Colorimetric Processing of Digital Colour Image!

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Abstract— Today, advancement in microelectronic technologies, high definition displays (HD), high quality digital imaging systems redefining our world of vision. Microsoft and HP developed sRGB colour space which covers approximately 35% of CIE colour gamut to communicate well via different displays, digital imaging systems, internet etc. Subsequently ColourMatch RGB, Adobe RGB, Apple RGB, wide gamut RGBs etc. had evolved to meet technical and professional need. Commonly used imaging systems use a three band colour encoding scheme or triplets to represent human visual system. The Red Green Blue (RGB) response highly dependent on the optical filters or sensors characteristics, lighting environment and many a parameters of image capturing devices. Until now their device independent standardization, theoretical conversion error, colorimetric characterization by empirical modelling, validations and most importantly reproducibility provide only mediocre colorimetric accuracy. How safe we are in processing a RGB image or a grey scale in digital domain! We discuss here the fundamental implications.

Keywords— Colorspace, Tristimulus value , Color calibration, grey scale image, sRGB, Adobe RGB, Apple RGB, wide gamut RGBs, CIE chromaticity diagram
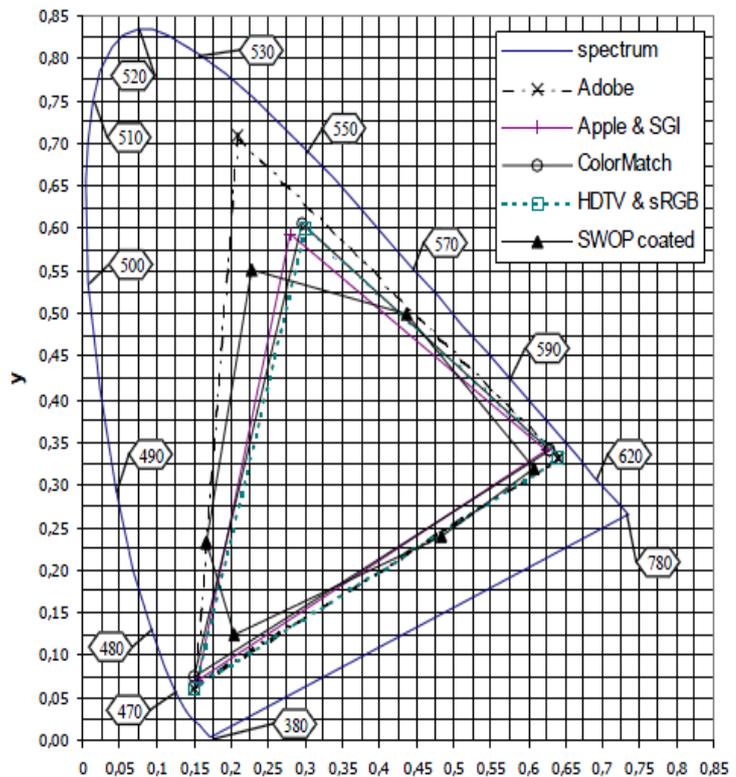
I.   Introduction :

Digital imaging is becoming indispensible tool for their quicker performance, large data storage, media commutation, displays, real time visualization, rendering and so on. Added features with gradually falling cost, near real-time applications, assure their bright futures. However their development direction focusing on getting visually pleasing photograph rather than reasonably accurate colorimetric image . Sensors, only is a part of imaging system, needs controlled illuminant and reference for calibration. The four major concerns of these triplets RGB sensors: white balance, metameric samples, non-visible (IR) light and different colour spaces. Toughest one is irrelevant profiling or white balancing of   surface spectral reflectance under spatially varying illumination. What sets an observer's white point even at its initial stage of RAW processing is unclear in most of the cameras! The other issue is the colour coordinates defined by the spectral sensitivity functions of the sensors do not correspond exactly to the standardized colour space.

The first comprehensive treatise of colour measurement and principles of applications became available in 1936 [1]. The surface reflection properties of materials is one of the most important parameter in identification , qualitative and quantitative analysis of textiles, paints, polymers , pharmaceuticals, agro-chemicals, plastics, and paper and so on . The non-invasive determination of optical absorption and scattering properties of materials is much challenging area in current imaging domain even in number of medical applications of light, e.g. Photo dynamic therapy (PDT or Laser Surgery), calculation of concentration of certain exogenous and endogenous chomophores. Their potential applications has been extended to: medical imaging[2-7], forensics[8,10]), soil science and ecology[10-23], food science[24-26], and detection of skin, face[27-29],textiles [30], fire propagation [31] and so on, demanding extremely reproducible experimental and instrumental conditions.   Study of image capturing device's metric performances (system spatial uniformity and frequency response, tone reproduction, colour reproduction accuracy, noise, colour-channel registration etc.) and colour space limitations are the fundamental requirements before concluding that it will be capable of precise measurement. Even if we set a reference imaging parameters and ensure their repeatability and robustness, we are prone to errors in computation of extrapolation and interpolations of different colour spaces. Fig.1 shows typical imaging parameters a RAW format of Canon DSLR cameras. They produce different sRGB values at pixel levels significantly when we change internal parameters.   Various color spaces have been evolved to meet application needs. Table 1. summarises the applicability and pros and cons of different colour spaces .

[Fig.1 A typical imaging parameters in RAW file Format of Canon DSLR cameras]

[Fig.2 CIE Chromaticity Diagram and colour Spaces (*Bable*)]

sRGB standard approximately have 35% coverage in CIExy space [32]. As large numbers are being clipped at the edges of their gamut corresponds to densely packed, gamma compressed colours (Danny pascale [32,33], their conversion can lead to noticeable errors at clinging points . "It is highly unlikely that there will ever be a "standard" source RGB space" Sabine [34]. This needs domain knowledge and knows how. Gamma in display is again a debatable subject to correct the RGBs.

Table 1. Summary the applicability and pros and cons of different colour spaces.

Colour space	Colour mixing	Primary parameters	Used for	Pros and cons
RGB	Additive	Red, Green, Blue		Easy but wasting bandwidth
CMYK	Subtractive	Cyan, Magenta, Yellow, Black	Printer	Works in pigment mixing
YCbCr YPbPr	additive	Y(luminance), Cb(blue chroma), Cr(red chroma)	Video encoding, digital camera	Bandwidth efficient
YUV	additive	Y(luminance), U(blue chroma), V(red chroma)	Video encoding for NTSC, PAL, SECAM	Bandwidth efficient
YIQ	additive	Y(luminance), I(rotated from U), Q(rotated from V)	Video encoding for NTSC	Bandwidth efficient

The entire algorithm we use to detect pattern or colour analysis or feature extraction etc. dependent of these triplet responses or RGB values. Gray scaling is being extensively used but they do derived from these triplets. A greyscale image is also called a gray-scale, gray scale, or gray-level image. Rgb2gray in MATLAB converts RGB values to greyscale values by forming a weighted sum of the *R*, *G*, and *B* components:

0.2989 * R + 0.5870 * G + 0.1140 * B the same weights used by the rgb2ntsc function to compute the *Y* component.

In the NTSC colour space, the luminance is the grayscale signal used to display pictures on monochrome (black and white) televisions. The other components carry the hue and saturation information. Luminance (*Y*) and chrominance (*I* and *Q*) colour components as columns that are equivalent to the colours in the RGB colourmap.

rgb2ntsc [MATLAB] defines the NTSC components using

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.274 & -0.322 \\ 0.211 & -0.523 & 0.312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

II . Experimental:

We choose two images fig.3. , a] a typical fabric image and b] a natural scene image with respective CIE chromaticity diagram.
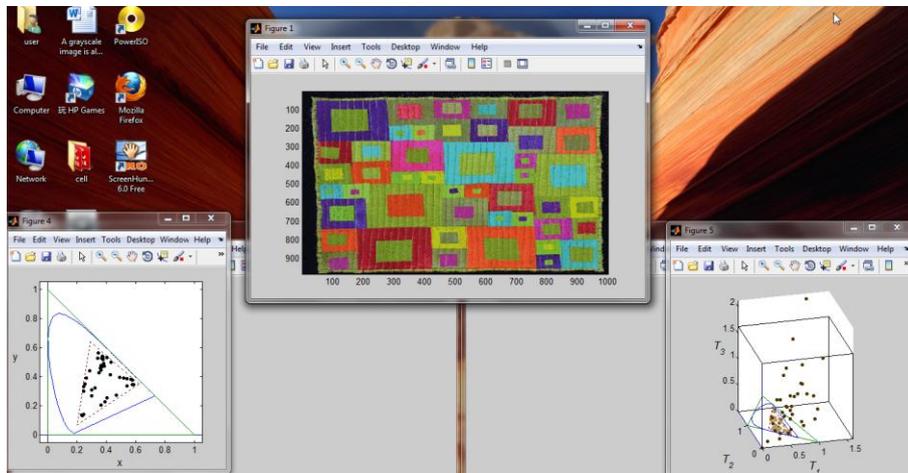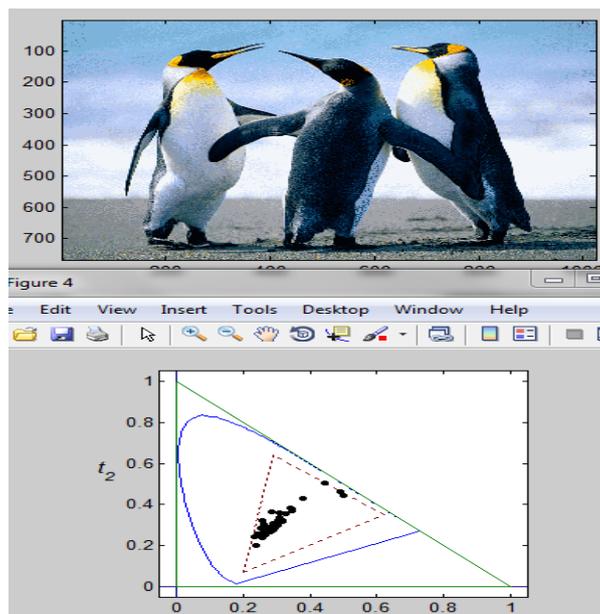

Fig.3 a] Typical coloured textile image in CIE chromaticity space

3   b] A natural image in CIE chromaticity space

III . Results And Discussion:

The colour gamut of different RGBs colorspace in CIE chromaticity diagram is shown in Fig.2 gives idea of error implication on precision colour conversion to colorimetric data. From experimental images (fig.3) we can able to understand that those points clinging to the sRGB boundaries will be giving bad CIE colour conversation results than

inner points. Here we propose to the researchers to verify their colour gamut before moving forward for colour conversations and their limitations. It is noteworthy to show the results of X-rite 140 SG colour checker results in IMTEST imaging analysis (fig. 4)
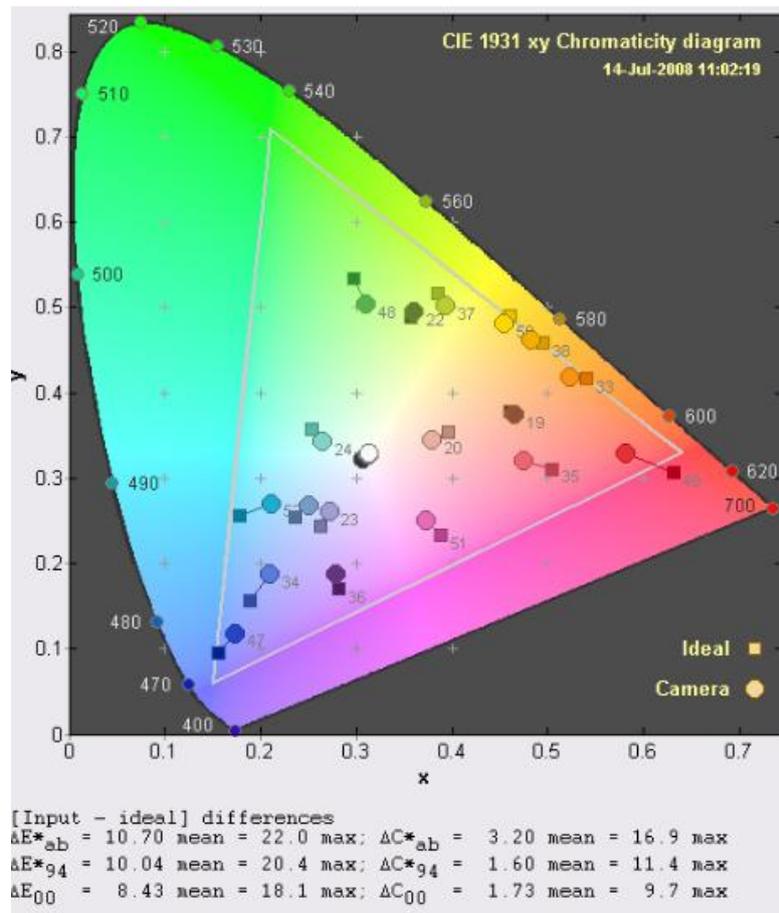
[Fig. 4 X-rite 140 SG colour checker results in IMTEST imaging analysis (www.stillephotographie.at)]

IV. Conclusion:

The physical CIE measurements are much more specific and accurate in colour difference (+-0.05DE) and they are being performed under precise geometry of viewing with a standard illuminant and observer condition. It is pity that most of the image processing researchers who are using RGB2Lab or any colour space transformation are neither aware of the kind of RGBs they are converting to which specific CIELABs and under which specific illuminant and observer as per the reference of ASTM. History and condition of image capturing should be investigated before processing a colour image. Secondly, how useful is it for solving a specific problem from device dependent to device independent CIE conversation and profiling! Because every material, its texture, colour, surface roughness has a unique property of absorption transmission and reflection over specific wavelength of light and we are correlating only the tristimulus responses to map perpetual uniform CIEL*a*b* colour space ignoring it's complex reflectance profile. Also many a cases of colour calibration and profiling, the actual spectral measurements are being avoided by inappropriate references those are derived in specific conditions and assumptions. We urge researchers to verify their device metrics and colour gamut before moving forward for colour conversations along with their limitations over colour space. Broader colour space such as Photo Pro- RGB, RAW imaging data now being explored much that accommodate more colours precisely. May be in that case they can use statistical colour difference in their own digital domain without the colour space transformation. It may be recommended to use broader colour gamut like wide RGB, pro-proto etc, compromising with data storage, for quality evaluations.

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