A simple LCD response time measurement based on a CCD line camera

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Abstract: A response time measurement system has been developed to dynamically capture a LCD temporal change of brightness. Based on a CCD line camera and an intuitive GUI, this system allows LCD experts as well as novices to measure and to check the consistency between the announced response time and the measured values, compliant with the VESA FPDM standard. In result, we propose in this article a low-cost, portable and accurate system with respect to professional and non professional use

Key Words: Response time measurement system, CCD line camera

1 Introduction

With the recent wave of enthusiasm for Liquid Crystal Displays, the consumer market had to determine a new metric to evaluate the display image quality provided by LCD panels. But the problem persists that on the one hand, consumers are expecting a metric in accordance with their visual perception of the display quality while on the other hand, the industry hopes for a metric taking into account the technological improvements. Finally, the response time, an inherent LCD parameter responsible for the motion blur and the tailing phenomena, has been naturally chosen to depict the LCD image quality.

However, behind the commercial response time, printed on the consumer products, two different response time metrics are hidden. On the one hand, we can find a normative value called ISO 13406-2, created in 2001 by the International Organization for Standardization [1] and on the other hand, the Gray-to-Gray (or G2G), a specific industrial measurement that is different among companies and more and more used for consumer products.

A kind of “fuzziness” persists around the measurement methodology and consequently on the consumer response time relevance. Therefore, taking measurements by oneself seems to be the only way to obtain the actual liquid crystal reactivity. This implies the conception of a test bench.

In order to allow LCD experts as well as novices to measure and check the consistency between the announced response time and the measured values, we have fixed some constraints on the specifications of our test bench.

First, we impose the solution to be “user friendly” which means a portable, compact and intuitive solution. Then, in order to obtain a low-cost solution, we exclude specific hardware and favor “common” equipment that could be used for another application; we stress this point as the most important of our specifications. At last, our system must be obviously as accurate and fast as possible.

In this paper, we propose a new test bench for LCD response time measurement in agreement with our above-mentioned constraints. After presenting two existing solutions, we describe our system by detailing the hardware part and the software applications. Finally, we verify experimentally the effectiveness of our measurement equipment by pointing out results and statistical values.

2 The existing solutions

Different prototypes and commercial products are already used to measure the LCD response time. In this section, we make a succinct survey of the two main commercial solutions by identifying their strengths and weaknesses compared to our specific needs and constraints.

2.1 MPRT-1000 by Otsuka Electronics Co.

Among the existing measurement systems, the MPRT series by Otsuka Electronics Co. [2] forms part of the first commercial solutions entirely dedicated to global LCD quality measurement.

With this system, the LCD quality value is represented by the Motion Picture Response Time [3], or MPRT, a standard measurement since 2001. MPRT values take into account the LCD response time but also the hold effect, responsible for 70% of the motion blur [4]. That makes these values closer to subjective quality metrics regarding LCD motion blur.

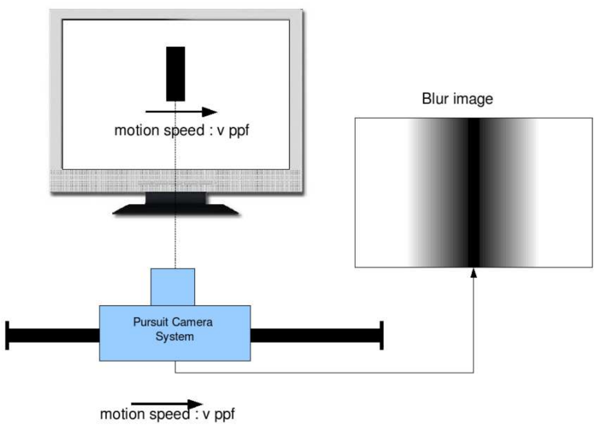

Figure 1 MPRT-1000 Principle

The hardware part of the MPRT-1000 is composed of a are scan pursuit CCD camera, a single point light sensor to trigger the camera and a video signal generator, controlled by a PC. Figure 1 shows the principle of the measurement with the MPRT series.

In spite of its accuracy, the MPRT series have the disadvantage to be too general-purpose concerning our specifications. Actually, we desire to measure only the LCD response time by excluding other LCD effects that contribute to motion blur like the hold effect. Moreover, such a versatile product implies a higher cost, that runs counter to our cost constraint.

2.2 Eldim's OPTISCope

The OPTISCope system from Eldim Co., shown in figure 2, appeared in 2002 on the LCD measurement system market. It permits to measure some LCD parameters like the response time (in compliance with ISO and VESA FPDM standards [5]), the gamma curve and the flicker effect [6].

The system is based around a CMOS area scan camera coupled with a photo-diode, with a sampling period of 10 µs and connected to a PC interface with a USB connection. These characteristics make OPTISCope a "friendly-user", portable and very accurate solution, three important points raised in our specification.

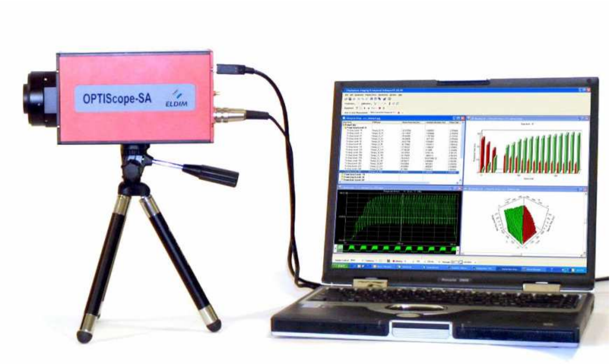

Figure 2 Eldim's OPTISCope

However, the unique disadvantage in respect to our constraints is the use of a specific area camera. In spite of its outstanding precision, this hardware is too expensive to our "quest" for a low-price.

2 Proposed solution

In this section, we present the details of our test bench, divided into two different parts: the hardware part with a CCD line camera and the software part with (i) a transition generator and acquisition program and (ii) a data processing software. Moreover, a specific hardware and software protocol have been added to obtain the best temporal luminance transition and consequently, the most relevant response time measurement.

3.1 The hardware

With respect to professional but also non professional use, we decided to opt for a test bench based on a PC connected to a camera.

Nowadays, the average LCD response time is about 8 ms. Consequently, to obtain accurate results and with the general profile of LCD response, we decide to fix the sampling period under 500 µs; actually, the camera frequency must be over 2kHz.

This acquisition speed corresponds to a camera frame rate of 2000 fps. If it seems very difficult to find such a frame rate for classical area camera, on the other hand, this speed can be easily reached for both specialized area cameras and linear cameras.

As we mentioned in our specifications, the cost reduction of the test bench represents an important constraint. Consequently, we have opted for a CCD line camera that offers interesting characteristics for the measurements. Table I shows some characteristic of the chosen linear camera.

	Characteristics
Imaging Device	Linear CCD
Sensing Area	8.00 mm x 125 µm
Pixel Depth	14 bit
Line Scan Rate	10 kHz
Pixels	1024 x1
S/N Ration	70 dB

Table I Line-scan camera characteristic

For a better integration of luminosity, the test bench has been completed by an appropriate lens and a tripod for a good stability. Finally, the whole measurement system, shown in figure 3, is composed by the test display, a CCD line camera coupled with an objective and a tripod, connected to a PC by a IEEE-1394 connection.

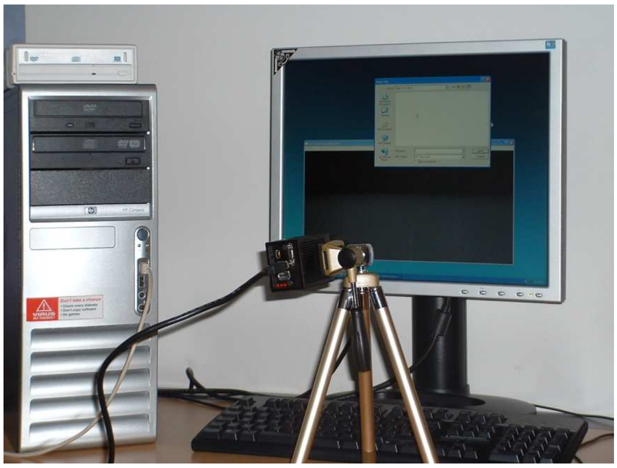

Figure 3 Proposed test bench

3.2 The protocol

This subsection succinctly presents the rules or protocol. It is composed of three steps in order to obtain optimal results.

First, external light or reflected light must not disturb the acquisitions on the test display at the risk of corrupting the coherence of the results.

Secondly, the distance between the measurement system and the test display must be set according to the chosen lens and the tripod; an optimal distance, depending on the focal length and the aperture improves the contrast of the screen captures.

Finally, with the software we have developed, presented in the next section, the user can automatically or manually change intrinsic parameters of the camera, like luminosity, time shutter, analog gain and digital gain. The aim of this last operation is to obtain the best range possible between black and white.

3.3 The software

Two pieces of software have been developed: the first one LCDacquire controls the camera: it includes a transition generator and is in charge of the image acquisition. The second one, LCDprocess performs the data processing by computing the LCD response times using the images acquired. (cf figure 4)

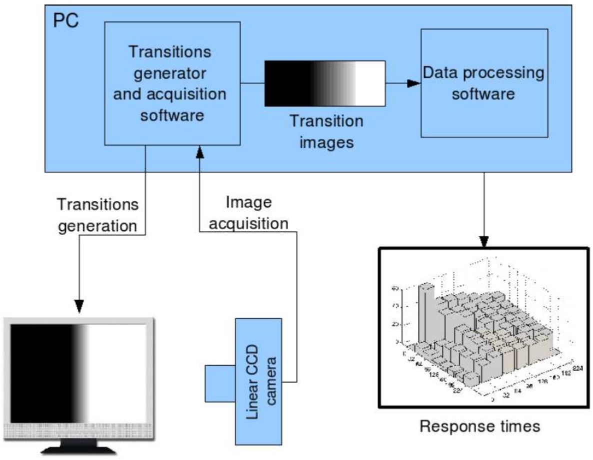

Figure 4 Scheme of the software organization.

LCDAcquire integrates three different functions: the camera control, the transition generation and the image capture.

In order to accept most of the linear cameras, the driver is based on the free Carnegie Mellon University IEEE-1394 driver [7] and permits controlling, loading and saving intrinsic camera parameters such as luminosity, time shutter, analog and digital gain.

The user can choose predefined transition sequences but he can also simply create its own transition sequence in a formatted text file: the sequence file is a simple series of gray levels, between 0 (black) to 255 (white) and can be directly imported in the application.

At last, after tuning the camera parameters and importing a transition sequence, LCDacquire can make the acquisitions. First, the application displays in the center of the panel a rectangle whose gray level will temporally change according to the values stored in the transition sequence. Each gray level appears in the display during about 500 ms.

At the same time, the linear camera makes 512 consecutive acquisitions, around the gray level temporal change. These acquisitions are grouped into a single 1024x512 image and saved in a file. Figure 5 shows the principle of the acquisition with the synchronization between the command and the capture.

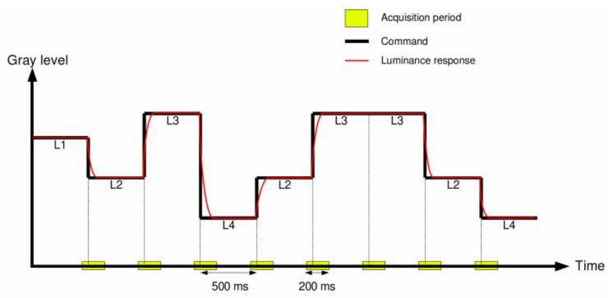

Figure 5 Principle of the acquisition

Once all the transition images are saved, the second software, LCDprocess, is used to visualize and compute the LCD response time (in compliance with the VESA FPDM standard [5]). Each image file is processed in order to extract the response time and the blur profile from the user-defined transition.

Let us recall that each image is a temporal concatenation of lines of 1024 pixels. These 1024 columns represent 1024 different transition captures and actually, different blur profiles. Figure 6 shows an example of transition image form 0 to 128.

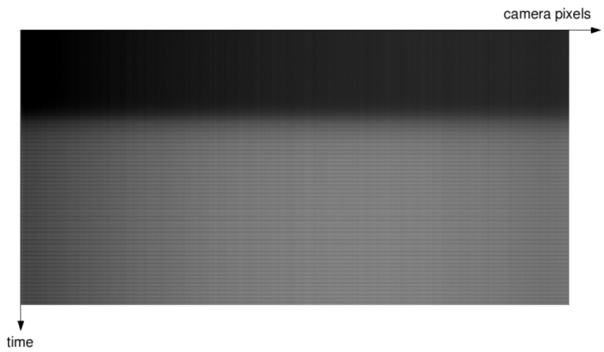

Figure 6 Example of a transition image (from 0 to 128).

So, each blur profile is averaged and the response time is finally computed.

In order to obtain robust results, it is possible to compute statistical values from a set of N identical transitions: the average response time T of the selected images (Eq 1.) and the relative standard deviation RSD (Eq 2.) that gives the percentage of error capture between all the acquisitions.

$$T = \sum_{i=1}^{N} \frac{\tau(i)}{N} \qquad \text{(Eq 1.)}$$

$$RSD = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\tau(i) - T\right)^2} \qquad \text{(Eq 2.)}$$

$\tau(i)$ being the response time of the i[th] images of the N transitions.

4 Experiments and results

The response time, the RSD and the computation time were calculated using the proposed approach for a classical consumer liquid crystal monitor on a 3.4GHz PC with 2048 MB of RAM. Table II shows the characteristics of the test display.

	Characteristics
Response Time (ISO)	20 ms
White Luminance	160 cd/m2
Black Luminance	0.16 cd/m2
Resolution	1280x768
Frequency	60 Hz

Table II Test disaplay characteristics

Each test sequence is composed of a succession of 20 transitions of different gray levels (L_1 and L_2, with $L_1 < L_2$) that produce a set of 10 rising transitions (from L_1 to L_2) and a set of 10 falling transitions (from L_2 to L_1). For example, the 0-64 test sequence is coded by:

0-64-0-64-0-64-0-64-0-64-0-64-0-64-0-64-0-64-0-64-0

The 20 images produced by each sequence are processed into the data processing software and numerical values are computed: average response time and relative standard deviation, both for the rising and the falling transition.

Table III shows results for different transitions.

Transition (in gray level)	Average response time (in ms)	RSD (in %)
0-64	51.54	5.9
64-0	5.79	11.7
0-128	37.46	2.3
128-0	6.92	14.4
0-192	24.40	4.2
192-0	8.08	6.8
0-255	11.46	4.6
255-0	9.28	7.8
64-128	26.26	4.9
128-64	30.77	5.6
64-192	19.30	3.6
192-64	29.06	5.4
64-255	6.19	7.0
255-64	29.04	5.8
128-192	18.01	1.9
192-128	23.92	4.8
128-255	5.22	8.6
255-128	24.60	4.0
192-255	5.37	14.0
255-192	20.71	6.4

Table III Statistical values from different acquisitions

Figure 7 shows the response time 3D curve corresponding to our test display.

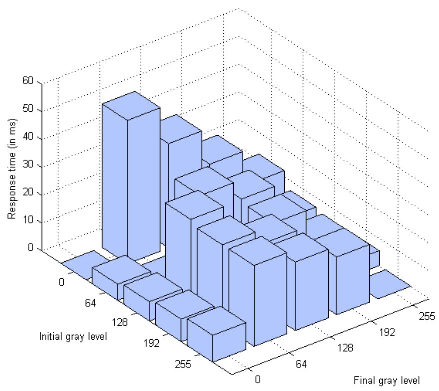

Figure 7 Response time 3D curve.

From these results, the ISO response time is calculated as the sum of the mean response time from 0 to 255 and the mean response times from 255 to 0:

$$T_{ISO} = 11.46 + 9.28 = 20.74 \text{ ms}$$

As we expected, the 20 ms response time of our test display has been found.

Concerning the precision of our measurement system, we notice that the average RSD is around 5% for most of the gray to gray transitions. However, when the LCD response time is around 5 ms, the relative standard deviation rises up to 10%, due to our too-slow sampling period (0.5 ms). In fact, a 5ms transitions is represented by about 10 lines in the transition image and a difference of one line equals to a difference of 0.5 ms, or 10%, on the final results. For a long response time, a difference of one line equals less than 5%.

All the measurements have been saved into 230 transition images and have been processed in about 400s.

Finally, these results show that our measurement system allows the users to rapidly check the consistency of the announced response time with a good precision. It also shows interesting values that are hidden by the ISO response time.

6 Conclusion

In this article, we have presented a new LCD response time measurement system based on a CCD line camera. We proposed a portable, intuitive, low-cost and accurate solution. In spite of a non-specialized hardware, the response time and the associated relative standard derivation values show reliable results.

Admittedly, the existing commercial solutions give more precise results, however, this accuracy implies irremediably a higher cost compared to our measurement system.

As the next step, we envisage to improve the precision of the measurement thanks to a LCD response time model that could help us to detect faulty values due to software trigger and that could consequently decrease the global relative standard deviation for all the transitions.

7 Acknowledgment

The authors wish to thank the ANR for funding the study and Chloe Gachet who has contributed to the transition generator and acquisition software programming.

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