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An Improved Color Deviation Calibration for the Color LCD Monitors of the Ultrasound Diagnostic Equipment

Rankwon Kim*, Sungguk Cho, Hyunmi Yoo*** and Byungkook Jeon*****

*KOSTEC Co., Wonju City, Gangwon Prov. 26403, Korea,

** Dept. of Multimedia Eng., Gangneung-Wonju National University, Wonju City, Gangwon Prov. 26403 Korea,

*** Dept. of Software, Gangneung-Wonju National University, Wonju City, Gangwon Prov. 26403 Korea,

***Corresponding author: ByungKook Jeon, Ph.D.

Abstract

The monitor as a sonography image display device is required to display a gray scale technique satisfying DICOM(Digital Imaging and Communications in Medicine) GSDF(Grayscale Standard Display Function), which is an medical image standard, in order to display high quality sonography images during the period of use. However, because the monitor attached to the ultrasonic diagnostic equipment unlike general monitors is the monitor that is used only in the ultrasonic diagnostic equipment, it should display the sonography images with uniformity and consistently high quality.

In this paper, we propose an SIPCB(sonography image processing circuit board) and two hardware/software calibration algorithms for the color LCD(or LED) monitors attached to the ultrasonic diagnostic equipment in order to obtain the improved color sonography images. As a result, the improved color LCD monitors attached to the ultrasonic diagnostic equipment satisfies the color coordinate deviation of ±0.004 or less using the proposed SIPCB architecture and two hardware/software calibration algorithms.

Key Words: Color deviation calibration, Color LCD monitor, Sonography image, Ultrasound Diagnostic Equipment, DICOM GSDF

INTRODUCTION

There has been significant work done already over the past few years to characterize and describe the behavior of color monitor systems for color medical images[1-5]. However the DICOM GSDF standard describes still only how grayscale medical images need to be visualized to ensure consistent and high quality visualization and to maximize probability that small subtle image features will be visible[6-11]. Because the color monitor for the color sonography images unlike general monitors is only used in an ultrasonic diagnostic equipment, it should display the color sonography images with uniformity, consistently high quality[1,3].

Therefore, in this paper, we propose an SIPCB(sonography image processing circuit board) and two hardware/software calibration algorithms for the color LCD(or LED) monitors attached to the ultrasonic diagnostic equipment in order to obtain the improved color sonography images with uniformity and consistently high quality. The proposed SIPCB consists of a luminance uniformity circuit, an HDMI port, and a user interface. As well, the proposed calibration algorithm performs optimally re-calibrating to match for the target color coordinates and color temperature by reconstructing the gamma curve. So we can get the sonography images with uniformity and higher quality on the color LCD monitors of the ultrasound diagnostic equipment.

The paper begins with a review of related work, then goes on to describe an SIPCB architecture and two algorithms, before providing results from an early user study, followed by a discussion and conclusion

RELATED WORKS

For grayscale medical imaging, the DICOM GSDF standard describes how grayscale medical images need to be visualized to ensure consistent and high quality visualization and to maximize probability that small subtle image features will be visible[6-11]. But, there is no agreed upon standard yet that describes how color medical images need to be visualized and how calibration and quality assurance of color medical displays need to be performed. Therefore, there has been significant work done already over the past few years to characterize and describe the behavior of color monitor systems for color medical images. One particularly relevant publication describes a consensus opinion of various stakeholders from the medical imaging community[1-5]. This work lists various forms of color instability in modern state-of-the-art display systems. All color instabilities listed are not compensated for by means of DICOM GSDF calibration since GSDF only calibrates the grayscale behavior of display systems and leaves the color behavior unchanged. Nevertheless, CSDF(color standard display function) had recently been proposed as an extension of the DICOM GSDF standard toward color[4].

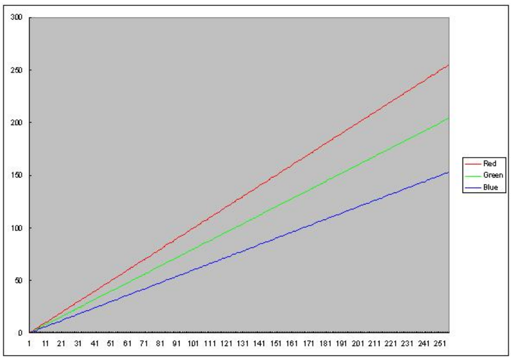

Figure 1. The White Balance

The existing technology in order to ensure uniformity of the color monitors adjusts the gain of each of R, G, and B by adjusting the slope of red, green, and blue as shown in Fig. 1. This adjustment technology is so called “White Balance” and is adjusted by objective values (color coordinates, color temperature), so it is generally used for displays such as LCD, LED, PDP, CRT because of productivity improvement. When using the existing technology, the color coordinate deviation is ± 0.02 or less, the DICOM curve deviation is 15% or less, and the luminance and color uniformity deviation is 30% or less[7-11]. These deviations are very poor when high quality medical imaging is needed. But, basically according to the reference set required in the ultrasound diagnostic equipment, the target color coordinates are controlled to have a deviation rate of less than ± 0.008, a DICOM curve deviation of less than 7%, and a luminance and color uniformity deviation of less than 20% to optimize the ultrasound images and ensure uniformity of the color monitors.

Therefore, the gains of red, green, and blue must be adjusted to obtain higher quality medical images. However, the gain adjustment of red, green, and blue changes the slope of red, green, and blue. This results in loss of the output signal for each level (Level: 0 to 255) of the input signal. That is, there are some disadvantages that the medical images displayed on the color LCD monitor, especially the sonography images, are lost so that the images are not uniform and optimal. Therefore, it is necessary to overcome these disadvantages.

AN SIPCB ARCHITECTURE AND TWO CALIBRATION ALGORITHMS

In order to obtain uniformity and higher quality sonography images on the color LCD monitors of the ultrasound diagnostic equipment, we design a block diagram of a SIPCB architecture for the color LCD monitors as shown in Fig 2. The block diagram in Fig. 2 consists of a luminance uniformity circuit as a sonography image processing circuit which is the adjustment of luminance, color and gamma curve for ensuring luminance uniformity as light source of the LCD panel, an HDMI port as the input port for interfacing with the ultrasound diagnostic equipment, and a user interface.

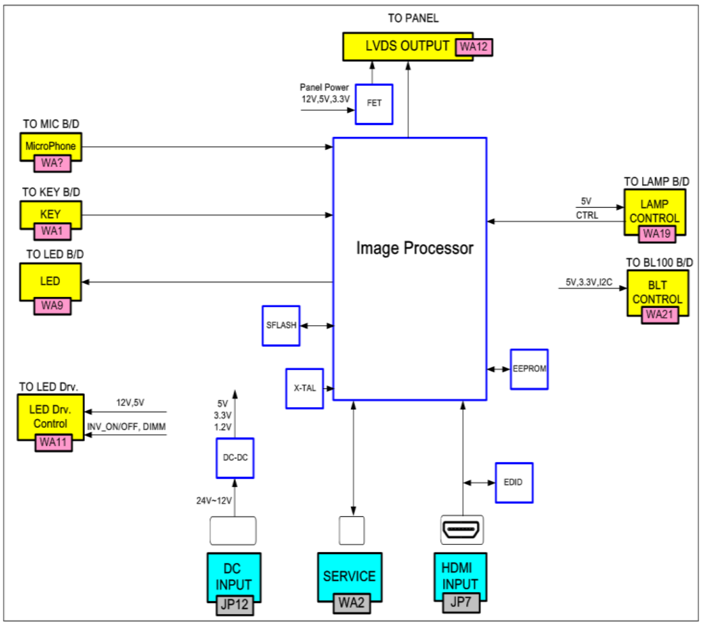

Figure 2. A block diagram of the proposed SIPCB architecture

A luminance uniformity circuit is configured as a backlight sensor board, which is detected by the light hole of the LCD panel and is interfaced with the MCU(micro control unit) of the main image processing board as shown in Fig. 3.

Figure 3. A color LCD monitor with built-in luminance uniformity circuit

The color sensors on the front of the LCD panel senses the color coordinates and color temperature of the LCD screen. And the color coordinates and color temperature sensed are improved by the calibration algorithm proposed below 2 to re-map the LUT(Look UP Table) values of the curves of red, green, and blue to match the target value color coordinates and color temperature.

Therefore the SIPCB control firmware algorithm for the luminance uniformity circuit controls the color monitors by the following Algorithm 1.

Algorithm 1.

detects the luminance of backlight by the backlight sensor

while (*obtains the luminance value of backlight until optimized*)

{

if *the default luminance value of main board = the obtained luminance value*

then *continue*

else if *the default luminance value of main board < the obtained luminance value*

then

increases the luminance of the backlight by increasing the dimming of the inverter

else

decreases the luminance of the backlight by decreasing the dimming of the inverter

}

Next, the calibration algorithm to calibrate with software for the color monitors is as follows. The gamma configuration divides each of red, green, blue 256 step inputs into 18 steps and measures the color coordinates with the external color sensor device. Then, the independent LUT values of red, green, and blue corresponding to the target color coordinates required by the ultrasonic diagnostic equipment are automatically changed, and the LUT values of red, green, and blue for each optimum input step are extracted in 256 steps. The extracted LUT values are uploaded to the SIPCB, re-mapping is performed, and the gamma curve is reconstructed. The re-mapped LUT values are compared with the target color coordinates and color temperature by the calibration software of the control computer. If there is a difference between the target color coordinate and color temperature, the LUT is recalibrated by controlling the red, green, and blue image signal values output from the LCD main board so that the color coordinates and color temperature are maintained uniformly.

The following Fig. 4 shows the result of applying the calibration algorithm proposed in this paper and shows a gamma curve that processes an ideal and uniform sonography image consistent with the target color coordinates (Reference Set) required by the ultrasound diagnostic equipment.

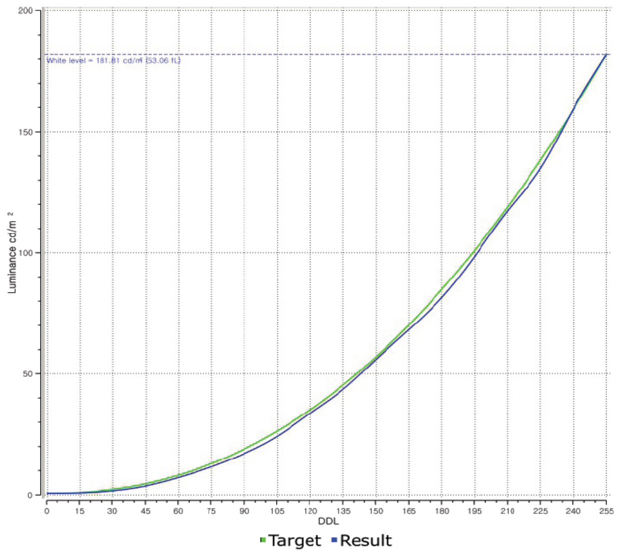

Figure 4. A gamma curve by the proposed calibration algorithm

EXPERIMENTAL RESULTS

The performance tests are evaluated by the AAPM TG18(Assessment of Display Performance for Medical Imaging System) and the JESRA X-0093(Japan Industries Association of Radiological Systems Standards) as performance testing, quality management standards and methodologies of display devices used for medical purposes.

Using the Display Color Analyzer Measuring equipment (model name: CA-210, manufacturer: KONICA MINOLTA), after measuring the color coordinates of the monitor in the white state, we have confirmed that the color coordinate deviations of the measured values compared with the reference x(0.312) and y(0.343) satisfy ± 0.004 or less as shown in the following Fig 5.

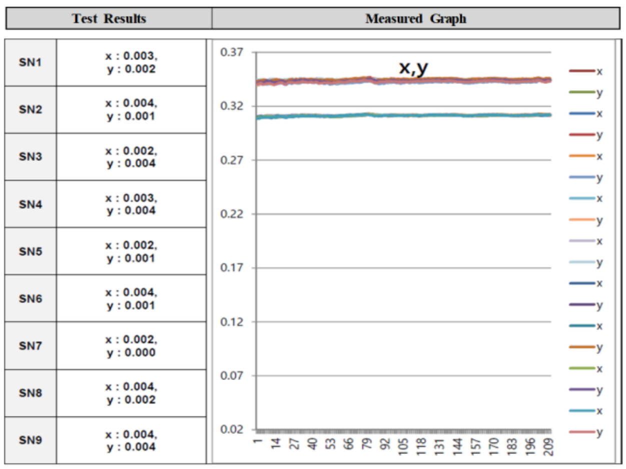

Figure 5. The color coordinate deviations of the measured values

CONCLUSIONS

This paper presented the improved color LCD monitors attached to the ultrasonic diagnostic equipment that satisfies the color coordinate deviation of ± 0.004 or less using the proposed SIPCB architecture and two hardware/software calibration algorithms. As a result, the color LCD monitors obtain the improved color sonography images with uniformity and consistently high quality. Thus, imaging diagnostic doctors can read more accurate and distortion-free color sonography images for the patient, which can lower the rate of misdiagnosis.

In the future, we expect that the proposed calibration mechanism will be reflected very effectively when DICOM presents color standards for high-precision color images.

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REFERENCES

[1] A. Badano, C. Revie, A. Casertano, W.-C. Cheng, P. Green, T. Kimpe, E. Krupinski, C. Sisson, S. Skrøvseth, D. Treanor, P. Boynton, D. Clunie, M. Flynn, T. Heki, S. Hewitt, H. Homma, A. Masia, T. Matsui, B. Nagy, M. Nishibori, J. Penczek, T. Schopf, Y. Yagi, and H. Yokoi, "Consistency and standardization of color in medical imaging: A consensus report," *J Digit Imaging* 28 (2015)., 41–52

[2] Kuprinski EA. "Medical grade vs off-the-shelf color displays: influence on observer performance and visual search". *J Digital Imaging* (2009); 22: 363–8.

[3] Geijer H, Geijer M, Forsberg L, Kreddache S, Sund P. Comparison of color LCD and medical-grade monochrome LCD displays in diagnostic radiology. *J Digit Imaging* (2007) 20: 114–21.

[4] Tom Kimpe, Johan Rostang, Gert Van Hoey, and Albert Xthona. "Color standard display function: A proposed extension of DICOM GSDF", Med. Phys. 43 (9), Sep., (2016), 5009-5019.

[5] S. Zabala-Travers, M. Choi, W.-C. Cheng, and A. Badano, "Effect of color visualization and display hardware on the visual assessment of pseudocolor medical images," Med. Phys. 42 (2015), 2942–2954.

[6] National Electrical Manufacturers Association(NEMA). Digital imaging and communications in medicine (DICOM) part 14: greyscale standard display function. Rosslyn, VA: *NEMA Publishing*; (2006).

[7] McIlgorm DJ, Lawinski C, Ng S, McNulty JP., "Quality of commercial-off-the-shelf(COTS) monitors displaying dental radiographs", *Br Dent J* (2013).

[8] D. J. Mcllgorm, J. P. McNulty, "DICOM part 14: GSDF-calibrated medical grade monitor *vs* a DICOM part 14: GSDF-calibrated "commercial off-the-shelf" (COTS) monitor for viewing 8-bit dental images", Dentomaxillofac Radiol, (2015) Mar., 44(3).

[9] Bender S, Lederle K, Weiss C, Schoenberg SO, Weisser G. 8-bit or 11-bit monochrome displays—which image is preferred by the radiologist? *Eur Radiol* (2011) 21: 1088–96.

[10] Fetterly KA, Blume HR, Flynn MJ, Samei E. Introduction to grayscale calibration and related aspects of medical imaging grade liquid crystal displays. *J Digit Imaging* (2008) 21: 193–207.

[11] McIlgorm DJ, Lawinski C, Ng S, McNulty JP. Could standardizing "commercial off-the-shelf" (COTS) monitors to the DICOM part 14: GSDF improve the presentation of dental images? A visual grading characteristics analysis. *Dentomaxillofac Radiol* (2013).