Multi-Reference Imaging Light Measurement Device

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Abstract

Emerging display technologies, such as OLEDonSi displays, present both new opportunities and challenges in display metrology. To achieve accurate color measurements for displays with spatially inhomogeneous spectral emissions, we propose a novel measurement concept. This concept aims to quickly and precisely measure the angular properties of a display.

Our solution is an imaging system equipped with a conoscopic lens, offering a wide field of view and multiple spectral reference spots to correct for spectral variations. All spectral reference spots are recorded in parallel by separate spectroradiometer. By combining camera images with spectral data, we effectively characterize the angular color properties of the display.

Author Keywords

OLEDonSi; colorimetry; conoscopic camera; spectroradiometry; micro-display; Imaging light measurement device; multi-angle measurement; VR; AR

1. Introduction

The angular properties related to luminance and color are important characteristics of a display. To measure them several approaches have been developed. A goniometer setup [1] or a conoscopic setup [2] are common approaches to solve this task. In the presented setup a camera based system with a conoscopic lens is shown. The benefit of using a conoscopic setup is that the complete angular range can be covered with one image of the camera. For accurate luminance and color measurements several spectral reference spots are distributed over field of view of the camera. The results are compared to measurements obtained with a goniophotometer, which acts as reference device.

As display a relative new display technology OLED on silicon [3] is selected which exhibits angular color shifts. It is a combination of white Organic Light Emitting Diodes (OLED) and monocrystalline silicon wafers. To obtain a RGB display the white light of the OLED is filtered by color filters of colors red, green and blue. The benefits are compact size, high resolution, high contrast ratio and fast response time. All properties are useful for characterizing a VR headset as it is realized in Apple's Vision Pro [4].

2. Setup

The setup is a camera based system similar to the design of the LumiTop camera [5]. The LumiTop camera is a system to measure spatial resolved luminance and color values of displays. It using a spectroradiometer which allows accurate and fast color measurements of the display. In the light path of the LumiTop a 3-way-beam splitter is placed which allows to measure the spectrum, the camera image and also flicker simultaneously and speed up the measurement (Figure 1).

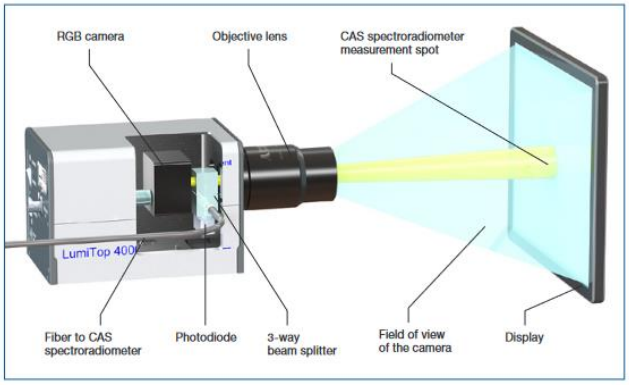

Figure 1 Function principle of LumiTop (from [5]).

To improve the color accuracy measurement the LumiTop setup is changed. Instead of using one central spot position for the spectroradiometer several spot positions distributed over the field of view of the conoscopic lens are defined. For each spot a separate spectroradiometer is used. Using the information of all recorded spectra an optimized color conversion matrix (CCM) is determined. In addition to the spectroscopic measurement also a color filter wheel is installed. The system has a monochromatic camera with 12 MPx resolution with a tristimulus filter wheel. The conoscopic lens has a field of view of 120°x85° and the display is located in the virtual plane of the conoscopic lens. Up to 17 separate spectroscopic measurement spots can be measured (Figure 2).

For the test an OLEDonSi microdisplay (Sony ECX335S) is used and mounted on an alignment stage. The display has a resolution of 1920x1080 px and a display size of 0.71" (3078 PPI). For detailed technical information of the display visit Sony product page [6].

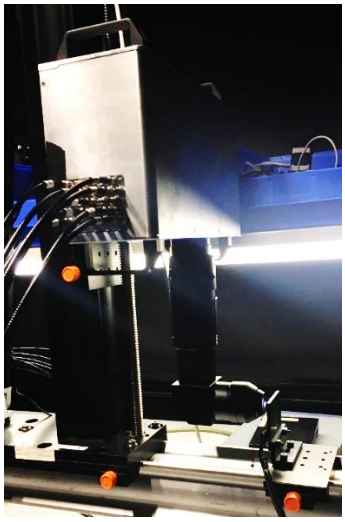

Figure 2 Image of the setup. The conoscopic lens has a

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periscopic design. The glass fibers of the up to 17 spectroscopic channels are visible.

In addition to the measurement with the camera system a goniometric system (DMS 803, Instrument Systems) has been also used to obtain reference data which are compared to the camera measurements.

3. Measurement and results

For a measurement typically a red, green and blue pattern is displayed. A typically image is shown in Figure 3. In the image also the position of the 17 spectral reference spots are indicated as green circles. It is easy to see that the color of the blue pattern shifts from blue in center (0° incident) to red or yellow/green for higher elevations.

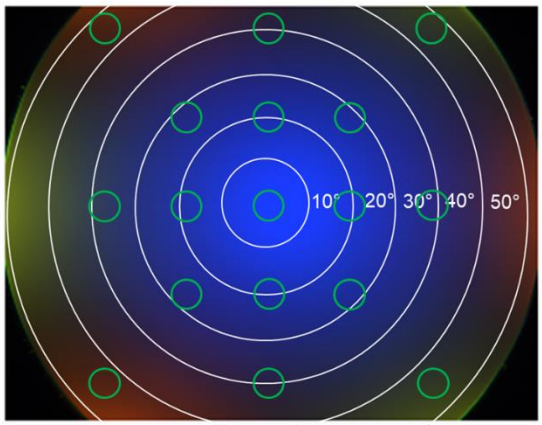

Figure 3 Typical image obtained by the camera (here with a blue pattern). Positions of the spectral reference spots in the camera field of view are indicated by green circles.

In the shown case of a blue pattern the left top spectrum is given in Figure 4 and the middle spot in the center of the image is shown in Figure 5. Comparing both spectra a strong red contribution appears in Figure 4 leading to significant color shift compared to the color measured in the middle.

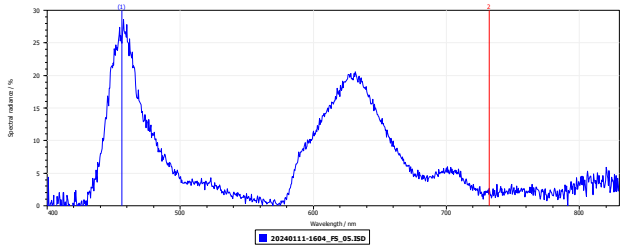

Figure 4 Spectrum of the left top spot in Figure 3.

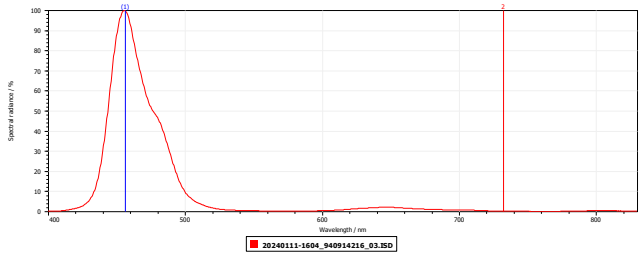

Figure 5 Spectrum in the middle spot at the center of the image (Figure 3).

As reference the display is also measured with a goniophotometer as mentioned above. The measurement consists of 1752 points and takes several hours compared to the camera setup which takes few minutes. At each measurement point the spectrum is recorded and the chromaticity coordinates x and y are deduced (Figure 6). Large color shifts are visible depending on the azimuth and elevation.

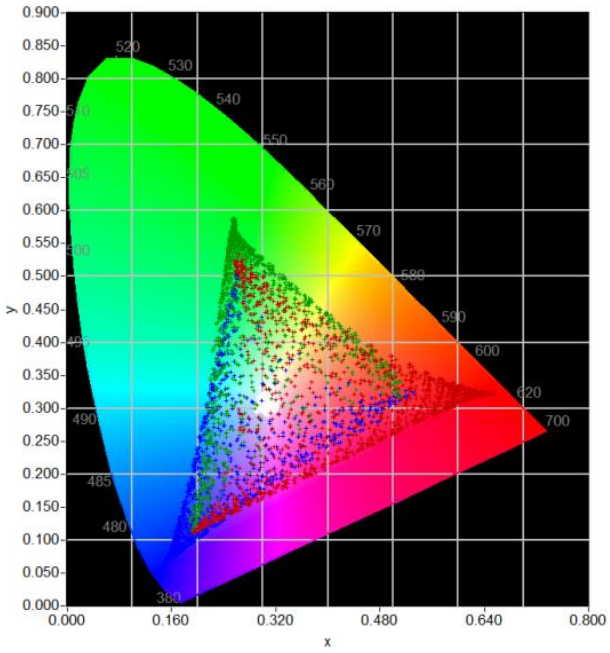

Figure 6 All measured chromaticity coordinates x and y for the pattern red, green an, blue and white (the symbol color corresponds to the pattern color) from azimuth 0°-360° (5° step size) and elevation 0° to 69° (3° step size).

Using all spectroscopic information the CCM is calculated and together with the color information of the camera the XYZ values are obtained for each pixel. Now the obtained values are compared with the goniophotometer measurements and the differences are calculated (Figure 7, Figure 8). For this comparision the pixel corresponding to a given measurement of the goniometer are averaged.

Up to elevation angles of 40° the difference between the goniophotometer and camera system is below 0.005, but for higher elevations the differences increases significantly, which is currently under investigation.

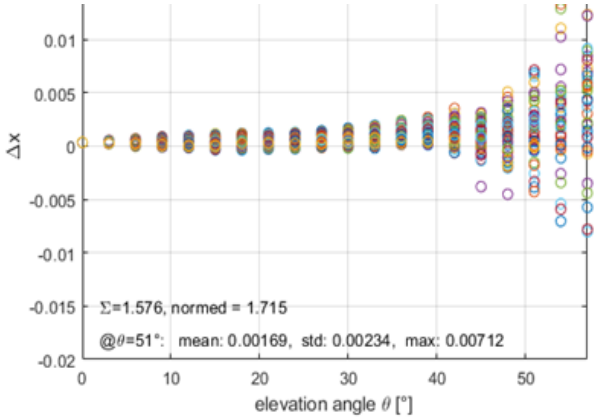

Figure 7 Difference Δx between goniophotometer and

camera systems.

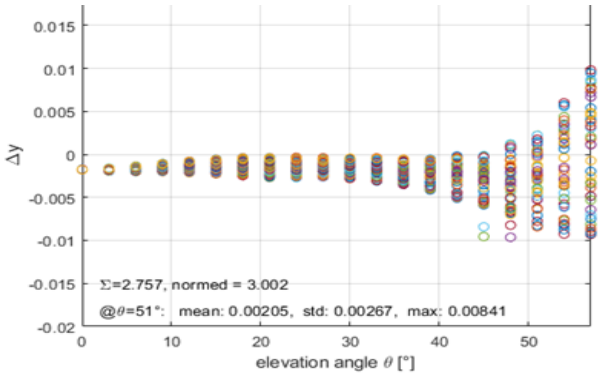

Figure 8 Difference Δy between goniophotometer and camera systems.

4. Conclusion

The presented promising approach to combine a conoscopic camera system with several spectroscopic reference spots distributed over the field of view of the camera shows a potential new measurement setup for displays with large color variations depending on the viewing angle. The comparison with a goniophotometer measurement shows a good agreement over a large angular range but larger deviation for higher elevation, which needs further investigations to understand the differences.

5. References

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