Time Resolved Photometric and Colorimetric 2D Measurements of both Dynamic and Static Luminance- and Colour Artifacts in FPD.

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Abstract

This paper reports of traceable and repeatable time resolved colorimetric measurements of the luminance- and colour variation occurring during the frame refresh period of FPD's. During one frame period a number of measurements are performed, and for the dynamic artifacts a simulated smooth pursuit eye tracking algorithm is included.

1. Introduction

The objective of this work was to demonstrate the possibility to do traceable, repeatable and reproducible colorimetric 2D measurements according to CIE and in very small time slices of a frame period.

It is well known practice to do colorimetric measurements on displays. This is done by a spectroradiometer or a colorimeter with no spatial resolution or by 2D colorimeters with spatial resolution. For both types the measurement usually requires a long period (compared to the refresh rate of the FPD) to do a proper measurement.

With the introduction of a 2D colorimeter with very high sensitivity (ICAM), it is possible to do colorimetric measurements with a sampling period down to app. 250 µs, depending of the brightness of the display. Combining this very short sampling period with an advanced trigger system for controlling the timing of the sampling periods, it is possible to measure and repeat measurements in the very same sub period of a frame period. Hereby very good measurements are achieved and where the noise is suppressed substantially.

In this paper results from measuring a LCD and a DLP will be given.

2. Experimental

The equipment used, is a PC, a pattern generator and ICAM. Through a serial connection the PC controls the pattern generator and through a Firewire connection and a serial connection the ICAM is controlled. The pattern generator is driving the display under test (DUT) and feeds the 2D colorimeter with the vertical sync signal for synchronization and timing purposes. See fig. 1.

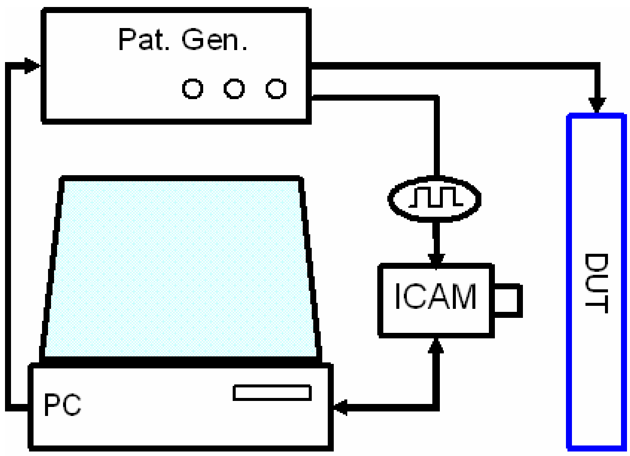

Fig. 1 System setup

Prior to the measurements a number of calibration tasks are performed. The gamma function and the uniformity (as a function of the gray level) of the DUT are measured and the geometric properties, like orientation and magnification, are obtained and utilized during the measurement and data handling.

Test patterns are automatically generated either in gray scale or in colour. See Fig. 2.

Two 60 Hz displays are tested. A LCD monitor, where overdrive (OD) can be turned on and off and a DLP projector with a colour wheel having 5 zones. R, Y, G, W and B. The test will reveal what is happening during a frame period of a display.

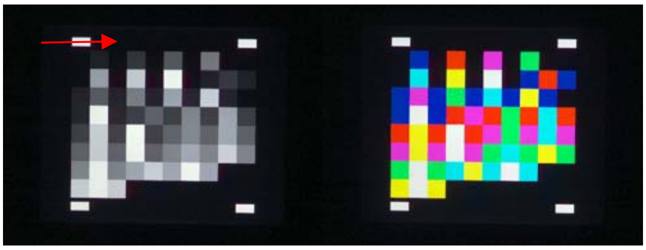

Fig. 2. Gray scale and colour targets with 8 levels of gray or 8 colours.

A frame period is divided into a number of sub frames and the emitted light during each sub frame has to be colorimetric measured. With an advanced trigger system a certain sub period, of the frame period can be measured several times. The emitted light must be measured with the spectral sensitivity of the three colour matching function, defining the CIE colorimetric standard observer.

For the LCD monitor the number of sub periods will be 16, each with a period of 1.041 ms and for the DLP projector the number of sub periods will be 35, each with a period of 0.476 ms.

The measurements gives the luminance and colour variation during a frame period. For moving artifacts, these sub period measurements can also be used to make a pursuit simulation showing the perceived luminance and colour variation across a moving target.

3. Results and discussion

The repeatability was tested by 3 measurements on the LCD display where the targets were moving (from left to right) with, in this case, a velocity of 12 ppf. Both targets are measured in the OD-off state, M1 and M2, and the gray scale target was further measured in the OD-on state M3. The last measurement was performed 48 hours after the first and second test which were separated by half an hour.

The luminance and chromaticity were sampled along the red arrow, shown in fig. 2. The arrow gives the direction of movement. Each sample is an average of 21 ICAM pixels from a line perpendicular to the velocity vector. See fig. 3.

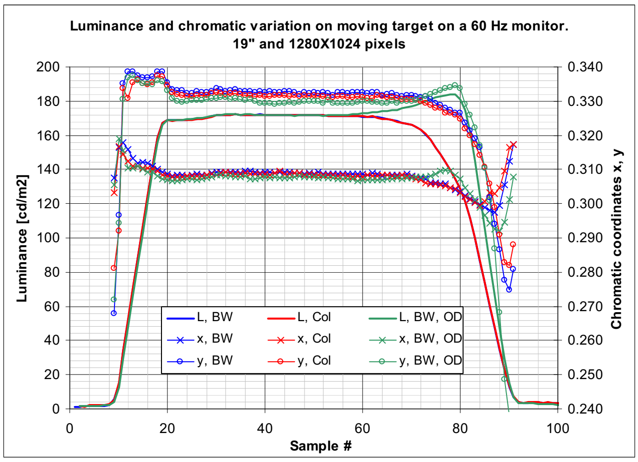

Fig. 3. Luminance and chromatic variation on a white target moving on a black background. BW indicates gray scale target, Col indicates colour target and BW, OD indicates gray scale target measured in OD-on state.

Comparing results for the M1 and M2 measurements gives the luminance variation to be below 0.5 % and the absolute differences in the chromatic coordinates are below 0.002 for the samples where the luminance is above 20 cd/m2. Comparing the average of M1 and M2 with M3 gives information of the reproducibility. From samples 50 and forward there is a difference in luminance caused by the overdrive. Comparing the luminance from the sample 50 and below gives a luminance variation of less than 0.8 %. The absolute differences in chromatic x are again less than 0.002, while the absolute differences in chromatic y are less than 0.003.

The colour target was measured on the LCD in both OD states. In fig. 4 the magenta to yellow transition is shown in details. The left and middle image shows the transition in the no OD state and in the OD state. The image to the right shows an alignment of the two images.

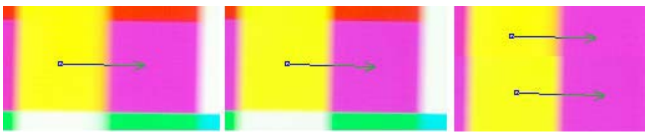

Fig. 4 Left No OD, middle OD, right Comparison of OD states.

The differences are clearly seen. The overdrive reduces the width of the transition zone and the chromatic artifacts but introduces a luminance variation in the transition zone that is seen as an edge.

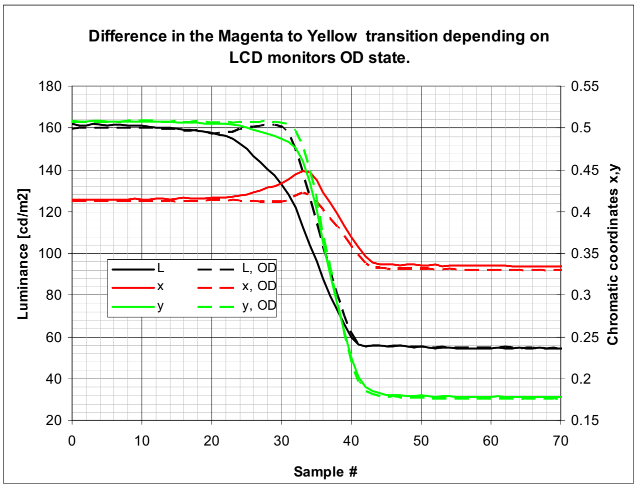

Fig. 5 Difference in magenta to yellow transition depending on OD state.

The luminance and chromaticity were sampled along the arrows shown in fig. 4 for the two OD states. See fig. 5. By comparing fig. 4 and fig.5 all the details are qualified and, most important, robust quantified.

This kind of traceable and repeatable measurement will be very useful in developing displays and optimizing the luminance and colour performance; further this robust data will be the basis for a future metric for quantifying various kinds of colour artifacts.

The DLP was measured with 35 sub periods. The targets were a gray scale target and a colour target.

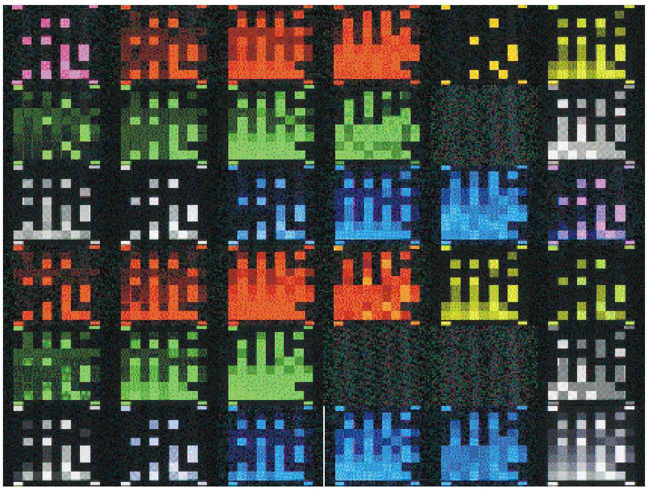

Fig. 6. 35 images of the sub periods of a gray scale target.

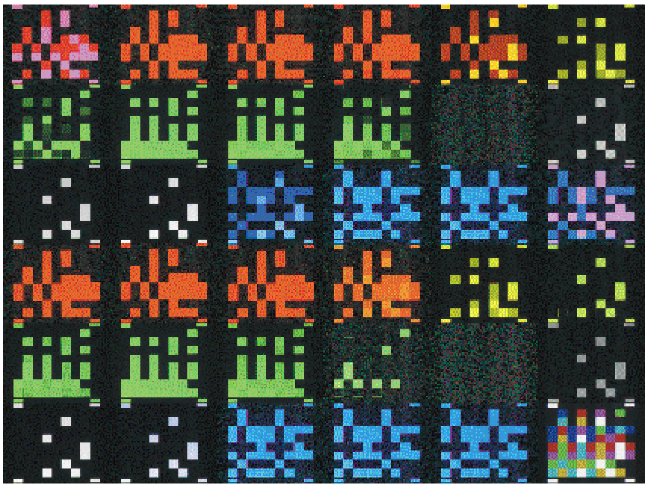

Fig. 7 35 images of the sub periods of a colour target.

Fig. 6 and 7 shows images of the sub frames measured of the gray scale and colour targets. In the lower right corners the perceived image is shown. The measurements show the 5 colours of the wheel and an additional colour namely black. All the colours are exposed 2 times during a frame period, meaning that the DLP has to present 12 images and the wheel must rotate twice during one frame period.

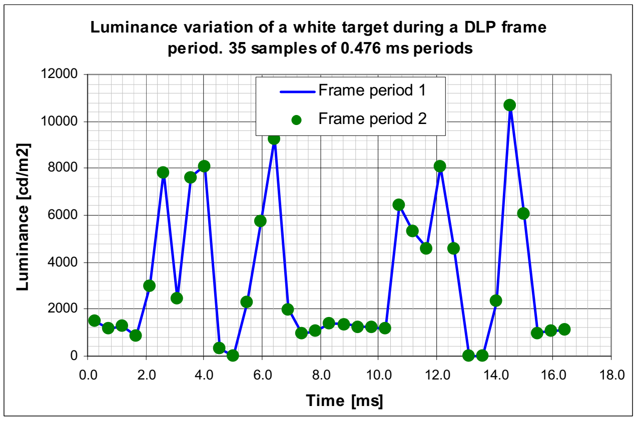

Fig. 8 Test of repeatability of measuring the luminance variation during a frame period.

In figure 8 are shown two measured luminance variations during frame periods for a DLP projector. The difference in measured luminance for the sub periods in the two frames was in average below 1 % +/- 0.5 %.

In fig. 9 the measured colour variation is shown.

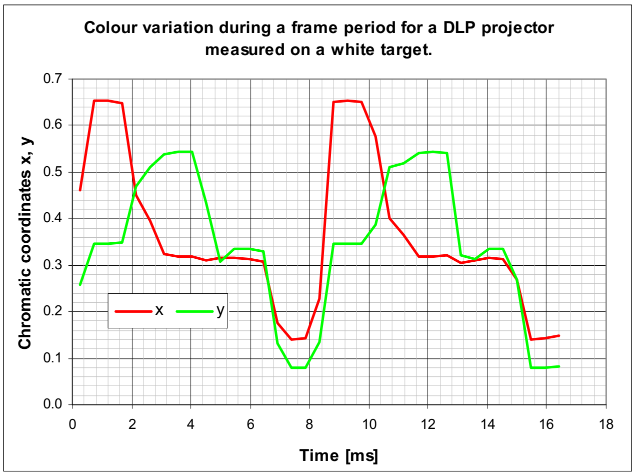

Fig. 9 Colour variation of a white target.

It is seen from fig. 8 and 9 that the measured luminance and colour for the first and second round of the colour wheel are close to but not completely identical. This is due to the number of sub periods chosen and no knowledge of the size of the individual colour zones on the colour wheel.

4. Summary

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This paper reports of traceable, repeatable and reproducible colorimetric 2D measurements according to CIE and in very small time slices of a frame period.

The ability to do this type of measurements makes it possible to study luminance and colour changes with a time resolution of down to less 250 µs depending of the brightness of the display.

The measurements can be used to make pursuit simulation of moving images and to make 'movies' of the frame refresh period.

5. References

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