LITERATURE SURVEY ON UNIFORM COLOUR SPACE FOR IMAGING APPLICATIONS INCLUDING WIDE COLOUR GAMUT AND HIGH DYNAMIC RANGE IMAGES

DR 8-17

REPORTERSHIP REPORT

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Introduction

Wide Colour Gamut (WCG) and High Dynamic Range Television (HDR-TV) provide an increased range of colours and luminance range images for the viewers than the conventional HDR TV does. This requires new studies into image format and colour appearance for accurate colour acquisition and control from camera to display.

In this report, the literature on WCG and HDR television is introduced, and a proposal made for developing possible CIE activities and studies into WCG/HDR imaging systems.

1 Colour Encoding Space

ITU-R BT.2020 [1] recommends the wide colour gamut for UHD TV using the ICtCp colour space [2] as the colour encoding space for the HDR TV system, which was proposed by Dolby and is most widely known as the HDR colour space. Since the ICtCp space is based on the LMS (cone) colour space there is no limit in terms of colour gamut. For luminance encoding, Rec. ITU-R BT.2100 [3] recommends perceptual quantization (PQ) and hybrid log-gamma (HLG) functions to encode the exact luminance values up to 10,000 cd/m^2. The PQ function is also a standard function for SMPTE [4]. The development of HDR TV is an on-going topic within ITU-R Study group 6 which has been publishing various Reports on HDR TV [5-8].

Note that the colour spaces introduced here are for colour encoding, and not for colour appearance prediction.

References on WCG/HDR colour encoding space

[1] Recommendation ITU-R BT.2020: Parameter values for ultra-high definition television systems for production and international programme exchange
[2] https://www.dolby.com/us/en/technologies/dolby-vision/ICtCp-white-paper.pdf
[3] Recommendation ITU-R BT.2100-2: Image parameter values for high dynamic range television for use in production and international programme exchange
[4] ST 2084:2014 - SMPTE Standard - High Dynamic Range Electro-Optical Transfer Function of Mastering Reference Displays
[5] Report ITU-R BT.2245: HDTV and UHDTV including HDR-TV test materials for assessment of picture quality
[6] Report ITU-R BT.2390-6: High dynamic range television for production and international programme exchange
[7] Report ITU-R BT.2408-2: Guidance for operational practices in HDR television production
[8] Report ITU-R BT.2446: Methods for conversion of high dynamic range content to standard dynamic range content and vice-versa

2 Perceptual Colour Spaces for HDR

There are only a few studies on colour appearance under HDR viewing conditions. Most of the previous studies on HDR are for representing HDR images on LDR displays.

Kim et. al [9] conducted a set of colour appearance experiments using a display having a wide range of luminance levels (up to 16,860 cd/m^2). Fairchild et. al [10] developed HDR colour spaces extending the existing CIELAB and IPT systems. Safdar et. al [11] proposed a $J_za_zb_z$ colour space using a wide range of experimental data.

References on HDR colour appearance / space

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[9] Kim, M. H., Weyrich, T., & Kautz, J. (2009). Modeling human color perception under extended luminance levels. ACM transactions on graphics (TOG), 28(3), 27.
[10] Fairchild, M. D., & Wyble, D. R. (2010, January). hdr-CIELAB and hdr-IPT: Simple models for describing the color of high-dynamic-range and wide-color-gamut images. In Color and Imaging Conference (Vol. 2010, No. 1, pp. 322-326). Society for Imaging Science and Technology.
[11] Safdar, M., Cui, G., Kim, Y. J., & Luo, M. R. (2017). Perceptually uniform color space for image signals including high dynamic range and wide gamut. Optics express, 25(13), 15131-15151.

3 Possible CIE activities for WCG/HDR imaging system development

Many international organisations such as ITU-R, IEC, SMPTE and Academy of Motion Picture Arts and Sciences are working on standardizing HDR camera, TV and cinema/broadcasting systems, while there are only a few studies on colour appearance in HDR viewing conditions.

Without sound scientific studies from the CIE on HDR colour appearance, HDR colour representation systems developed by other organizations will lack any scientific basis. At present, there is no agreed definition on HDR viewing conditions or HDR colour gamut.

Therefore, it is strongly recommended that the CIE should form new TCs within Division 8 and Division 1 (or a Joint TC) to lead the colour studies on HDR imaging.

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