3.1 Advanced Motion Artifact Analysis Method for Dynamic Contrast Degradation caused by Line Spreading

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Abstract

Moving-Line Spreading is an advanced method for evaluation of motion artifacts for displays. It can show motion blur and dynamic contrast degradation in a single measurement. Human perception with regard to the amount of motion blur is not well-correlated to results from conventional motion blur analysis algorithms, since they do not account for the human visual system. We explore ways to make moving-line spreading measurements and to validate the results with the human visual system for motion perception, as well as other methods of motion blur evaluation.

Introduction

Moving-Line Spreading is a method to evaluate motion blur magnitude plus contrast degradation as a function of speed, both within a single measurement. It is more efficient and simplified than dual edge methods such as for Moving-Edge or Box Edge Blur. It is easier to measure than the other methods, and can provide meaningful results for understanding motion performance of a display.

The width and amplitude or luminance of the spreading line in motion is measured, and several pieces of valuable motion artifact information are obtained. Figure 1 shows an example of how moving-line spreading can be visualized.

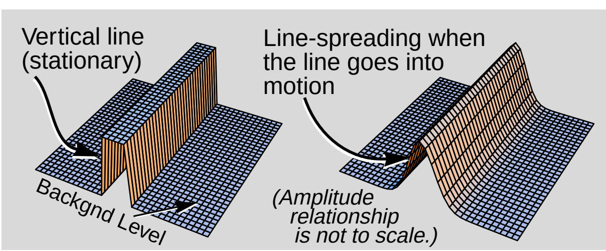

Figure 1: Moving-Line Spreading visualization

Note: Line Spreading is mentioned and used in the FPDM Update [1], as Moving-Line Contrast Degradation and Spreading and in the IEC TC110 61747-3 Motion Artifacts Measurement Standard in development [2].

Line-spreading, like motion blur analysis, requires smooth eye pursuit for proper evaluation or modeling, a key part of relevant motion artifact discrimination and analysis.

Background

Of the various types of motion artifacts, motion blur arguably remains at the top of the list of motion artifacts of concern which LCDs and other display technologies are trying to minimize. The main types of motion blurring evaluation methods are Moving Edge Blur and Box Motion Blur, which can be found in the FPDM (Flat Panel Display Measurements Standard) Update Document [1]. In this paper, we present Line Spreading, a straightforward method to evaluate motion blur. We show results of measurements using several different methods of evaluating motion blur.

Proper evaluation of motion blur on a display requires that the analysis method conform with the Human Visual System (HVS). The minimum model for the Human Visual System with regard to motion artifact recognition involves smooth pursuit of the moving object and a low pass filter response for spatial frequency limiting, such as a Contrast Sensitivity Function (CSF). Figure 2 is an example of a simple HVS model for perceiving motion with smooth pursuit.

Figure 2: Human Visual System model for motion perception, simplified

Discussion

Moving-Edge Blur is a commonly used method for motion blur assessment. This is seen when an edge, such as is shown in Figure 3 on the left, goes into motion. It is very useful for making measurement of the blur with instrumentation, but has reduced visual cues for the human vision response to validate what the instrument measures. Pursuit tracking devices can measure a value for the blur in time. The levels must then be reversed and the measurement taken again to give a complete assessment of the two levels.

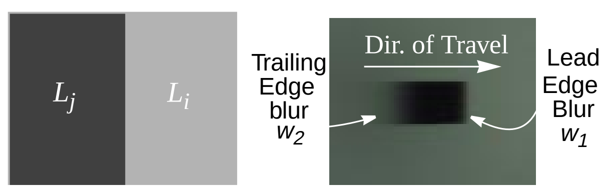

Figure 3: Moving-Edge Blur example (left) and Motion Blur of a moving box (right)

Similar to Moving-Edge Blur, Box Motion Blur, as seen in Figure 3 on the right, has moving edges for evaluation for blur, but allows for viewing of both edges plus the tops and bottoms simultaneously, to provide a number of useful visual cues of the motion blur characteristics with regard to the two levels used.

Moving-line spreading produces a motion blur evaluation pattern with good visual cues, a clear pattern for evaluating blurred width optically or visually, and it provides for dynamic contrast degradation. Figure 4 shows a representation of the moving-line spreading phenomenon.

When a narrow vertical line is placed into horizontal motion in a solid color background, it may be seen to dim and spread in width. As the speed increases, it may dim to the point where it becomes undetectable from the background level.

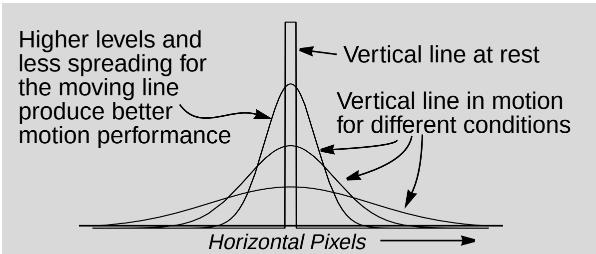

Figure 4: Visualization of line-spreading

Other than speed and display technology dependencies,, the severity of this motion distortion is dependent on the relationship of the levels of the line and background.

Figure 5 shows a representation of line spreading when the background luminance is higher than that of the line.

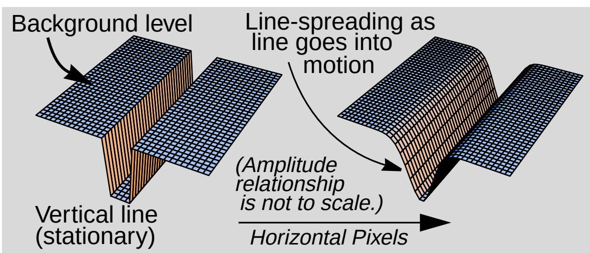

Figure 5: Moving-Line Spreading visualization for a bright background and dark line condition

Line spreading is a more efficient method for measuring blur than Moving-Edge or Box Motion blur measurements for a number of reasons.

- One measurement gives a meaningful number for motion blur.
- Two primary pieces of information are contained in this measurement: Motion Blurring and Contrast Degradation.
- Other information is also contained in the spreading line, such as rounding, sheen, overshoot, uniformity, peaking, dynamic aberrations, gradients, and contrast threshold detection, often easy to see but difficult to measure.

Line spreading, scattering, or dispersion over space is analogous to blurring, which can be present in static or moving images besides those seen on electronic displays. It is related to functions found for analysis of performance for other technical areas, like CCDs, fiber optics, and imaging. It can be represented in a number of different models such as Gaussian Distribution, Line-Spreading Functions (LSF), Point Spread Function (PSF), Modulation Transfer Function (MTF), interpreted as the Fourier transform of the LSF [3, et al.].

We have determined a Gaussian distribution model is suitable to equate reasonably well with Line-Spreading Motion Blur, as per Eq. 1.

$$F_g(S) = \frac{G_0}{u\sigma\sqrt{2\pi}} e^{-0.5\left(\frac{\lambda-\mu_g}{\sigma}\right)^2} \quad \text{[Eq. 1]}$$

Where

G_0 = Gaussian amplitude term
μ_g = the line centroid position
σ = Gaussian width as a functional wavelength
u = the velocity (pixels per frame)

And are all expressed as a function of Spatiotemporal sensitivity of the human visual system, $F_g(S)$.

Technical Summary

As stated, moving-line spreading is an efficient method to evaluate motion blur magnitude plus contrast degradation as a function of motion, all within a single measurement. It is more efficient and simplified than edge quantifying methods for motion blur evaluation.

A line is placed into motion against a background of a single fixed different level. Typically, the line is vertical, and moves from left to right. Grayscale is often used (as in this paper), but the method can also be applied to color evaluation.

We determine the width and level of the line when it is motionless. We can assess it in this state to account for any fringing or other effects. We determine maximum luminance level of the background and of the stationary line to establish the reference for the contrast evaluation. We then evaluate contrast during motion. The ratio of the two give us a contrast ratio using a contrast degradation forumla. Note that we can use voltage or other magnitude

$$\%\text{Contrast degradation} = CR_{deg} = 100 \times \left(\frac{CR'_{max} - CR'_{min}}{CR'_{max}}\right) \quad \text{[Eq. 2]}$$

metrics in place of contrasts to evaluate contrast degradation by means of voltages shown on oscilloscope trace representations of the line-spreading method. With this latter alternative, no luminance level measurements are needed, and relative luminance degradation can be determined.

Following is an equation to evaluate blurred width in time for moving-line spreading.

$$MLS = \frac{w_t - w_w}{w_w \times u \times \frac{1}{\delta_t}} \quad \text{[Eq. 3]}$$

Where

w_t = the Line-Spreading distortion total pixel spread
w_w = the line width in pixels, typically equal to 1
$1/\delta_t$ = the vertical refresh rate
u = the velocity (pixels per frame, ppf)

For Figure 6, the static bright line on the left (A) is the stationary line. When it goes into motion, it is converted into blur by smooth eye pursuit tracking, the characteristics of the human eye, as seen on the right (C). The center case (B) is as the moving line would be seen with a fixed

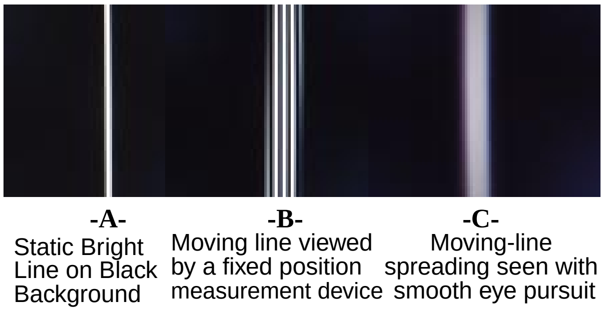

Figure 6: Line-Spreading views

gaze. That is how a non-tracking optical detector would see the moving line. Preliminary results have shown some promise in using a fixed static device to evaluate this type of view to correlate with the human vision results by spatial or other processing of the multiple lines. The results are not yet conclusive and the methods not yet well enough defined to include here.

Results

First we look at moving-line spreading test results using an MPRT tester to obtain the line-spreading data.

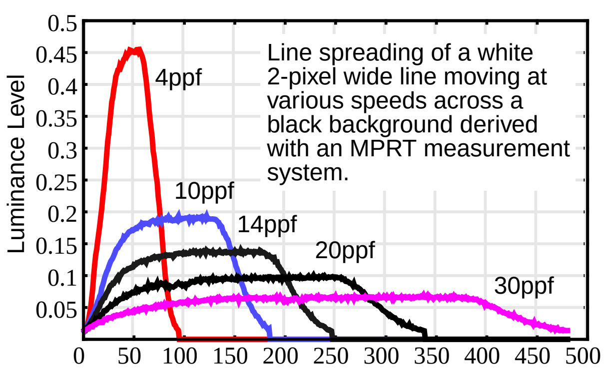

Figure 7: Line Spreading with an MPRT tester

Figure 7 shows moving-line spreading measurement results for the case of a white (level 255) line moving across a black background at various speeds.

Speed (PPF)	*Width (Pixels)*	*MLS*	*Con-trast*	*Max Ampl*	*%Cont Degr*
4	55	114.6ms	591.4	0.4549	54.51
10	135	112.5ms	251.36	0.1934	80.66
14	187	111.3ms	181.67	0.1397	86.03
20	268	112.1ms	130.21	0.1002	89.98
30	408	113.3ms	90.35	0.0695	93.05

Table 1: MPRT Line Spreading test results

Table 1 shows supporting data for the MPRT tester plotted results. Pixel width is the half width of the line-spreading pulses from Figure 7. MLS (Eq. 3) is calculated from the pixel width. Contrast is the real contrast of the maximum of each level, and %Contrast Degradation (Eq 2) is calculated from that. The pixels of the MPRT tester line-spreading plot are CCD pixels, not pixels of the display like the source 2-pixel moving line. As a result, there is a CCD-to-display pixel scaling factor not included in the above results.

Both the Contrast values of Table 1 and the Maximum Amplitude values calculate out to exactly the same % Contrast Degradation value. This shows any value measured can be used to calculate contrast degradation as long as the static case levels are known for reference. This could include luminance, contrast, voltage, current.

Figure 8 on the left shows a waveform from the MPRT test set being used for line-spreading testing. A 4-pixel wide line of gray level 91 was moved against a background of level 170. The figure on the right shows a visible image of the scrolling line luminance level over time, using the MPRT test set's sensing probe.

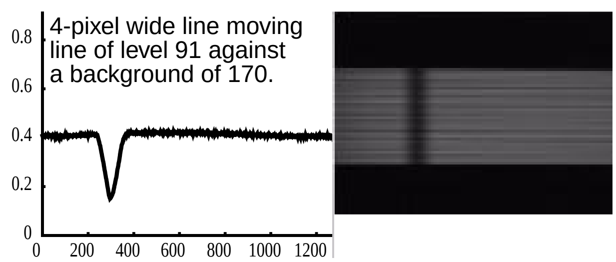

Figure 8: Line Spreading instrumentation view with MPRT test set measuring line spreading

Next we look at moving-line spreading results from the human visual perspective using a software tool (MAT) [4] for quantitative visual analysis.

For the following figures (Figures 9, 10, and 11), four technologies were assessed for motion blur and contrast degradation for line-spreading: The case shown is for levels of 0 and 139 alternately for the moving line and background. Both a black line on 139 and a 139 line on black are shown. The brighter traces are a black line on a 139 level background. This case is for a 2-pixel wide moving line from 2 to 15 ppf.

MLS compensates for scroll speed, vertical frequency, the line width of the stationary line, and test set or conditions which produce an offset for the static case. It can also compensate for other constants for any given test condition or setup.

Figure 9 shows the increased line spreading for increased speeds, significant for the LCDs. Figure 10 shows how doing an MLS calculation for the line spreading tends to level off the spreading equivalent time (in ms). This demonstrates that there is little sensitivity to the measurement as a function of speed. A single speed, optimized for the test method can be used, assuming similar insensitivity to contrast degradation over the same speed conditions.

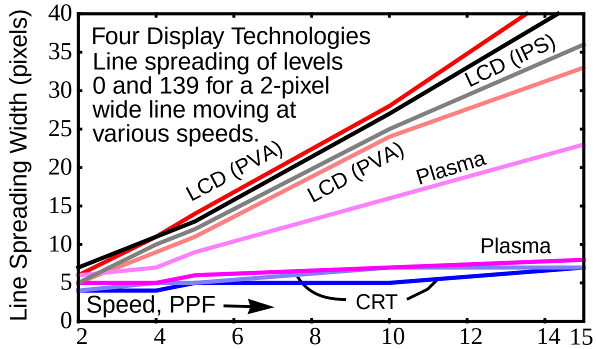

Figure 9: Line Spreading of 4 display technologies

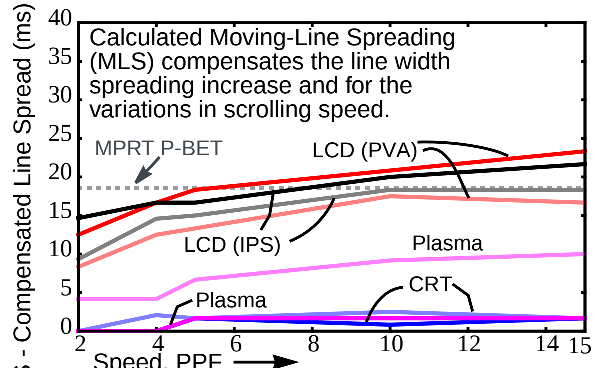

Figure 10: Line Spreading: 4 display techs at various speeds for a fixed 2 pixel line width for calculated Moving-Line Spreading (MLS)

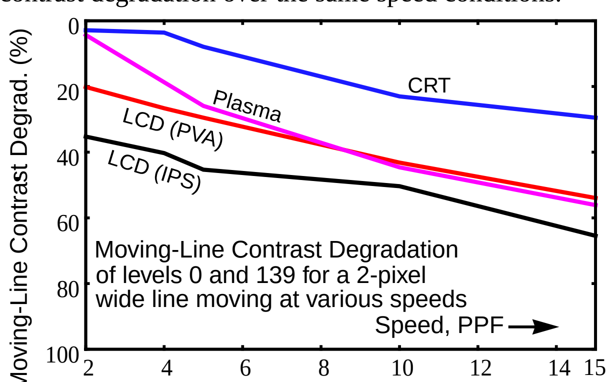

Figure 11: Moving Line Spreading Contrast Degradation for 4 display technologies

Figure 11 shows contrast degradation of four technologies for a moving 2-pixel wide line of level 139 on a black background.

CRTs are known to have good motion blur characteristics, a fact borne out in this work by minimal moving-line spreading observed and measured on a CRT. However, CRTs are shown to have significant moving line contrast degradation using moving line spreading techniques

Moving-line contrast degradation for the MPRT-tester line spreading measurements were shown to follow the same type of curve as Figure 10.

The MPRT reference shown on Figure 10 is the P-BET (Perceived Blurred Edge Width) for the edge motion blur luminance profile of an LCD (PVA) tested for levels of 0 and 255. This was the same display tested for the line spreading measurements with the MPRT tester in Fig. 7. The start = 255 and end = 0 case showed 17.3ms. The reverse levels measured a P-BET of 17.4ms. The 17.3ms value is shown for reference to show it is in the same range as the evaluation data. P-BET takes the blurred edge width and performs a convolution between the original edge and a CSF (Contrast Sensitivity Function) response to more closely represent the Human Visual Response System visualization of the blurred edge.

Conclusions

We have demonstrated an advanced method for motion artifact analysis. This "moving-line spreading" method evaluates, in one measurement, two motion distortions: (1) The magnitude of motion blur in terms of moving-line spreading width; and (2) contrast degradation as a function of motion.

Pursuit tracking devices, such as MPRT test sets, can be used for line-spreading measurements, as well as other methods. In general, pursuit measurement systems or human vision modelling systems for smooth pursuit eye tracking are suitable for the moving-line spreading method. Stationary systems may be usable, but further work is needed to determine the most suitable way to use them.

This method, and others, will be part of the "Motion Artifacts" measurements section of the VESA FPDM3 (Flat Panel Display Measurements) Standard, due in 2006 [1] and in the IEC TC110 61747-3 Motion Artifacts Measurement Standard in development [2].

References

[1] VESA FPDM2: Video Electronics Standards Association, *Flat Panel Display Measurements Standard*, Version 2.0, June 1, 2001.

[2] IEC TC110 61747-3 Document: *Motion Artifacts Measurement of Active Matrix Liquid Crystal Display Modules*, Standard in development.

[3] William Shamblin and Charles Bennet: *Fourier Analysis of CCD Sampled Imaging, Cancas, August 1993.*

[4] Joe Miseli, Sun Microsystems: *Motion Artifacts*, SID 2004, Paper 7.3, Pages 86-89.