7.3 Motion Artifacts

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Abstract

Motion artifacts for LCDs are an important performance quality determinant, one of the final major frontiers for LCDs. Motion issues addressed to date have often been limited to response time, a small portion of the vast scope of motion artifacts. This work defines a number of artifact categories and a method to generate and analyze them.

A program, MAT, was developed to translate what the eye sees as motion artifacts to a set of controlled variables which help evoke worst case conditions, often not analyzable with conventional display test equipment. The program allows for characterizing the artifacts as the eye sees them and can produce some motion anomalies perhaps not yet considered as problems to be solved.

Introduction

LCDs have become established as the preferred desktop monitors for many, if not most, situations which replace long-entrenched CRTs. They are moving closer to CRTs in performance in all necessary areas, and for a number of issues have already exceeded them to levels to which CRTs can never catch up. One of the last major frontiers of LCDs that is still to be conquered is motion artifacts. All display types can exhibit motion artifacts, and LCDs are especially susceptible to many variations of them.

This work does not try to explain causes of the motion artifacts. Rather, it is meant to break down artifacts into classes by which it is easy to identify and understand them, and to show a method for quantifying them individually by use of the program introduced.

Much time can be spent trying to equate camera or image detection equipment characterization of motion artifacts with the human visual system and motion psychology. The goal of this work is to describe characterization of motion artifacts with regard to the way the eye sees them, and without regard to instrumentation equivalents or alternate interpretations of what we see, other than passing curiosity. Arguably, what we see may not be as precise as what a camera sees, but how we see motion artifacts is what is important, not how the camera or other equipment sees them.

Motion performance testing per this work was done using different types of LCDs, as well as some PDPs and CRTs. No differentiation of display technology modes for any category is presented or intended.

Background

Let us consider two categories of image quality on displays with respect to time: temporal and motion-induced.

Temporal performance refers to the class of degradations, distortions, or other artifacts or changes of displays which happen over time with respect to static position of visual content. It may require an image changing in a fixed space or a full field pattern with no image. This could include such characteristics as response time, flicker, residual image (like phosphor burn-in on a CRT), and luminance change over time, such as from latent image (short term), warm-up (medium term), or aging (long term) affects. This may be referenced as temporal performance, static-temporal performance, fixed-position temporal, etc. This class exists in the VESA FPDM [1] today with standard methods for evaluating them, and is not the concern of this work.

Motion-induced performance refers to the class of display anomalies, distortions, or other artifacts which happen over time with respect to moving content on the display screen. Visual content which appears properly when stationary may have a wide variety of degradations if it goes into motion. This can be especially complex with motion picture video content, which can change motion in its visible area for any random and haphazard way imaginable, at any time, and have any effects randomly intermixed, including color, gray level, spatial content density, direction, and speed. This work discusses a controlled way to dissect the many variations.

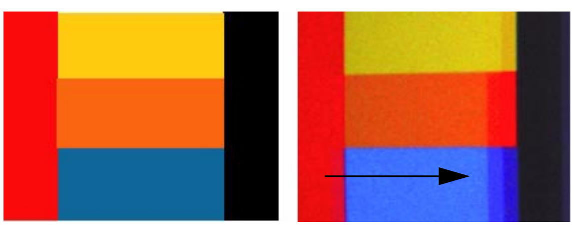
To date, the LCD display industry has mostly focused on response time and inter-gray level response time as primary contributors to motion artifacts. Motion blur has been the primary parameter to visualize it. Some LCDs, especially LCD-TVs, use overdrive techniques to try to speed up the LCD response characteristics and compensate for imbalances in response times. Recently, a consortium of Japanese companies has written a proposed standard for MPRT [2] to try to characterize the blurred edge of a moving line across the screen. Response time and MPRT don't go far enough to analyze the distortions of motion. Rather, they are like a starting point.

For motion artifacts to be understood and analyzed, they must be produced in a controlled and repeatable manner easy to view and control, and be organized to assess the motion artifacts results.

This work presents a method for identifying and evaluating motion artifacts. It is called MAT, or MADAT (Motion Artifacts Detection and Analysis Tool). It is a program developed for viewing and analyzing motion artifacts by controlling motion variables, and allowing a vast number of motion and content conditions to be produced under dynamic user control. This patent-pending method allows for finding many types of motion artifacts on nearly any display

Some examples of artifacts of motion that might be seen in normal use of LCDs for moving content are as follows:

- Smearing or tails, such as from mouse cursors.
- Blurred edges of moving objects.
- Color bleeding, such as in the moving object shown in Figure 1.



Object at rest *Object moving left-to-right*

Figure 1: Motion-induced color bleeding

- Text characters smearing, shifting color, or juddering.

- Flickering of high spatial content, such as dense lines or text. This can be found in moving wireframe images and is very important for CAD and high-detail graphics applications.
- Blurring over fine details, resulting in loss of detail and edge recognition. As shown in Figure 2, lines between the sections of the object disappear when the object moves vertically on an LCD.

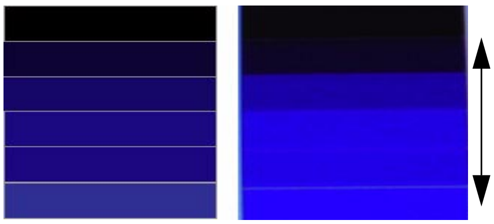


Figure 2: Motion-induced Detail Loss

Assessing Motion Artifacts

Cameras, LMDs (Light Measurement Devices), and other optical equipment will often interpret artifacts of motion differently than does human visual perception. It is the contention of this work that it is best to identify, characterize, and analyze motion artifacts as a human sees them, not as per the results of optical devices.

Following are some conventionally viewed LCD response times, as seen as luminance change of an image turned on and off in place.

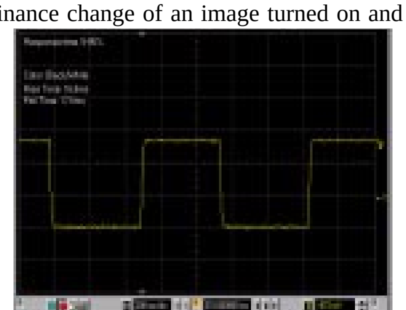


Figure 3: Typical LCD response time waveform

Figure 3 shows a response time waveform with minimal artifacts

Figure 4 shows an oscilloscope LMD waveform from two different LCDs with significant susceptibility to motion artifacts switching between the RGB colors pairs of 88, 77,16 and 121, 7, 128.

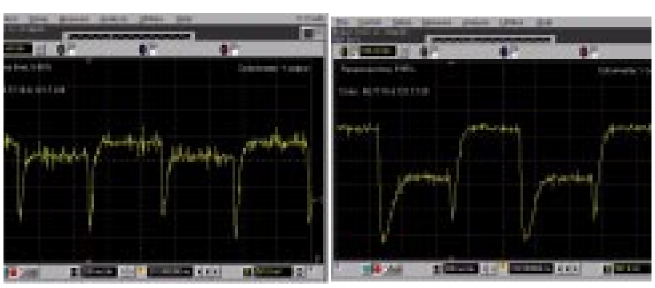
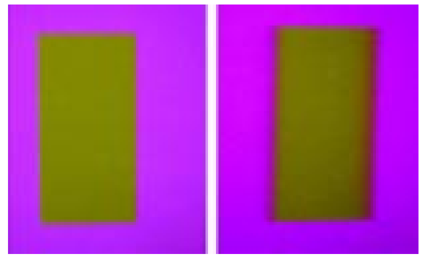


Figure 4: Example LCD Response Time waveform with severe motion distortion. Two different LCDs show the results differently.

The LMD response time measurement shows downward spikes at the edge transitions. Figure 5, a photograph of the object in motion, shows that the edges do have lower luminance levels. What the eye sees, that the LMD misses for this case, is that there is virtually a new color developed by the edges. The LMD cannot capture the essence of the color and luminance aberrations that the eye easily sees.

This color combination was particularly effective for making LCDs show motion artifacts dramatically. Figure 5 shows the color object generated with MAT as seen on an LCD.



Background
Color: 121, 07, 128
x = 0.3197
y = 0.1693
Foreground
Color: 88, 77, 16
x = 0.3969
y = 0.4446
Combined
CR= 1.336
Δu'v' = 0.2006

Figure 5: Object colors which produced Figure 4's waveforms

Evaluating Motion Artifacts

Considerations and Assumptions:

- CRTs are generally quite good in their motion performance, and can often be used as a reference for desired motion goals.
- LMD waveforms on an oscilloscope are usually quantified with respect to 10% to 90% levels of the amplitude of the waveform. Visual evaluation of motion artifacts can determine the full duration of the motion anomalies.
- Significant factors for analyzing motion artifact performance include speed, color/luminance relationships, direction, shape, contrast between the object and background, viewing angle, and other variables.
- Display motion artifacts should be assessed the way the eye sees them, not the way of electro-optical measurement equipment.
- Variances in the human visual system may be a factor in accuracy for quantifying motion artifacts, but not for visualizing them.
- Motion artifacts can be visualized differently and uniquely under different conditions, even when there may be similar root causes (e.g. line-spreading vs. edge motion blurring).
- The graphics generation systems must capable of producing the motion video without artifacts. Motion object driving software must have timing coherence to assure that it does not produce nonsynchronous or nonoptimized driving techniques. Operating system and related software and hardware components must be suitable for high-speed and smooth image rendering of highly complex content.
- Analog video may be slightly worse than digital due to A/D and D/A conversion nonlinearities.
- Direction of movement is sometimes a factor in the magnitude and visibility of motion artifacts.

A number of motion artifact categories have been identified.
This will presented for inclusion in the 2004 FPDM3 [1].

1. **MPRT** [2] defines moving edge smearing, in terms of magnitude of blurred edge width, and provides methods to quantify it. Primarily oriented toward LCDs, this is the phenomenon that shows smearing or trails when a cursor is moved quickly across the display screen. It is the product of black-white and inter-gray level response times, along with other display physical characteristics which affect an image in motion.

2. **Blinking Motion Artifacts** defines rapidly changing solid objects which produce a visual effect such as erratic turning on and off. These can be objects in place or in motion, and may appear to have strobe effects.

3. **Moving Solid Objects Artifacts**. For moving solid objects, there can be object-specific artifacts beyond those of blurring, per the MPRT, such as smearing, discoloration, and geometric distortions like tails and overall object shape changes.

4. **Moving Line or Wireframe Flickering**. For moving lines or high spatial content details, there can be temporal artifacts such as break-ups, dropouts, flickering, flashing, jitter, choppiness, hesitation, discoloration, and false rendering. Unlike conventional flicker as seen under large area bright conditions on CRTs, or high spatial frequency content flicker which can result from timing circuits, power loading, etc., wireframe flicker is seen as erratic changes in luminance or color of a line or lines moving on a display.

5. **Line Spreading**. Moving lines may distort over speed and with regard to their characteristics. They appear to dim but spread in width as speed increases. Although the source of this effect may be similar to that of other motion artifacts, it allows a different way to visualize a display's motion quality.

Results of Use of the Software Tool

Subtle items can be assessed with MAT. As good as a CRT is for motion image quality, a case in which a CRT's performance is worse than an LCD's is shown. For moving objects of high contrast against the background, the CRT produced a long luminance trail (possibly due to phosphor persistence) readily apparent to the eye.

Table 1 shows a sample of the MAT data file comparing the case in which a CRT has a very long motion response time compared to an LCD and PDP.

Tech	Colors		Motion Response Time (ms)		
	Backgnd	***Foregnd***	***Lead time***	***Trail time***	***Total***
CRT	Black	b1fa95h	0.95	127.19	128.19
LCD	Black	b1fa95h	13.16	29.82	42.98
PDP	79fa73h	Black	10.80	13.30	24.17

Table 1: CRT/LCD/PDP Motion Response Time for a case where the LCD time is better than for a CRT.

MAT generates conditions that show moving content distortions which occur directly due to motion. They can be viewed, quantified, and accumulated into a data file. Figure 6 is an example using MAT of how color distortion appeared to the eye for an object in motion.

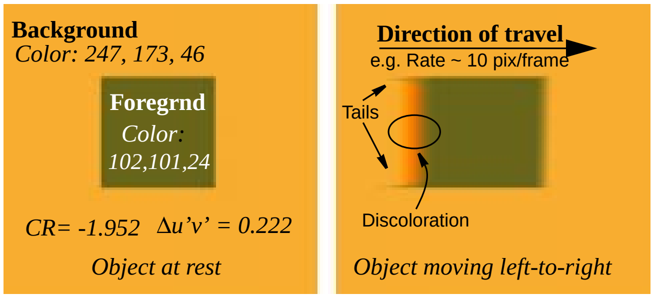


Figure 6: Object in motion showing chrominance distortion

Figure 7 shows an example of how luminance degradation appeared to the eye for an different color condition object in motion.

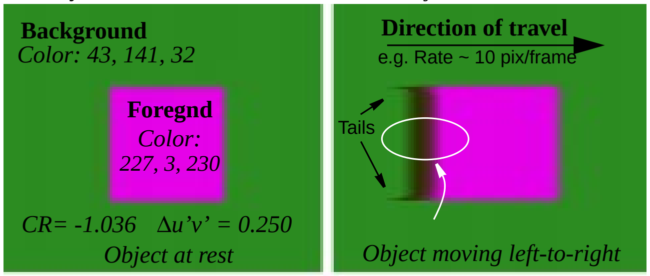


Figure 7: Object in motion showing chrominance distortion

Figure 8 shows a way to view line color motion artifacts on a plasma display. The color distortion was recorded with MAT for line spreading, where the magnitude of spread in time was referenced as a type of motion response time.

Levels shown are luminance level equivalents of the program's generated RGB values.

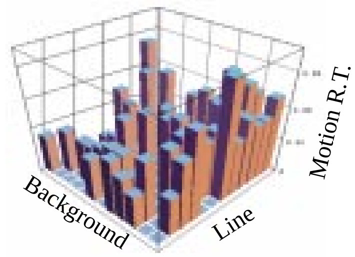


Figure 8: Line-spreading motion distortion for a PDP

This chart shows the background color against the line color, with the vertical axis showing the distortion time.

MAT helps find motion-induced artifacts of inter-gray level response time deficiencies, color distortions, bit depth limitations, temporal dithering techniques, angular dependencies, technology variabilities, compensation techniques, timing generation paths, etc.

Impact

This work presents a way through use of MAT to assess motion performance of displays, and to help assure motion artifact corrections and improvements are implemented properly and are well balanced. It provides a way to assess motion artifact variations as a function of direction.

Data measurements can be easy and quick using this tool but, interestingly, data visualization can be tricky since there is so much information that represents a single motion artifact measurement, especially for the color case.

MAT generates the conditions to search for motion artifacts and it provides the tool to evaluate them when discovered. It also allows for simple characterization of displays for comparison.

It also has a GUI Server-Client interface for remote operation, as well as full keyboard control for direct interactive access.

MAT generates objects, colors, and positioning to find motion weak points. In addition, it handles geometry, motion speed, direction. Finally, it does needed timing calculations, data manipulation, and capture. Data visualization enhancement, greater color accuracy, and supplemental color evaluation methods are planned.

Figure 9 shows a way of visualizing flat-field colors differentially between a moving box a background, such that color coordinates are shown on a 1931 CIE Chromaticity diagram whose gamut is equal to that of the MAT range, and with 3D blocks indicating direction of the color change, the xy points, and the magnitude of the total motion artifact response time.

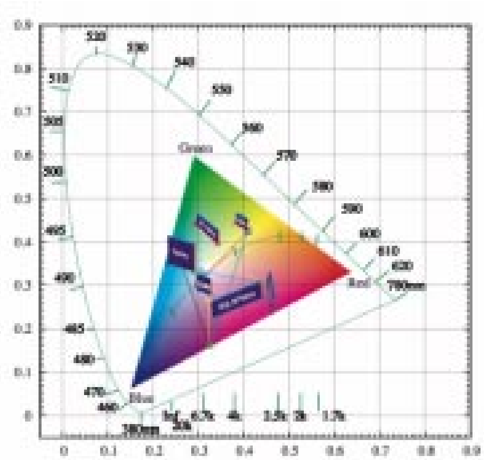


Figure 9: Motion Response Time Visualization

The program does all the required math, converting motion to time and speed, as well as converting distortion of objects in motion to numeric values. It is possible, for example, to get a quick suite of grayscale levels and proportional motion distortion quantification.

Transformations done in the MAT data evaluation to allow for extensive parameter generation based upon the RGB input, include conventional *RGB* to *xy* conversion methods.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} Xr & Xg & Xb \\ Yr & Yg & Yb \\ Zr & Zg & Zb \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$x = \frac{X}{X+Y+Z} \qquad y = \frac{Y}{X+Y+Z}$$

where the X, Y, and Z coefficients are the CIE XYZ tristimulus values of the display or class of displays to be evaluated. MAT starts with default tristimulus values based upon typical television values of the late 1900's, to enable its use immediately.

RGB values are generated by the program for both the foreground and background. The transformation enables determination of many other evaluation parameters, such as u'v', contrast ratios, Δ u'v', etc.

Motion equations include constant velocity equations and distortion equations to determine the motion artifact equivalent of response time. Pixels per frame (*ppf*) is the base velocity calculation, upon which other program speed variants are determined. There is acceleration control for oscillation modes, to assess display motion performance with dependencies other than linear velocities. Some interesting motion distortion variants have been observed with such modes.

Response time is calculated as follows:

$$RTtotal = \frac{dlpix}{(Vr + ppf)} + \frac{dtpix}{(Vr + ppf)}$$

Where *dlpix* is the object leading edge distortion pixel spread, *dtpix* is the object trailing edge distortion pixel spread, *Vr* is the display vertical refresh rate*, and *ppf* is pixels per frame, generated MADAT under user control.

A key to the some of the real power to the MAT analysis system is *dlpix* and *dtpix*, the parameters which define the velocity-induced magnitude of the motion distortion.

Conclusions

Motion artifacts on LCDs and other displays are real, dramatic, and in need of a solution to fully define and analyze them in a vast variety of ways. Their effects can be readily noticeable and their presence tends to reduce the perception of quality on a display.

It is hoped that the MAT system will help establish visualization guidelines, provide a set of measurements, and introduce an industry software tool to help find, qualify, and quantify a number of motion artifacts. This may help both to steer LCD technologies toward greater excellence with respect to motion image quality, and give some users a tool by which they can verify motion performance perceptually and comply with the VESA FPDM3 standard.

Instrumentation for characterizing motion artifacts is limited in its ability to associate its results with the way humans see motion artifacts. (Some motion tracking optical devices may be the exception to this rule.) The eye sees much more than can be viewed with electro-optical instrumentation, especially for motion content, and the eye is correct, because visual assessment is the way motion image quality is determined.

Whether motion artifacts can be entirely explained in terms of non-moving objects is arguable. They can only be totally assessed by properly viewing known objects setups in motion under controlled conditions. It is not arguable, however, that the human visualization of video content in motion is the final judge of a display's motion performance.

The MAT program calculates many parameters, and can accumulate a wide variety of results in a data file, including the motion dynamics and configuration setup, then calculates a great deal of parameters, producing over 30 columns of data. There is a lot of information to be gained and analyzed through its techniques and more research to determine its fullest capabilities.

References

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

[2] MPRT, SID 2003, Article: Proposal of the Perceptive Parameter Motion Picture Response Time (MPRT)," and The MPRT Workgroup of VESA Japan, write-up, "Motion Picture Response Time Proposed Standard," Rev. 1p, Draft 4, August 19, 2003

*As per the timing for CRTs, or the panel rate instead of the timing vertical rate for displays with timing converter interfaces.

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