown in Fig. 5.

Generally, end users of LCD systems are not familiar with the overdrive technology. However, they can extract optimum OD values only if they can distinguish the least blur condition of the scrolling pattern by moving the sliding bar back and forth. Set makers don't need a time-consuming job to find out LUTs.

4. Conclusions

We realized a low cost, high performance, an effective overdrive implementation method for LCDs. Overdrive implementation using higher order approximation is very powerful and costs very low. The technique can calculate OD values very accurately. Set makers don't need to measure tremendous response transitions to obtain OD LUTs because only three visual observations are sufficient.

If set makers prefix parameter α, β, γ, and C, users can get OD values regardless of LCD panels with scrolling slide. If set makers implement the OD technology inside a graphic chipset, users can tune their display by a very simple way. We found that very simple relationship that can be applied regardless of LCD panels.

We expect a brand-new laptop computer that can support high speed LCD screen image with user controllable feature in the near future.

5. Acknowledgements

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6. References

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