A HANDY CALIBRATOR FOR COLOR VISION OF A HUMAN OBSERVER

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ABSTRACT

The variability among human observers is a challenge to the calibration of modern displays based on Light Emitting Diodes (LED) and lasers. The spectra of the displayed colors are so peaky that slight differences in the cone sensitivities in human color vision are sufficient to make two observers perceiving different colors on the same screen. Recently published results give evidence to the existence of a small number of classes of human observers. In this paper, we present first results on the development of a prototype for a lightweight, inexpensive, temporally stable and easy to calibrate and easy to use instrument that allows classification of an observer with normal color vision in a small number of categories. The instrument employs a set of LEDs having specific wavelengths and is controlled by a computer interface. The use of such an instrument will allow adapting displays and viewing conditions to individual observers in color-critical applications.

Index Terms— Human color vision, color reproduction, Light Emitting Diodes, displays

1. INTRODUCTION

The variability among color-normal observers is a challenge to the calibration of modern displays (LED, OLED, LED backlight, laser…). With the recent use of these light emission technologies the spectra of the display primary colors (usually red, green, blue) are so peaky that slight differences in human color perception are sufficient to make two observers see different colors on the screen. This effect causes serious problems in industrial applications such as motion picture production, and desktop publishing proof viewing as well as in consumer electronics such as high end home cinema.

In previous work [1], a method for deriving seven distinct colorimetric observer categories was elaborated. Furthermore, an experimental method and instrument for classifying individual observers as belonging to one of these categories were developed.

In order to derive the colorimetric observer categories, existing data on human eye's cones of 108 observers from Stiles-Burch [2] and from the 2006 model of the International Commission on Illumination (CIE) [3] has been analyzed. Five representative cone types for each of red, green and blue cones (giving a total of 125 combinations) were derived through a cluster analysis. From these, a reduced set of seven representative observer categories were identified based on visible color differences.

In order to derive a method for classifying a human observer into one of the classes, an experimental set-up using two specific displays was developed. One of the displays has broad-band primaries and the other narrow-band primaries. Precisely selected sequences of color pairs (one on each display) are shown, and a sample observer has to give his preference for best matching color pairs. Analysis of results gives the category to which the sample observer belongs.

Unfortunately, the display-based experimental set-up has a series of drawbacks. The precision of observer calibration is limited to the precision and the time stability of the displays used. Additionally, the set-up is not portable and requires thorough installation and calibration.

In this paper, we present recent results in the development of a prototype called "color observer calibrator" for a light-weight, non-expensive, temporally stable and easy to use instrument allowing classifying the human color visual system of a sample person.

In Section 2, we present the architecture and technical details of the observer calibrator and in Section 3, we conclude on status of work and further steps to be done.

2. DEVELOPMENT OF A COLOR OBSERVER CALIBRATOR PROTOTYPE

In this section, we present the overall architecture as well as details in optical and electronics design.

2.1 Architectural overview

In the first step, an experimental method for observer classification was implemented using two displays (Figure 1). The first display was a Cathode Ray Tube (CRT) display having broad-band primaries, and the second was a Wide-Color Gamut Liquid Crystal Display (WCG-LCD) with LED backlight, thus with narrow-band primaries. The test conducted in 2010 with thirty observers showed that it was possible to classify observers in different categories [1].

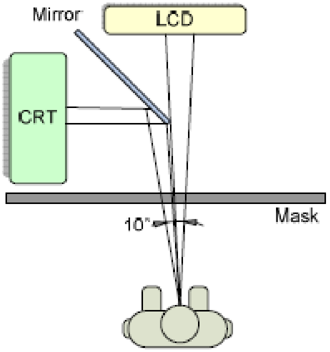

Fig.1. Display based color observer calibrator

In this work, a portable and more compact instrument has been designed for a wider scale experiment. This prototype (Figure 2) replicates the experimental observer classification method implemented earlier using two displays.

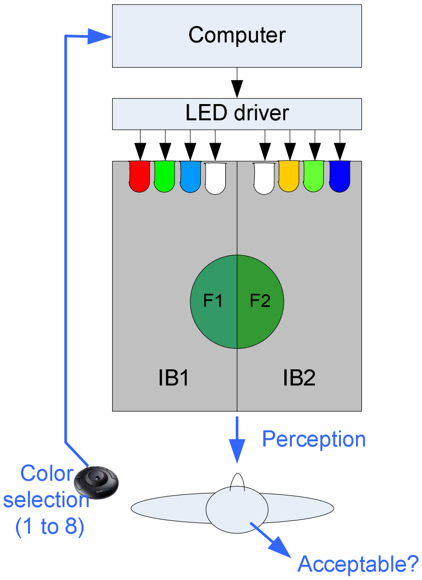

Fig.2. LED based color observer calibrator

The system is composed of two clusters of four LEDs, two adjacent integrating boxed (IB1, IB2) for light mixing, a LED driver and a computer. The software automatically generates colors for each bi-partite field (F1, F2). The user has a control mouse for choosing the colors.

The test procedure based on the calibrator is as follows:

1. The observer watches the bi-partite field with a single eye.
2. Eight versions of color matches are shown sequentially in the bi-partite field, where seven versions corresponds to an observer category [1], and with a supplementary one being CIE 10° standard observer.
3. For each trial, the observer has to classify eight versions of a color match into relatively superior, average or inferior matches.
4. Based on several such trials, the category that most often produces the best match is identified, which is the category assigned to the given observer.

2.2 LED module

The bi-partite field is composed of two trichromatic LED light sources with very different spectral characteristics (highly metameric). As shown in Figure 3, one set of LED (for F2) has red and green maxima in high variability among observers regions (520nm and 592nm) while the second set (for F1) has the maxima outside these regions (506 nm and 644nm). Additionally a white LED is used for eye adaptation between two color stimuli. Each color luminance is greater than 15 cd/m^2 to ensure photopic viewing conditions.

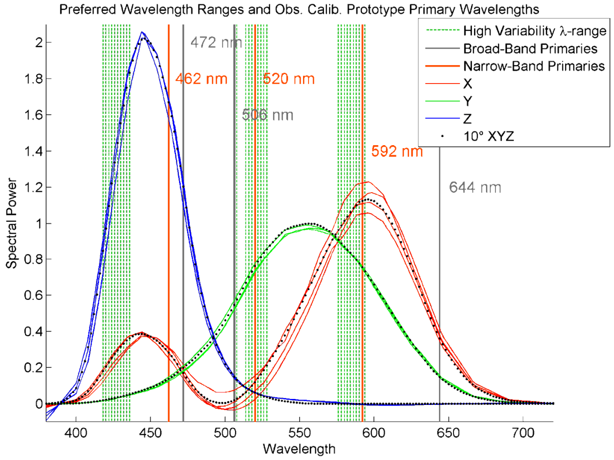

Fig.3. Wavelength regions with a high variability among various observer categories and color observer calibrator primaries

2.3. Optic design

Main requirement for optics was to get a satisfactory luminance uniformity for each bi-partite field. Several prototypes were built and tested. The optical design shown in Figure 4 exhibits a luminance variation [1 – (Lmin / Lmax)] of less than 5% based on four measurement points. This uniformity is obtained by a first LED light mixing inside a light guide followed by a second mixing into an integrating box. The measurements were performed by a spectroradiometer (PR-670) through the monocular hole. The housing is designed to be compliant with the 10° viewing angle specified by CIE. The monocular hole is located at around 15cm from bipartite field.

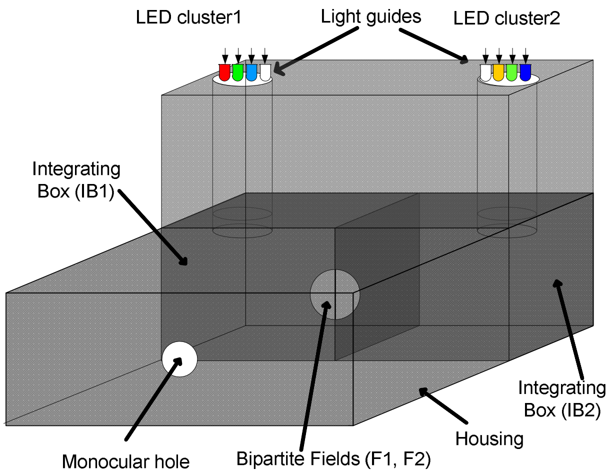

Fig.4. Optical design

2.4. Electronic design

The light intensity of each LED is controlled by Pulse Width Modulation (PWM) signal generated by the LED driver. The internal constant current generator provides a very stable intensity (less than 2% variation). The driver chip is capable to control ten LEDs in parallel. Each output has a 8 bit register that can be controlled by computer through an I2C bus interface. An advantage of this lighting device compared to the discussed display system is the highly linear response of luminance versus digital code (Figure 5).

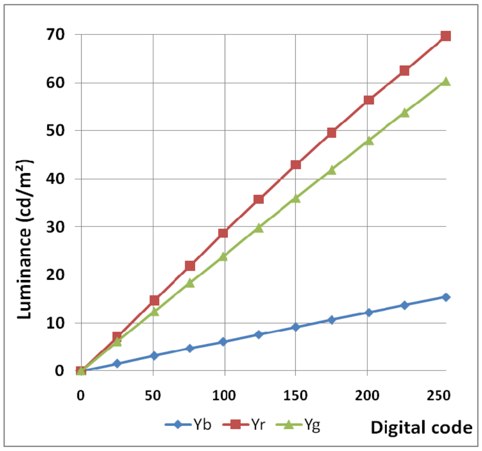

Fig.5. LED luminance for 3 different LEDs (RGB)

2.5. Mechanic design

The external view of the prototype (Figure 5) shows the reasonable size of the calibrator's housing (W=15cm,H=15cm,L=20cm). The second view shows the optic and electronic components arrangement inside the device.

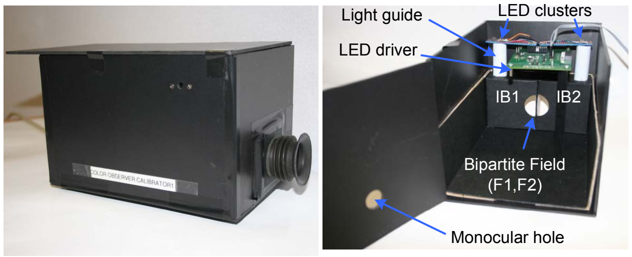

Fig.5. External and internal views of the prototype

3. CONCLUSIONS

In this paper, we presented the design of a handy and lightweight color calibrator compared to the cumbersome system from previous work based on professional displays. It's a compact device thanks to the high integration of electronics and opto-mechanical components. It can synthesize colors accurately thanks to LED luminance stability, color uniformity and reasonable precision (8bits).

The developed observer calibrator prototype confirmed that we can classify normal color observers into a reduced number of categories. The full precision classification requires 45mn of test but will be speed-up in the near future to last only 10mn to 15mn thanks to a color presentation strategy optimization.

Future work includes the use of the color observer calibrator prototype for wider scale experiment involving 60 persons to extend the results obtained until now.

Applications include the development of an observer-dependent color imaging workflow in motion picture post-production. Long time used reference monitors such as the Sony BVM32 CRT will soon be replaced by new display technologies such as LED LCD (Dolby PRM-4200) or OLED (Sony BVM-E250). However, at the moment, it is difficult to get consistent color reproduction using regular color management tools on both CRT and new displays. The main reason comes from observer variability when watching very different color spectra on the different screens. The color observer calibrator will help to adjust more accurately color reproduction for each viewer. This prototype is at the first step toward an industrial use of an observer classification tool in color-critical application. Further, this can be a highly useful research tool in the domains of color science, color imaging and color vision.

4. REFERENCES

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