Motion Perception on Liquid Crystal Display (LCD) Panels

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1. INTRODUCTION

High quality Liquid Crystal Displays (LCDs) rival the visual quality of Cathode Ray Tubes (CRTs) used traditionally in the film and video production and post-production environment. Resolution, brightness, size and weight, and energy consumption are just some of the advantages of high-quality LCDs. There are, however, some fundamental differences between the two technologies, including the way motion is perceived by the Human Visual System (HVS) on the two devices. This paper familiarizes the reader with motion perception issues associated with LCD technology.

2. MOTION PERCEPTION ON LCD PANNELS

An LCD motion blur is caused by both the characteristics of the LCD display and the nature of the HVS [1]. The sample and hold (S&H) characteristics of the LCD panel can be measured and photographed (objective factors). The HVS introduces a perception-related artifact that can only be described (subjective factor), but not measured. The two effects are cascaded and produce the way we see motion on LCD displays as illustrated in Figure 1.

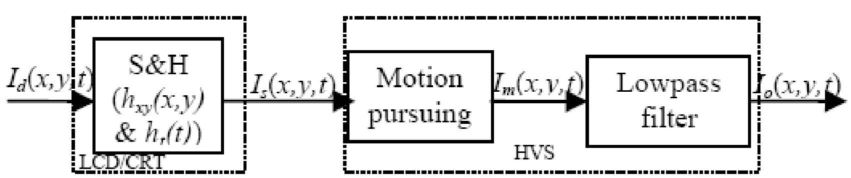

Figure 1: Motion perception on LCD panels [1]

To illustrate this phenomenon, we designed a simple visual experiment. A single line rectangle (Fig. 2) is moved across a high quality LCD display at a rate of 2-10 pixels per frame (1920x1080i 30 or 1440x720p 30). HD SDI input is utilized on a high quality LCD display. The moving pattern (Figure 2) is projected, and the resulting image is observed and tracked (Figure 3), observed using an on-screen marker (preventing eye tracking) and photographed using both digital and film cameras (Figure 4).

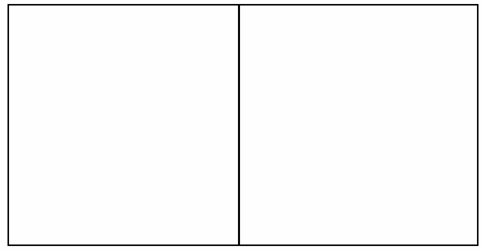

Figure 2: Cine-tal test pattern

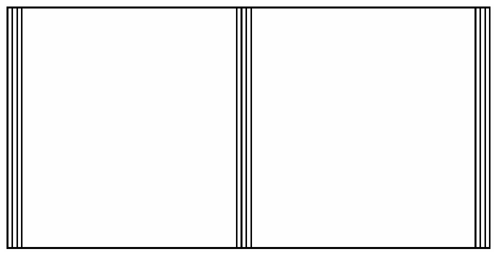

Figure 3: Observed (tracked) moving Cine-tal test pattern

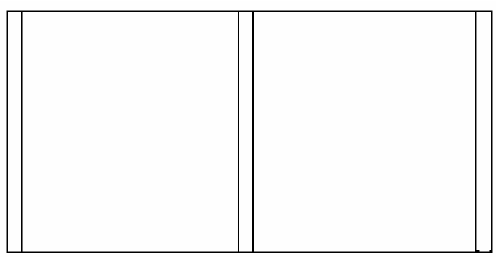

Figure 4: Photographed moving Cine-tal test pattern

When the horizontally moving pattern is simply tracked by the eye on the screen, the observer perceives a band of vertical lines where there only should be one. The width of the band is approximately equal to the number of pixels that the image moved frame to frame (see Section 4).

When a marker is placed on a screen, and the observer focuses on the marker rather than the moving pattern behind the marker, it becomes apparent that there are only two lines. The spacing between the two lines is approximately equal to the number of pixels image moves frame to frame. The same result is confirmed when a camera is used to capture the image (objective analysis).

The same effect will be produced for vertical motion or a combination of horizontal and vertical motion. The width of the blur pattern will always be approximately equal to the displacement frame to frame in the respective directions (see Section 4 for details).

Section 3 of this paper explains the objective S&H characteristics of the LCD display and some of the solutions beginning to appear on the market. Section 4 focuses on the HVS and the way we process motion.

3. SAMPLE AND HOLD IN LCD PANELS

The basic physical difference between the way an image is displayed on a CRT and an LCD is as follows. On a CRT, a beam of electrons excites a phosphorous point which then begins to decay as soon as the beam moves on. By the end of the frame being displayed, the phosphorous point is dark and needs to be re-excited with the next pass of the beam (impulsive display type, pictured in Figure 5b). Thus, in the case of our moving object in Section 2, the previous frame (complete with its vertical lines) has disappeared completely before the next frame is drawn. Incidentally, the low pass filter (LPF) function of the HVS described in section 4 prevents us from seeing the flicker associated with 60Hz (US) refresh rate of the CRT display.

The LCD panel displays the frame in a hold-type pattern illustrated in Figure 5b. That is, each pixel remains illuminated with the designated value up until the very end of the frame (held). It is during the next frame that a change in field intensity is processed. For any non-zero response time on the LCD display, this will result in a residue of the previous vertical line in our experiment being displayed along with the new vertical line position. Hence the two lines we are measuring in our experiment. The longer the LCD panel response time, the more pronounced the effect.

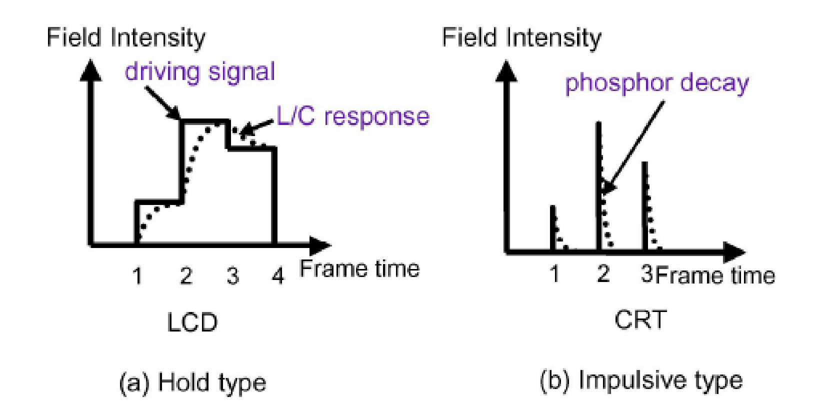

Figure 5: LCD and CRT display comparison [3]

Two relatively new techniques have been developed to make the performance of an LCD more similar to that of a CRT. They are LCD overdriving techniques and cyclic data blanking [3].

When decreases to response time below 16ms are needed, a pre-tilt voltage can be applied in the frame time prior to application of the overshoot voltage [5]. Sub-8ms response times can be achieved for any gray-gray transition [3]. Figure 6 illustrates this approach. It is worth noting, however, that this still results in the motion artifact we observed in our experiment, and only improves gray-gray transitions.

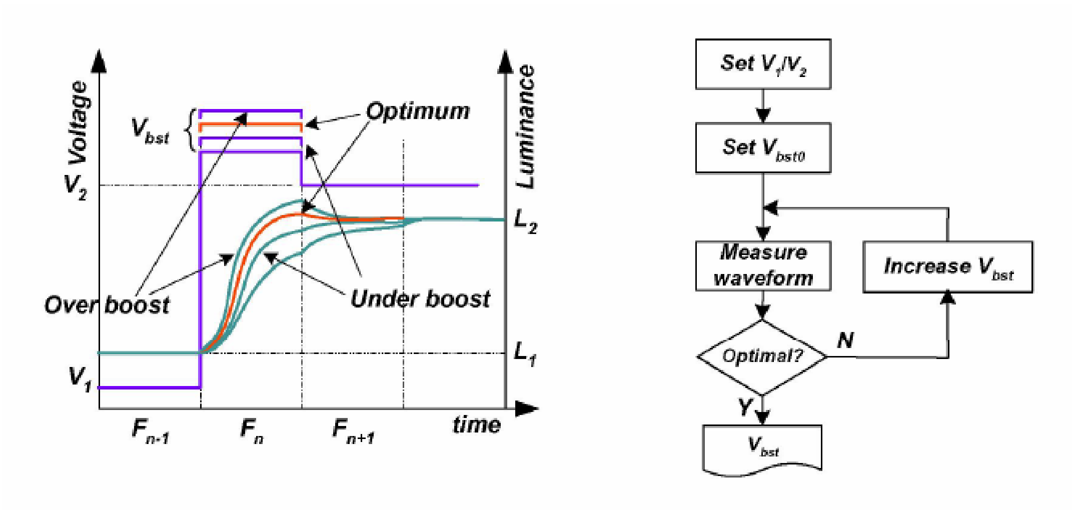

Figure 6: LCD overdriving technique [3].

Cyclic data blanking has been developed by Hong et al [3] and is illustrated in Figure 7. It results in real black level between the luminance peaks, and minimizes flicker while producing motion reproduction similar to CRTs [3]. Image data is reset every frame by inserting a black image of specified size in a frame image. The position is changed during frame time.

As an alternative to cyclic data blanking described above, techniques have been developed by others [6] utilizing turning the back light off at the beginning and end of each frame and increasing the intensity of the short-exposure backlight to compensate for luminance loss. Both techniques achieve performance more similar to a CRT and theoretically eliminate the dual line we observed in our experiment (motion blur).

If and when professional quality panels effectively implementing the new techniques become available, Cine-tal will incorporate them in its product line.

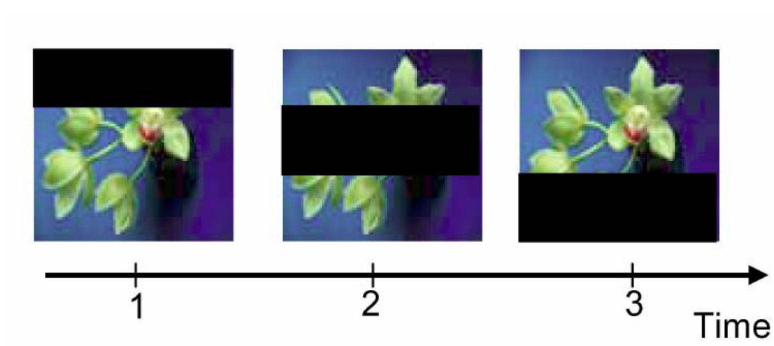

Figure 7: Cyclic data blanking [3]

4. HVS MOTION PERCEPTION BLUR

In addition to the objective phenomenon described earlier in this document, there are subjective properties of the HVS impacting motion perception. Motion pursuing and low pass anti-aliasing features of the HVS are the properties contributing to altered motion perception. These features of the HVS were identified prior to the emergence of digital display technologies [4] in the context of still photography of sequential images and cinematography.

HVS possesses the ability to track fast moving objects in nature without blur. This same ability causes the human visual system to attempt to track and low-pass images represented by a digital display system such as an LCD panel (Fig. 8).

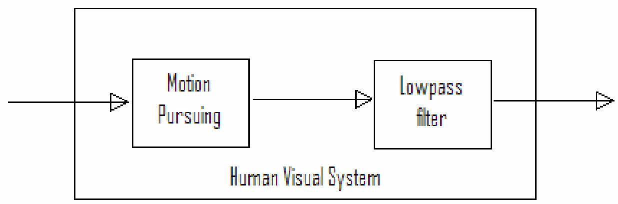

Figure 8: HVS [1]

In the experiment described in Section 2, the edges (when observed and tracked) appear to consist of a band of lines, the width of which is proportional to the speed of motion (Fig. 3).

Pan et al [1] have constructed a mathematical model for the perceived moving edge on a CRT and an LCD.

If the perceived moving edge on CRT is

$$I_{\circ}^{CRT}(x,y,t)=\begin{cases}0, & x\le 0\\ 1, & x>0\end{cases}$$

Then, under the linear transition model developed in [1], the perceived edge on an LCD becomes:

$$I_{\circ}^{LCD}(x,y,t)=\begin{cases}0 & x\le 0\\ \dfrac{x^2}{v^2T_h} & 0<x\le vT_h/2\\ T_h/2-\dfrac{(vT_h-x)^2}{v^2T_h} & vT_h/2<x\le vT_h\\ T_h/2 & x>vT_h\end{cases}$$

The blur width, *BW*, is defined as the spatial width between edges with low value + 10% of the difference and low value + 90% of the difference [1]. For the linear model developed in [1], *BW* is as follows:

$$BW_L = (1 - \sqrt{0.2})vT_h \approx 0.55vT_h = 1.1vT$$

Where v is the velocity of image and $T_h = 2T$ = temporal span of the function. An example of this is shown in Figure 9 (along with the more complex, sinusoidal transition model example also developed in [1]).

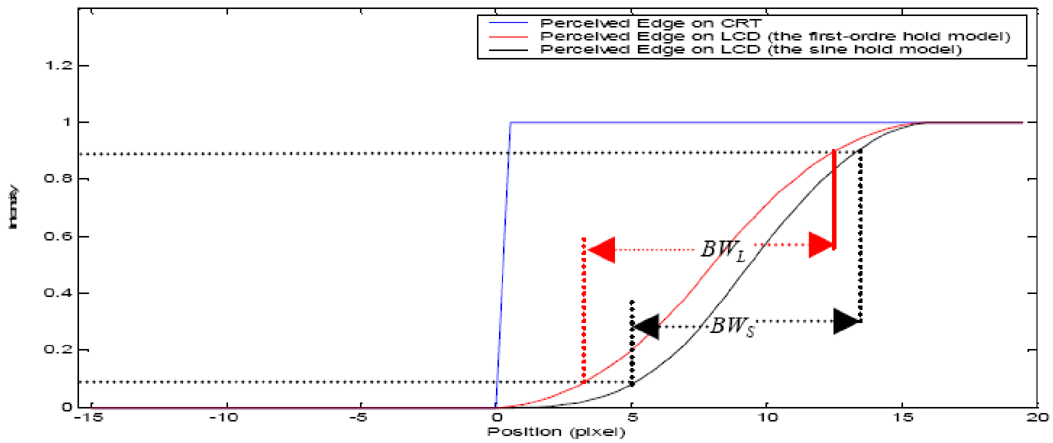

Figure 9: Perceived edges on CRT and on LCD [1].

In our experiment in Section 2, this would result in blur that is approximately 9 pixels wide for an object moving at 8 pixels per frame. This blurring is attributable to the HVS (subjective effect) cascaded with the LCD's properties described earlier. Note that in case of a dual peak measured and photographed in Figure 4, it is the distance between the two vertical lanes that will measure approximately 9 pixels. Thus blur width describes both the width of the perceived motion blur, and the measured distance between the two lines pictured in Figure 4.

5. CONCLUSIONS

Both subjective and objective factors contribute to the differences in motion perception between CRTs and LCDs. The differences are important to understand for any professional previously accustomed to CRTs that is viewing and processing video on LCDs.

The next few years are likely to see an implementation of technology that will diminish the differences with respect to CRTs, while continuing to provide superior performance with respect to many other features of the LCDs. With motion perception differences reduced, LCD is almost certain to become the dominant display technology for the foreseeable future.

REFERENCES

[1] Hao Pan, Xiao-Fan Feng, Scott Daly, *LCD Motion Blur Modeling and Analysis*, IEEE 0-7803-9134-9/05, 2005
[2] Charles Poynton, Motion *portrayal, eye tracking, and emerging display technology*, Proceedings of the 30th SMTPE Advanced Motion Imaging Conference, 192-202, Seattle, WA, Feb. 1-3, 1996
[3] S. Hong, B. Berkeley, S. S. Kim, *Motion Image Enhancement of LCDs*, IEEE 0-7803-9134-9/05, 2005
[4] David Burr, *Visual processing of motion*, Trends in Neuro Sciences, 1986
[5] J. K. Song, et al, "DCC II: Novel method for fast response time in PVA mode," *SID 01 Digest*, p986-p989, 2001
[6] *Excitement from every pixel – Philps Aptura lighting technology*, Koninklijke Philips Electronics N.V., 3222 635 59701, June 6th 2006