WHAT IS IC_TC_P - INTRODUCTION?

IC_TC_P is a color representation designed for high dynamic range (HDR) and wide color gamut (WCG) imagery and is intended as a replacement for Non-Constant Luminance (NCL) $Y'C'_BC'_R$ with HDR and WCG signals.

The television industry is going through a major evolution. Wide color primaries and high dynamic range along with higher spatial resolution are the technologies of the future. Distortions already known to be caused by non-uniformity of standard dynamic (SDR) range NCL $Y'C'_BC'_R$ (hue linearity and constant luminance) will become more prevalent as display capabilities improve. When setting a new standard for HDR and WCG (new non-linear encoding curves, new color primaries, and increased bit depth), a significantly improved color representation designed for the coming evolution should be included.

Displays of the future will likely have widely varying primaries and luminance ranges. To account for the variations, display mapping will become a routine process. In addition, color processing such as blending, fading, chroma-subsampling, and resizing will need to be processed quickly, with minimal error. As the volume of color essence increases, color transformations will become more costly. Performing these tasks in an efficient essence representation reduces complexity and increases speed. IC_TC_P is designed for this purpose.

IC_TC_P follows the same operations as NCL $Y'C'_BC'_R$, and has similar benefits as Constant Luminance (CL) $Y'_CC'_{BC}C'_{RC}$ while additionally improving color uniformity. This is achieved by utilizing aspects of the human visual system and by optimizing for lines of constant hue, uniformity of just-noticeable-difference (JND) ellipses, and constant luminance.

The transformation from ITU-R BT.2020 primaries [1] into IC_TC_P using the PQ ST 2084 [2] non-linearity is given below. IC_TC_P has also been defined utilizing the HLG non-linearity, but that derivation will not be discussed in this paper. Minimal testing utilizing the HLG non-linearity has been completed assuming a 1000 cd/m^2 display. Relative results are comparable.

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HOW TO TRANSFORM LINEAR ITU-R BT.2020 INTO IC_TC_P

Start with ITU-R BT.2020 linear RGB, then:

1. Calculate LMS

$$L = (1688R + 2146G + 262B) / 4096$$
$$M = (683R + 2951G + 462B) / 4096$$
$$S = (99R + 309G + 3688B) / 4096$$

2. Apply the ST 2084 [2] non-linearity (See the "Design Criteria" section for the equation)

$$L'M'S' = EOTF_{PQ}^{-1} (LMS)$$

3. Calculate IC_TC_P

$$I = 0.5L' + 0.5M'$$
$$C_T = (6610L' - 13613M' + 7003S') / 4096$$
$$C_P = (17933L' - 17390M' - 543S') / 4096$$

IC_TC_P DESIGN CRITERIA

IC_TC_P was designed utilizing key aspects of the human visual system (HVS). In a simplified form, there are three important steps [3] to color processing in the eye.

1. Incoming light is captured by the three photo receptors (cones) in the eye that have peak sensitivities in the L(ong), M(edium), and S(hort) wavelengths.
2. The linear light is transduced (converted) into a non-linear signal response to mimic the adaptive cone response of the HVS.
3. The non-linear signal goes through a color differencing process to separate the signal into three distinct pathways (the light-dark Intensity axis, the yellow-blue Tritan isoluminant axis, and the red-green Protan isoluminant axis).
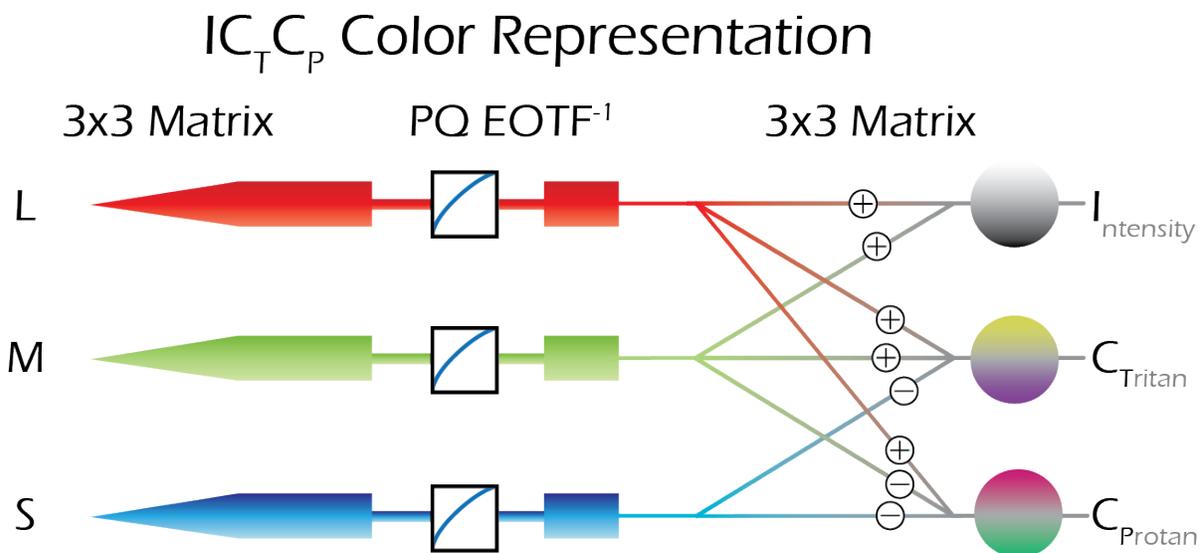
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IC$_T$C$_P$ Color Representation

3x3 Matrix   PQ EOTF^{-1} 3x3 Matrix

Figure 1: IC$_T$C$_P$ and the relationship to the Human Visual System

IC$_T$C$_P$ mimics the HVS, employing the operations of NCL Y'C'$_B$C'$_R$ (See Figure 1). The three steps for color processing in the eye are implemented with the constraints of two 3x3 matrices and a non-linearity curve. Further breakdown of the derivation of the three steps in the IC$_T$C$_P$ transform are given below.

Step 1- Calculating LMS: The LMS 3x3 matrix transform is a refined version of the Hunt-Pointer-Estevez (HPE) [4] XYZ to LMS transform normalized to a D65 white point. It has been formally defined from BT.2020 primaries for convenience. Basing the IC$_T$C$_P$ color representation on the commonly used HPE LMS cone fundamentals improves the uniformity of the color representation, especially near the BT.2020 gamut boundary.

A crosstalk matrix was applied to the HPE LMS transform to reduce the concavities of BT.2020 RGB represented in IC$_T$C$_P$, reducing interpolation errors. The crosstalk was refined to achieve improved lines of constant hue [5] and improved uniformity of JND MacAdam ellipses. The specific calculations to derive the BT.2020 RGB to LMS matrix are given below.

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GIVEN MATRICES:

$$\text{HPE} \begin{bmatrix} L \\ M \\ S \end{bmatrix} \text{(normalized to D65)} = \begin{bmatrix} 0.4002 & 0.7076 & -0.0808 \\ -0.2263 & 1.1653 & 0.0457 \\ 0 & 0 & 0.9182 \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

$$\text{BT.2020} \begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.7167 & -0.3557 & -0.2534 \\ -0.6667 & 1.6165 & 0.0158 \\ 0.0176 & -0.0428 & 0.9421 \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

C = 0.04 (4% crosstalk)

$$\text{Crosstalk\_matrix} = \begin{bmatrix} 1\text{-}2C & C & C \\ C & 1\text{-}2C & C \\ C & C & 1\text{-}2C \end{bmatrix} = \begin{bmatrix} 0.92 & 0.04 & 0.04 \\ 0.04 & 0.92 & 0.04 \\ 0.04 & 0.04 & 0.92 \end{bmatrix}$$

COMPUTE THE BT.2020 TO LMS MATRIX:

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = \begin{bmatrix} 0.92 & 0.04 & 0.04 \\ 0.04 & 0.92 & 0.04 \\ 0.04 & 0.04 & 0.92 \end{bmatrix} * \begin{bmatrix} 0.4002 & 0.7076 & -0.0808 \\ -0.2263 & 1.1653 & 0.0457 \\ 0 & 0 & 0.9182 \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

$$= \begin{bmatrix} 0.3592 & 0.6976 & -0.0358 \\ -0.1922 & 1.1004 & 0.0755 \\ 0.0070 & 0.0749 & 0.8434 \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = \begin{bmatrix} 0.3592 & 0.6976 & -0.0358 \\ -0.1922 & 1.1004 & 0.0755 \\ 0.0070 & 0.0749 & 0.8434 \end{bmatrix} * \begin{bmatrix} 1.7167 & -0.3557 & -0.2534 \\ -0.6667 & 1.6165 & 0.0158 \\ 0.0176 & -0.0428 & 0.9421 \end{bmatrix}^{-1} * \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$= \text{round}\left(\begin{bmatrix} 0.4120 & 0.5239 & 0.0641 \\ 0.1667 & 0.7204 & 0.1129 \\ 0.0241 & 0.0755 & 0.9004 \end{bmatrix} \times 4096 \right) / 4096 * \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$= \begin{bmatrix} \mathbf{1688} & \mathbf{2146} & \mathbf{262} \\ \mathbf{683} & \mathbf{2951} & \mathbf{462} \\ \mathbf{99} & \mathbf{309} & \mathbf{3688} \end{bmatrix} / \mathbf{4096} * \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Step 2- Applying the Non-Linearity: SMPTE ST 2084 defines an EOTF (PQ) designed to match the contrast sensitivity function of the human visual system [6]. Applying the inverse of this curve efficiently and perceptually distributes the HDR linear LMS values for encoding with limited bit depth. The equation is given below.

PQ NON-LINEARITY:

$$\text{EOTF}^{-1}[F_D] = \left(\frac{C_1 + C_2 Y^{m_1}}{1 + C_3 Y^{m_1}}\right)^{m_2}$$

$$Y = F_D/10000$$

where

F_D is the luminance of the linear component {*L, M, S*} in cd/m².
Y denotes the normalized linear color value, in the range [0:1]

$m_1 = 2610/16384 = 0.1593017578125$
$m_2 = 2523/4096 \times 128 = 78.84375$
$c_1 = 3424/4096 = 0.8359375 = c_3 - c_2 + 1$
$c_2 = 2413/4096 \times 32 = 18.8515625$
$c_3 = 2392/4096 \times 32 = 18.6875$

Step 3- Calculating IC_TC_P: The final matrix derivation is based on the L'M'S' to IPT color representation transformation defined by Ebner and Fairchild [7]. The most notable change is the weighting of the I (Intensity) channel, which is now optimized for constant luminance. Although there is no S' input to this signal, the crosstalk added to the RGB to LMS conversion assures contribution from all three cones. The coefficients to calculate C_T and C_P remain the same as T and P in the Ebner L'M'S to IPT matrix.

The L'M'S' to IC_TC_P matrix been scaled to fit the full BT.2020 gamut inside the -0.5 to 0.5 region for compatible scaling with Y'C'$_B$C'$_R$. For improved backwards compatibility (signal presence verification on existing monitors and ability to use existing tools such as scopes), the coefficients

have been rotated and flipped to align skin tones with SDR BT.709 $Y'C'_BC'_R$. The full derivation of the L'M'S' to IC_TC_P matrix is given below.

GIVEN MATRICES:

$$\text{Ebner} \begin{bmatrix} I \\ P \\ T \end{bmatrix} = \begin{bmatrix} 0.4 & 0.4 & 0.2 \\ 4.4550 & -4.8510 & 0.3960 \\ 0.8056 & 0.3572 & -1.1628 \end{bmatrix} * \begin{bmatrix} L' \\ M' \\ S' \end{bmatrix}$$

Alpha = 1.134464 radians (to align skin tones)

$$\text{Rotation} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\text{Alpha}) & -\sin(\text{Alpha}) \\ 0 & \sin(\text{Alpha}) & \cos(\text{Alpha}) \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0.4226 & -0.9063 \\ 0 & 0.9063 & 0.4226 \end{bmatrix}$$

$$\text{Scalar} = \begin{bmatrix} 1 & 1 & 1 \\ 1.4 & 1.4 & 1.4 \\ 1 & 1 & 1 \end{bmatrix} \text{ (to fit chroma between -0.5 and 0.5)}$$

COMPUTE THE L'M'S' TO IC_TC_P MATRIX:

$$I_{new} \text{ (Optimized I Coefficients)} = \begin{bmatrix} 0.5 & 0.5 & 0 \end{bmatrix} * \begin{bmatrix} L' \\ M' \\ S' \end{bmatrix}$$

$$\begin{bmatrix} I \\ C_T \\ C_P \end{bmatrix} = \left(\left(\begin{bmatrix} 1 & 0 & 0 \\ 0 & 0.4226 & -0.9063 \\ 0 & 0.9063 & 0.4226 \end{bmatrix} * \begin{bmatrix} 0.5 & 0.5 & 0 \\ 4.4550 & -4.8510 & 0.3960 \\ 0.8056 & 0.3572 & -1.1628 \end{bmatrix} \right) \times \begin{bmatrix} 1 & 1 & 1 \\ 1.4 & 1.4 & 1.4 \\ 1 & 1 & 1 \end{bmatrix} \right) * \begin{bmatrix} L' \\ M' \\ S' \end{bmatrix}$$

$$= \text{round} \left(\begin{bmatrix} 0.5 & 0.5 & 0 \\ 1.6137 & -3.3234 & 1.7097 \\ 4.3781 & -4.2455 & -0.1325 \end{bmatrix} \times 4096 \right) / 4096 * \begin{bmatrix} L' \\ M' \\ S' \end{bmatrix}$$

$$= \begin{bmatrix} \mathbf{2048} & \mathbf{2048} & \mathbf{0} \\ \mathbf{6610} & \mathbf{-13613} & \mathbf{7003} \\ \mathbf{17933} & \mathbf{-17390} & \mathbf{-543} \end{bmatrix} / \mathbf{4096} * \begin{bmatrix} L' \\ M' \\ S' \end{bmatrix}$$

COMPARISON OF HDR NCL $Y'C'_BC'_R$ AND IC_TC_P

In the following comparison, BT.2020 NCL $Y'C'_BC'_R$ using the PQ non-linearity and IC_TC_P using the PQ non-linearity will be analyzed.

Constant Luminance: A color representation has true constant luminance [8] when the luma channel (Y' of $Y'C'_BC'_R$ encoded with $EOTF^{-1}_{PQ}$ for example) matches with $EOTF^{-1}_{PQ}$ encoded luminance ($EOTF^{-1}_{PQ}$ encoded luminance Y of XYZ). The closer a color representation meets the constant luminance criteria, the better the decorrelation of the chroma and luma channels.

A decorrelated representation holds a significant advantage in color processing such as chroma sub-sampling. The consequences of a representation that does not meet the constant luminance criteria is that any form of interpolation (gamut mapping, color sub-sampling, blending, etc.) will result in luminance changes even if only color information is being altered.

To analyze the constant luminance characteristics of a color representation, the luminance of a color cube of BT.2020 colors from 0.005 cd/m^2 to 10000 cd/m^2 in each representation was compared with the corresponding luma channel.
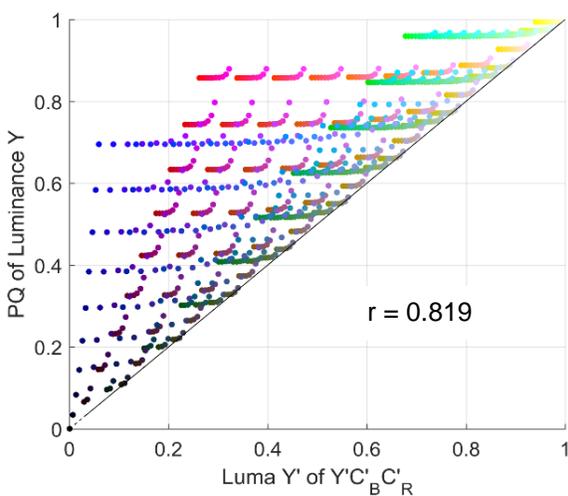

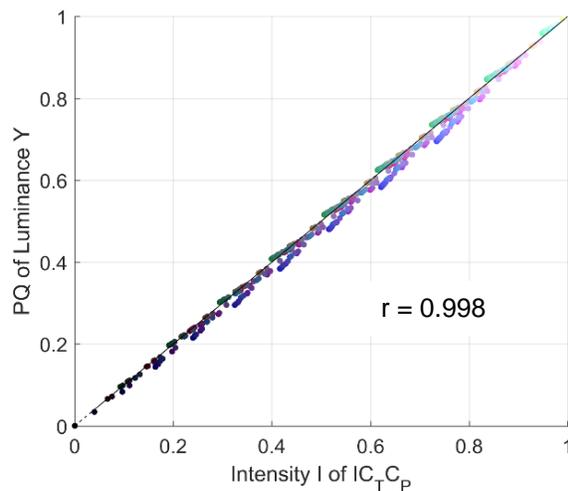*Figure 3: PQ based BT.2020 NCL $Y'C'_BC'_R$ luminance analysis*   *Figure 2: IC_TC_P luminance analysis*

Those luminance values were also encoded in PQ for comparison. A perfectly constant luminance space would have a 1:1 relationship between luma (Y' of Y'C'$_B$C'$_R$ and I of IC$_T$C$_P$) and EOTF$^{-1}_{PQ}$ encoded luminance and would also have a Pearson Correlation Coefficient (r) of 1 [9].

The results from NCL Y'C'$_B$C'$_R$ are shown in Figure 3. The most significant crosstalk occurs in the saturated red and blue colors. Therefore, manipulation of these colors has the most luminance error. Desaturation (decreasing C$_B$ and C$_R$) will result in decreasing luminance.

The results from IC$_T$C$_P$ can be seen in Figure 2. The Intensity channel of IC$_T$C$_P$ was optimized for constant luminance and therefore has an improved correlation. This improvement leads to enhancements in chroma sub-sampling due to the decorrelation of the chroma and luma channels. As the saturation is changed (C$_T$ and C$_P$) the luminance will remain nearly constant.

<u>Hue Linearity:</u> Lines of constant hue are important if saturation adjustments are made. Gamut volume mapping is a common example where desaturation techniques are frequently used. In order to maintain accurate image representation when mapping between volumes, it is expected that relative hue will remain constant. If a color representation has crosstalk between hue and saturation, the gamut mapping algorithms must be complex to account for non-uniform shifts. A completely decorrelated color representation allows hues to remain constant as saturation is changed, therefore simplifying complex operations.

Desaturating highly saturated colors in NCL Y'C'$_B$C'$_R$ leads to hue shifts mainly in the blue and magenta color regions. To analyze lines of constant hue, the Hung and Berns [10] data set was analyzed in NCL Y'C'$_B$C'$_R$ and IC$_T$C$_P$.

As anticipated, the maximum hue deviation of NCL Y'C'$_B$C'$_R$ (Figure 4) is in the blue. This maximum deviation is 23.2 degrees. IC$_T$C$_P$ reduces the maximum hue angle deviation to less than half, having a maximum of 8.0 degrees.
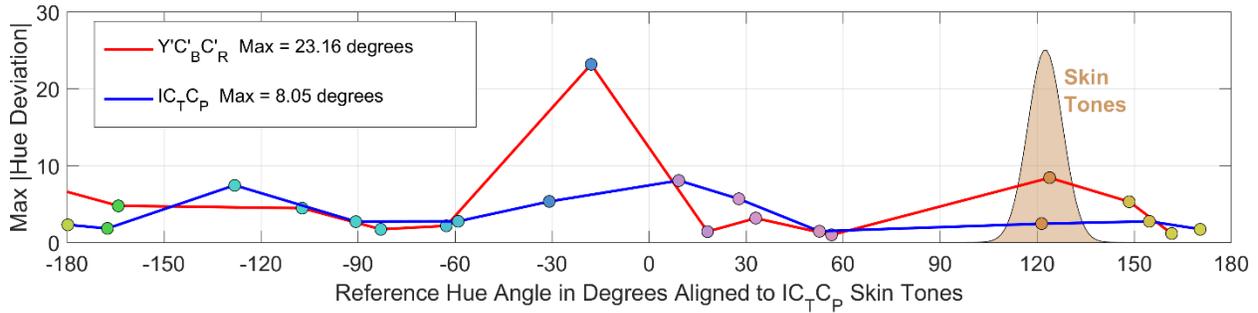
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Figure 4: Hung and Berns maximum hue error comparing IC_TC_P and PQ based BT.2020 NCL $Y'C'_BC'_R$

Also plotted in Figure 4 is the normal distribution of skin tone hues that was derived from a large database of skin tone reflectances. IC_TC_P produces skin tones averaging 122.5 degrees and BT.2020 NCL $Y'C'_BC'_R$ produces skin tones averaging 136.2 degrees. To account for this difference, in Figure 4, the hue angles for $Y'C'_BC'_R$ have been shifted 13.7 degrees to the left for comparison. At this critical skin tone angle, IC_TC_p has less hue deviation than $Y'C'_BC'_R$.
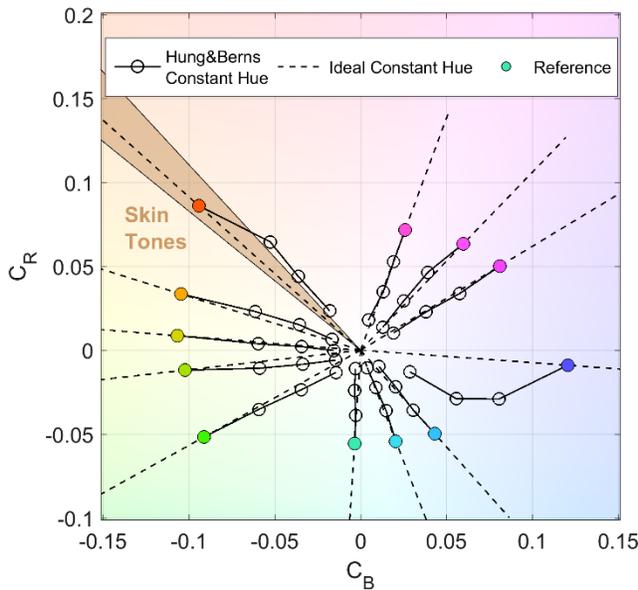

Figure 5: PQ based BT.2020 NCL $Y'C'_BC'_R$ Hung & Berns hue linearity analysis
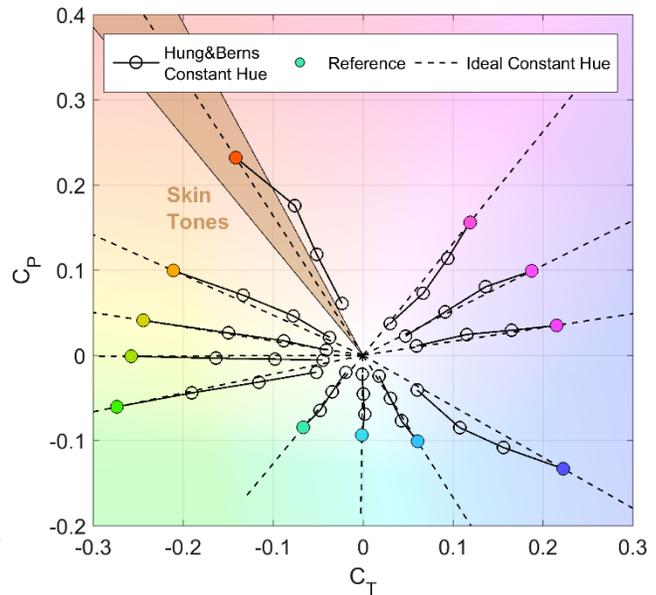

Figure 6: IC_TC_P Hung & Berns hue linearity analysis

The deviation hue line plots are shown in Figure 5 and Figure 6 where the curvature in blue can be seen. This curvature is a visualization of the hue shifts that happen in NCL $Y'C'_BC'_R$ during desaturation and gamut mapping.

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Just-Noticeable-Difference (JND) Uniformity: The uniformity of a color representation relates directly to its efficiency. In an efficient representation, an equal step in every direction would have the same perceptual difference. This way, when bit depth is limited, the code words are distributed evenly and errors are minimized.

To analyze uniformity, MacAdam JND ellipses [11] were plotted in NCL Y'C'$_B$C'$_R$ and IC$_T$C$_P$. A perfectly uniform space would render circles, equal in size. As seen in Figure 7, the ellipses in Y'C'$_B$C'$_R$ differ significantly in size and shape.

IC$_T$C$_P$'s design (Figure 8), based on LMS, significantly improves the uniformity of the ellipses. The largest improvements occur in the cyan and magenta regions where NCL Y'C'$_B$C'$_R$ is most inefficient.
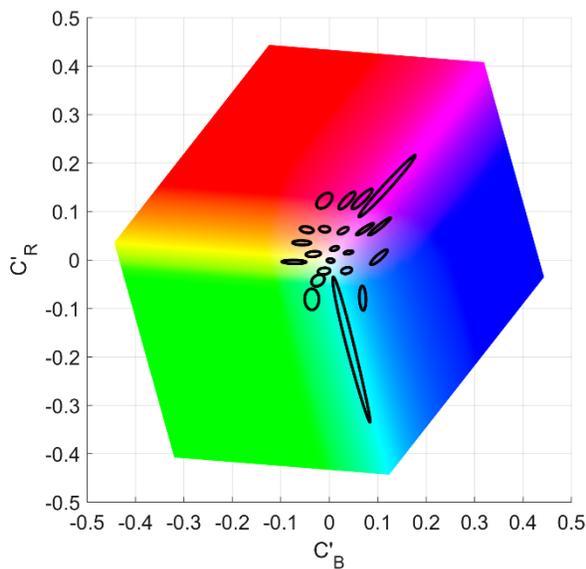
Figure 7: PQ based BT.2020 NCL Y'C'$_B$C'$_R$ JND analysis

Figure 8: IC$_T$C$_P$ JND analysis

To objectively analyze the relative size and shape of the JND ellipses, the standard deviation from the population was computed. In each color representation, to find the average size of an ellipse, a population median was calculated. Then each individual ellipse was analyzed to find the standard deviation from the computed population median (including normalizing the answers

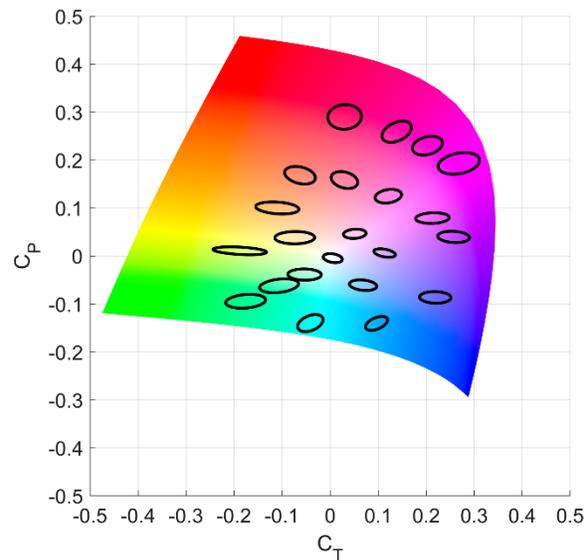for comparison). The results of this calculation are shown in Figure 9. Both the average and maximum JND uniformity are improved with IC_TC_P.
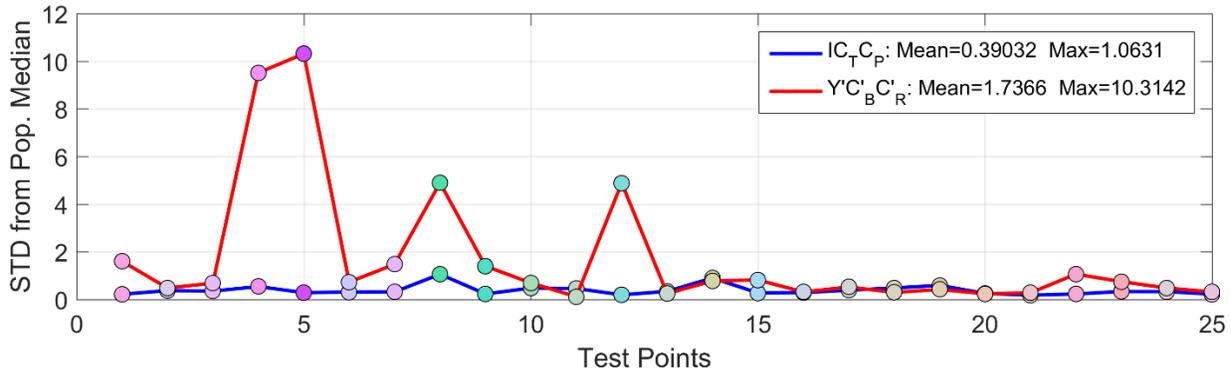

Figure 9: Objective analysis of the uniformity of MacAdam ellipses

Baseband Quantization Performance: A second measure of efficiency is the baseband quantization performance. This is the color rendering performance when a signal is quantized to some number of bits (no data compression involved) which may occur due to encoding efficiency or bandwidth limitations. When imagery is quantized too aggressively, distortions such as contouring, noise boosting, loss of detail, and color shifts may be visible. The efficiency goal is to maintain the highest quality imagery (least visible distortions) while fitting within practical bit depths used for signal interchange.

To analyze the baseband performance of each color representation, a cube of BT.2020 colors at various luminance levels was transformed into each color representation and quantized to 10 and 12 bits. The maximum ΔE2000 [12] color difference was used for analysis. Although it is the current industry standard, it should be noted that ΔE2000 is not reliable below 1 cd/m^2 and has not been verified above 100 cd/m^2.

The 10 and 12 bit results can be seen in Figure 10. A ΔE2000 below 1.0 is below visual threshold. Below this level, quantization distortions should not be visible. A ΔE2000 of 3.0 is the

Digital Cinema Initiatives (DCI) commercial cinema theater white point tolerance specification [13] and may be referenced as a practical commercial tolerance criteria.

The maximum color deviation in 10 bit $Y'C'_BC'_R$ is above theater tolerance at every luminance level. Therefore, with some imagery, quantization distortions such as banding and contouring will be visible. Increasing to 12 bit precision is necessary to decrease these distortions.
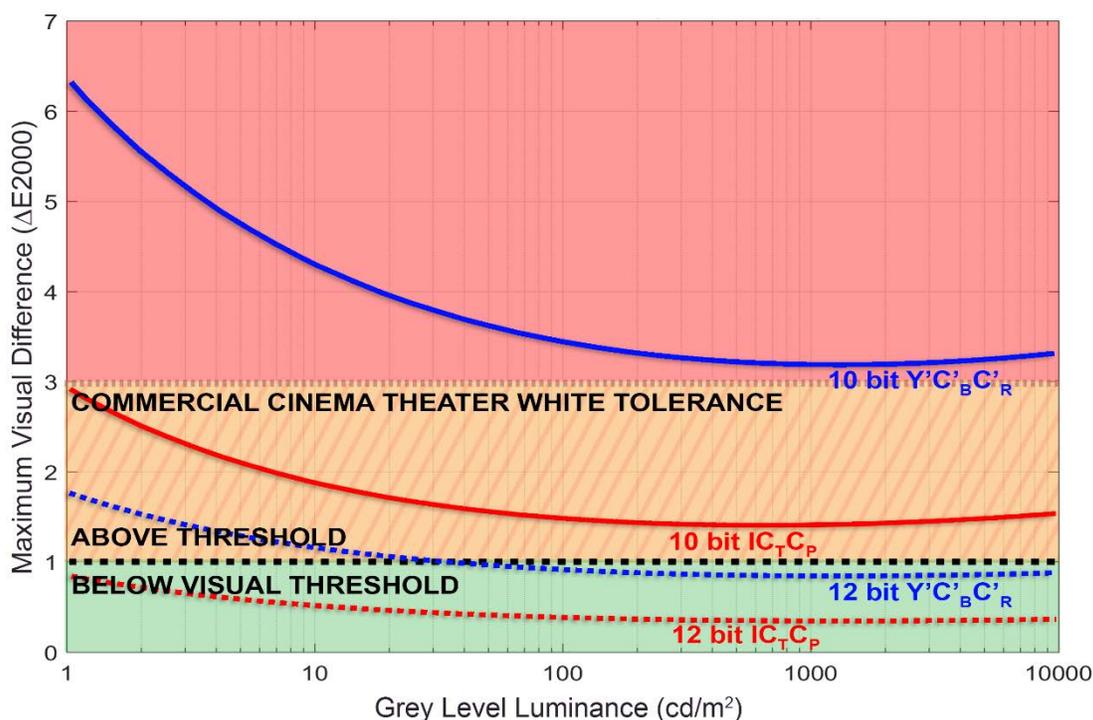
Figure 10: Baseband quantization comparison at 10 and 12 bits

10 bit IC_TC_P lies below DCI theater tolerance at every point. This means that 10 bit IC_TC_P will have less color quantization error than 10 bit $Y'C'_BC'_R$. Using various theoretical bit depths, it was calculated that 11.5 bits in $Y'C'_BC'_R$ is required for the same color performance as 10 bits in IC_TC_P. If 12 bit precision is viable, increasing the IC_TC_P signal to 12 bits brings every code value step below visual threshold.

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Implementation in Cameras and Displays: IC_TC_P and NCL $Y'C'_BC'_R$ share the same mathematical operations from a camera or to a display. With 10 bit representation, utilizing the entire 10000 cd/m² container, both linear RGB and linear LMS require 26 bit fixed point precision. 10 bit IC_TC_P may require up to 13 bits precision for intermediate non-linear processing. For inverse transforms from 10 bit IC_TC_P imagery, the inverse matrices should have, at minimum, 12 bit fixed point precision.

Below are the conversion steps needed to convert camera linear RGB sensor signals into NCL $Y'C'_BC'_R$ or IC_TC_P and then into display linear RGB. Note that the matrix coefficients are decimal values that differ slightly from the values shown in the "How to Transform" section. The 12 bit precision IC_TC_P transform from BT.2020 should be used in actual implementations.

Camera RGB to Y'C'_BC'_R

RGB to XYZ → XYZ to BT.2020 → PQ EOTF⁻¹ or HLG OETF → R'G'B' to $Y'C'_BC'_R$

$$\left[\begin{pmatrix} \end{pmatrix} \begin{pmatrix} 1.717 & -0.356 & -0.253 \\ -0.667 & 1.616 & 0.016 \\ 0.018 & -0.043 & 0.942 \end{pmatrix} \right] \begin{pmatrix} 0.263 & 0.678 & 0.059 \\ -0.140 & -0.360 & 0.500 \\ 0.500 & -0.460 & -0.040 \end{pmatrix}$$

Camera RGB to IC_TC_P

RGB to XYZ → XYZ to LMS → PQ EOTF⁻¹ or HLG OETF → L'M'S' to IC_TC_P

$$\left[\begin{pmatrix} \end{pmatrix} \begin{pmatrix} 0.359 & 0.696 & -0.036 \\ -0.192 & 1.100 & 0.075 \\ 0.007 & 0.075 & 0.843 \end{pmatrix} \right] \begin{pmatrix} 0.5 & 0.5 & 0 \\ 1.614 & -3.323 & 1.710 \\ 4.378 & -4.246 & -0.135 \end{pmatrix}$$

$Y'C'_BC'_R$ to Display RGB

$Y'C'_BC'_R$ to R'G'B' → PQ EOTF or HLG OETF⁻¹ → BT.2020 to XYZ → XYZ to RGB

$$\begin{pmatrix} 1 & 0 & 1.47 \\ 1 & -0.165 & -0.571 \\ 1 & 1.88 & 0 \end{pmatrix} \left[\begin{pmatrix} 0.637 & 0.145 & 0.169 \\ 0.263 & 0.678 & 0.059 \\ 0 & 0.028 & 1.061 \end{pmatrix} \begin{pmatrix} \end{pmatrix} \right]$$

IC_TC_P to Display RGB

IC_TC_P to L'M'S' → PQ EOTF or HLG OETF⁻¹ → LMS to XYZ → XYZ to RGB

$$\begin{pmatrix} 1 & 0.009 & 0.111 \\ 1 & -0.009 & -0.111 \\ 1 & 0.56 & -0.321 \end{pmatrix} \left[\begin{pmatrix} 2.071 & -1.327 & 0.207 \\ 0.365 & 0.681 & -0.045 \\ -0.049 & -0.050 & 1.188 \end{pmatrix} \begin{pmatrix} \end{pmatrix} \right]$$

COMPARISON OF HDR CONSTANT LUMINANCE $Y'_cC'_{BC}C'_{RC}$ AND IC_TC_P

Constant Luminance (CL) $Y'_cC'_{BC}C'_{RC}$ was defined in ITU-R BT.2020. Although it was not widely adopted due to increased computational complexity compared with NCL $Y'C'_BC'_R$, the improved performance (especially in chroma-subsampling) is acknowledged. For comparison with HDR and WCG signals, CL $Y'_cC'_{BC}C'_{RC}$ will be analyzed using the PQ non-linearity (coefficients have been re-optimized for PQ). IC_TC_P shares the same constant luminance properties as CL $Y'_cC'_{BC}C'_{RC}$, so color qualities will be analyzed here.

Hue Linearity: The Hung and Berns hue linearity data from Figure 4, including analysis in HDR CL $Y'_cC'_{BC}C'_{RC}$, is given in Figure 11. Although the maximum deviation is decreased compared to NCL $Y'C'_BC'_R$, the deviation is re-distributed to the critical skin tone region.
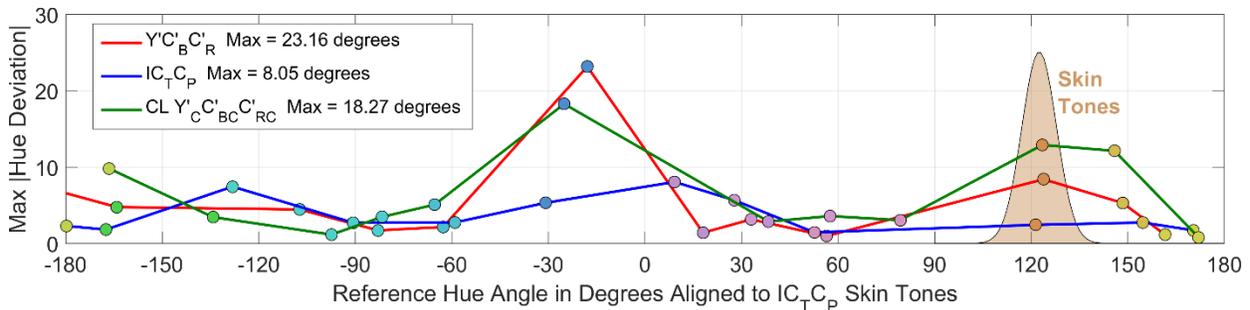

Figure 11: Hung and Berns maximum hue angle deviation comparison

MacAdam JND Uniformity: The JND uniformity plot was re-analyzed in HDR CL $Y'_cC'_{BC}C'_{RC}$. The resulting plot is shown in Figure 12. Although the magenta region of the representation has improved uniformity, the large non-uniform regions still exist.
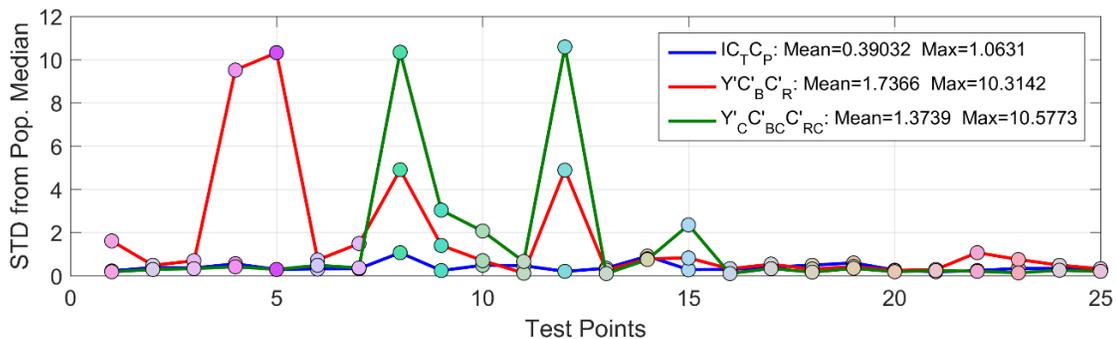

Figure 12: MacAdam JND uniformity comparison

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CONCLUSION

The range of display technologies, from various color primaries to increasing dynamic range, is creating a marketplace where color management is becoming increasingly important if artistic intent is to be maintained. In many applications, traditional color transformations may not be possible due to limitations in bandwidth, speed, or processing power. In these cases, image processing must be performed on the incoming signal. With growing color volumes and the increasing need for color processing, distortions created by the baseband quantization performance and the non-uniformity of NCL $Y'C'_BC'_R$ are increasing.

IC_TC_P is a more perceptually uniform color representation that is based on the human visual system. The improved decorrelation of saturation, hue, and intensity make IC_TC_P ideal for the entire imaging chain from scene to screen. IC_TC_P improves color accuracy with fewer bits, has been designed with the same operations as NCL $Y'C'_BC'_R$, and can serve as a drop-in replacement. The perceptually uniform design of IC_TC_P allows for complex tasks such as gamut mapping to be easily performed with minimal error.

The industry is making a large change to implement wider color primaries, high dynamic range non-linearity curves, and increased bit depth. With the improving technology and revamping of systems to meet these standards, this is the ideal time to also transition to an improved color representation, forming an over-arching next generation solution.

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