AUTOMATIZED GAMMA-CURVE MEASUREMENT OF CRT COMPUTER MONITORS

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Summary

Measurement and assessment of CRT monitors' gamma characteristic is both time consuming and requires lot of calculus. Computer design and DTP application requires fast and accurate measurement of gamma characteristic for the purposes of calibration. For that reason, designing and developing a device that would automatically measure and assess gamma serves a purpose.

1 INTRODUCTION

Computer planning, design and imaging is still being done on CRT monitors. The visual result of any computer procedure is heavily influenced by the CRT monitors' physically changeable and software-guided parameters. These parameters include among others luminance emitted by the monitor, color resolution, contrast, color temperature, and gamma-curves. The CRT monitor's gamma-curve is defined as the correlation between software-guided intensity and luminance of red, green and blue electron guns.

CRT monitor calibration involves measurement and necessary correction of the above mentioned parameters. Top quality requirements of visual presentation primarly emerge in the fields of printed press material preparation, architectural and machine design, but the need for CRT monitor calibration increases rapidly in other areas as well. The most up-to-date application field of CRT monitor calibration is in color vision analysis. Various color vision tests have been constructed for a color blindness correction method developed at TUB's Dept. of Precision Mechanics and Optics. Some of those tests were designed on CRT monitors [9]. In order to conduct computer based color vision tests calibrated CRT monitors had to be used including fast and accurate determination of gamma curves.

Measuring luminance and color temperature is easily accomplished with a spectrophotometer. Measurement of gamma-curves requires 50-100 trials and lots of computation, therefore automatization seems like a useful solution. The constructed measurement system consists of a detector with suitable optics, a D/A (digital/analog) PC-adapter, and a software developed specially for the device.

2 METHODS

The CRT monitor's gamma curve (gamma characteristic) expresses the function between software-guided primer color intensity (DAC intensity) and monitor luminance. The gray scale gamma curve is also a meaningful characteristic, it is measured by joint presentation of the three primer colors (red, green and blue).

Luminance meter and appropriate software is needed for conducting manual gamma curve measurement. The software's task is to produce homogenous green, red, blue or gray surface of arbitrary DAC intensity on the CRT monitor. A gamma curve is constructed by taking equidistant primer- or grayscale measurement points on a DAC scale. By presenting these DAC intensities on the monitor on a one by one basis, we can measure corresponding luminance for each intensity and get the $I_{DAC}=f(L)$ data pairs. The appropriate gamma curve is provided by using regression method to match up the discrete points with a single curve. We can apply a polynomial, complex or exponential regression method [2]. According to the literature the most commonly used exponential approximation equation is:

$$L_{R,G,B,N} = a_{R,G,B,N} + b_{R,G,B,N} \cdot I_{\mathbf{DAC},R,G,B,N}{}^{c_{R,G,B,N}} \qquad (1)$$

,where **L**[cd/m^2] is luminance; **a** is the offset luminance; **b** is gain; $\mathbf{I_{DAC}}$ is DAC intensity; c is a gamma exponent; **R**, **G**, **B** and **N** indexes denote a red, green, blue and neutral gamma curve respectively.

3 MEASUREMENT SYSTEM AND ITS FUNCTIONING

The automatic gamma curve measurement system consists of for units (Figure 1.):

- luminance measurement system
- electronic processing unit
- computer
- a PC compatible SVGA CRT monitor to be measured

The luminance measurement system was constructed from a Cosilux type illuminance meter. The original tool was only capable of illuminance [lx] measurement, therefore we designed a suitable optical unit in front of the detector, which we put in a tube along with the silicium based detector. The tube can be mounted on a pole and positioned, thus enabling measurement of any point's characteristic on the monitor. The lx units provided by Cosilux can be expressed in cd/m^2 through mathematical transformations using parameters of the optical unit.

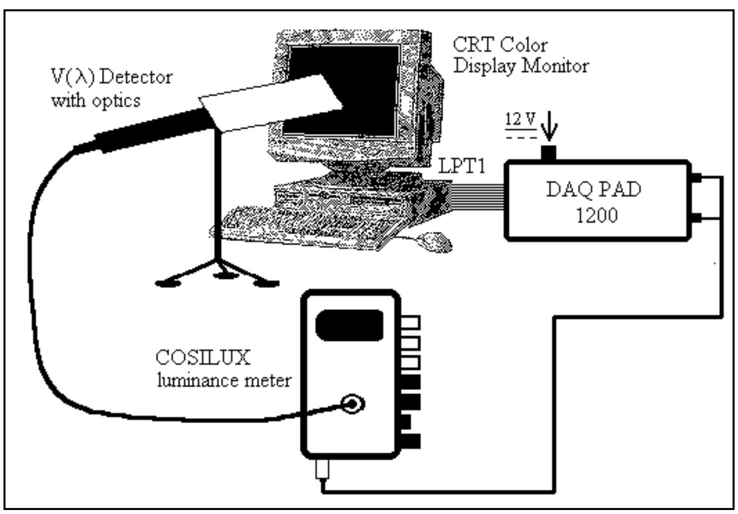

Figure1.

The first part of the electronic processing unit is the head unit of Cosilux, which has an analog output attachment to enable data capture in electronic format. From here the signal goes to the A/D converter, the second part of the electronic processing unit. As our A/D converter we have chosen the DAQ-PAD 1200 unit compatible with National Instruments' parallel port. Unlike PC-card solutions, parallel port plug-in enables usage on any computer without opening the PC towerbox. The measurement system is easily set up with appropriate drivers to any PC. The signal that comes through the parallel port is processed by a Labview program, designed specially for this experiment.

By running the software the CRT monitor serves both as a measurement tool and as a to be measured unit, because it operates the measurement system and provides results simultaneously, moreover it is a vehicle for presenting test patterns for the purposes of gamma curve measurement. The software can open, save, print and export data into Excel.

The software operates the measurement based on the following algorithm:

- Entering measurement parameters: Generating DAC series with unequal point density, which will serve as an independent variable for the gamma curve. Selecting between red, green, blue and gray scale gamma curve measurement. Setting sampling rate, which influences speed and accuracy of measurement.
- Starting the measurement algorithm: Software control panel disappears and the first full screen homogenous test pattern appears. During this procedure the analog signal captured with the luminance measurement system is loaded into the computer through the D/A converter, and stored.
- Processing stage: According to the exponential (1) form of the gamma equation the collected data set is analyzed by two methods. Logarithmically transformed data submitted to linear regression is a faster method, but conatins larger errors. The approximation method based on a selection of an exponential curve with the smallest MSE among those generated near the target function is more accurate, but takes about 20-60 seconds depending on the computer.

4 MEASUREMENTS AND RESULTS

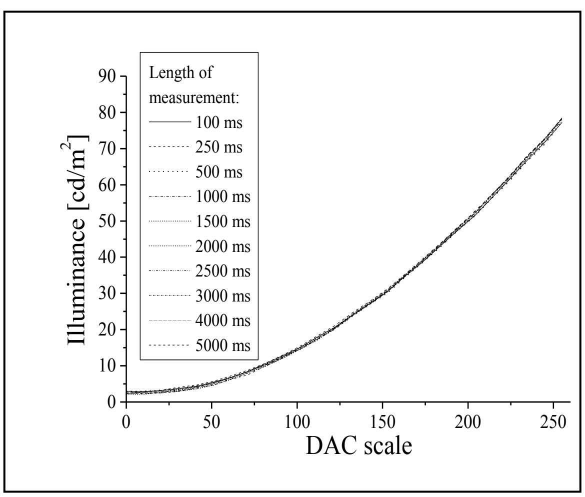

Figure 2

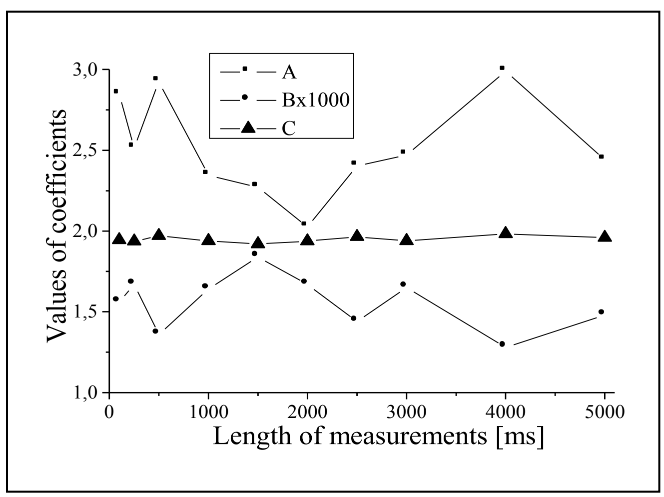

Figure 3.

Parallel with instrument development we conducted measurements about the instrument's accuracy and speed that helped determining the optimal measurement parameters (DAC point density, sampling rate). Measurements were done in a dark room on an LG 55i monitor.

The sampling rate in all sessions was 100 data/s. The duration of measurement is not irrelevant, because photometer accommodation and monitor flicker of 50-100Hz can alter the mean result calculated from an already large number of data. The analysis of the 100ms-5s interval did not show any significant difference between measured gamma curves and coefficients, thus the 100ms interval is adopted. The instruments and technology did not allow for a smaller measurement rate. Figure 2. shows the equivalency of the measured curves, figure 3. depicts gamma coefficients calculated with exponential approximation as a function of measurement duration time. The identity of the gamma exponent (c) consistently remains below 1% throughout the whole measurement, while gain (b) and offset (c) variability is also not significant. In order to determine chosen point density on the DAC scale let us examine figure 4. The 7 point density gamma curve measurements exhibit the highest level of identity based on statistical calculations with the 20 point density measurements resulting from a mean of 10 measurement sessions. In measurements using fewer measured points an erroneous value can have a big effect on the result of regression calculations. The usage of a different, more complicated eliminative statistical method, that is not included in our program's regression method, would allow us to get useful results from less than 20 measurements.

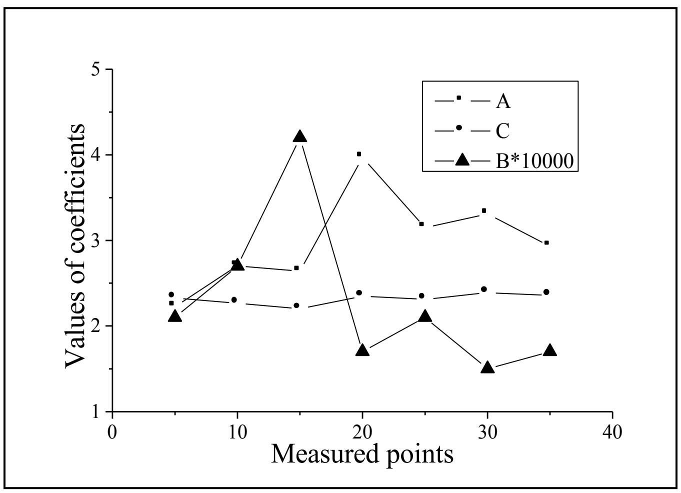

Figure 4.

Measurement system accuracy rests on photometer calibration and our method's genuineness. The instrument has been calibrated with a halogen lamp that was approved at OMH. Measurement system accuracy has been determined by producing 25 gamma curves and coefficients for all three primer colors and the grayscale, using parameters established in previous sessions (26 DAC points, 200ms measurement duration time).

Table 1. contains grayscale gamma curves' statistics. A confidence interval designated as narrow in relation to the average is appropriate for a gamma curve measurement system. The small error margin originating from the sampling rate is underpinned by the fact that only 39 measurement points out of 4650 show a difference of 5% on a given DAC level (Table 2.).

Comparing regression methods we can conclude that the approximative exponential method was identical with Origin software's Allometric2 approach, while coefficients in the linear regression method remained under a 10% error margin.

	Grayscale gamma coefficients		
	a	b	c
Mean	2,032	$2{,}800 \cdot 10^{-05}$	2,679
St. deviation	0,257	$5{,}000 \cdot 10^{-06}$	0,026
Confidence level (95,0%)	0,106	$2{,}064 \cdot 10^{-06}$	0,011

Table 1.

	5 % data difference
Red	8
Green	9
Blue	6
Grayscale	6

Table 2.

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5 CONCLUDING REMARKS

The gamma measurement system design is an easily and quickly applicable accurate tool for determining gamma curves and coefficients. The user friendly software enables fast measurement. Considering 100 ms measurement time, 20 measurement points and the exponential approximative method, one session requires 40s, and using logarithmic linear regression it lasts only 5s. The instrument is easily set up on any computer with minimal system requirements (Intel 486, 16Mb RAM, SVGA monitor, Win95). Measurement results are stored on a computer that enables further analysis. The developed instrument is an excellent tool for calibrating CRT monitors.

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