# Beyond Simple Additivity: A Two-Step Parametric Model for Digital Displays

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## Abstract

*Simple additivity is often used as basic model for digital display characterization. However, such a simple model cannot all the time satisfy the needs of demanding color management applications.*

*This paper presents an enhanced method to characterize the XYZ to RGB transform of a digital display. This parametric method exploits the independence between the luminance variation of the electro-optic response and the colorimetric responses for certain display types.*

*3-DMD projectors are the reference for high grade color management. However, the model is more generally applicable to Digital Displays (and not only projectors), including Single DMDs, CRTs, LCDs, etc, if the independence condition is satisfied.*

*While the problem to solve is a 3D to 3D transformation (from XYZ to RGB), the proposed parametric model is the composition of a 2D transform followed by a 1D transform. The 2D transform manages the chromatic aspects and, in succession, the 1D transform manages the Luminance variations.*

*This parametric digital model is applicable in the field of Color Management, with the objective to calibrate Digital Displays and apply a reference look such as a film look.*

## Introduction

### *Application context*

In cinematographic post-production, digital processing of images - called Digital Intermediates (DI) – replaces more and more (and in some contexts *has* replaced) the traditional film workflow. Digital post-production requires the preview of DIs with a reproduction of colors, dynamics and resolution comparable to the final film projection [1].

To reproduce colors on Digital Displays, the simple additivity [1] model has revealed its limits and more elaborated models need to be developed to satisfy the application requirements in term of color quality. This paper presents a parametric model, based on display physics, and compares it to the simple linear model (3x3 matrix) [2][3] as well as to a more complex non-linear model (Splines and Tetrahedral) [3][4] for different display configurations.

### *Technical problems to solve*

The technical problem to be solved is to find a reliable transform between the digital domain (e.g. *RGB* Values) and the visual domain (e.g. *XYZ* [2] Values) for an entire color space. Typically when *R*, *G* and *B* have a dynamic of $n = 8, 10$ or $12$ bits, a correspondence must be found between *RGBs* and *XYZs* for $N = (2^n)^3$ triplets (*N* is over $10^9$ for $n = 10$ bits).

For each candidate *XYZ,* the corresponding *RGB* must be estimated. This *RGB* values used as input to the Digital Display shall generate the required *XYZ* color with a sufficient accuracy for the application.

The problem to solve is to find a parametric model, which from *(RGB-XYZ)* measurements on a restricted set of colors will allow to efficiently compute a *RGB* triplet for each *XYZ* candidate.

### *Goal of the Parametric Digital Model*

The goal of a characterization model is to approximate a color transform between the input and the output of a visualization device. In this discussion we use the *RGB* and the *XYZ* color spaces. *RGB* is the device input signal space and *XYZ* is the CIE1931 standard observer *2°* color space. The transform addressed is the *XYZ* to *RGB* transform, sometimes named "inverse transform". This inverse transform is the one used to map a look (for example a film look) onto a characterized display.

The presented parametric digital model applies to Digital Displays where some assumptions can be made about the way colors are generated (see section *Context of Applicability*).

The main advantage of the model is the ability to decompose a 3D problem into a 2D + 1D transform. The model would be simpler to implement and faster to compute for the same precision. Another advantage is the reduction of the characterization data set to be measured, therefore reducing the measurement time.

### *Main ideas*

While in essence the characterization color transforms map an input 3D space into an output 3D space, the developed parametric model exploits knowledge on the Digital Displays.

Most Digital Displays are composed of two groups of components for the visual signal generation:

- Light intensity management components
- Color management components

[1] Simple additivity: adding up weighted light contributions of color primaries

[2] XYZ: CIE1931 standard observer tristimulus coordinates

The following table gives a view of what these components are for various displays:

| Display type | Light Intensity | Color Management |
|---|---|---|
| 3-DMD[3] Digital Projector | DMD On and Off states modulation | Lamp spectrum + Color filters on each path + Optics transmission+ Screen response |
| Single Chip Projector | DMD On and Off states modulation | Lamp spectrum, Color Wheel + Optics transmission+ Screen response |
| CRT | Electronic beam power modulation | Phosphors response |
| LCD | Liquid Crystal modulation | Pixilated color filters |
| PLASMA | Sub-fields addressing | Phosphors response |

***Table 1.*** *Display types*

The proposed model is based on the observation that, physically, the chromatic response (and thus, also the spectral repartition) is independent from the light intensity level.

The main idea of the model is to exploit these physical characteristics to modify a 3D to 3D problem into first a 2D transform followed by a 1D transform. The 2D transform will manage the Chromatic aspects and, in succession, the 1D transform will manage the Luminance variations.

## *Context of applicability*

The Chromaticity / Luminance independence hypothesis is only valid for reasonable quality displays with a controlled setup. It is sometimes required to disable some disturbing signal processing features to reach this situation.

For example: For a Single-DMD projector at a given white level, the spectral response is determined by the lamp and its spectrum, the color wheel, the optics transmission and the screen characteristics. It does not depend on the DMD modulation. However, the possibility of using a white segment in the color wheel must be disabled to reach a controlled colorimetric situation.

Specific features of some displays will prevent or disturb the use of the presented model.

Here are some examples:

| Display type / Feature | Cause of non-applicability |
|---|---|
| PLASMA / Automatic Power Limitation | For bright images, a Plasma display will moderate its output luminous power for electrical consumption reasons. The model will be applicable only below this "electrical protection" level. |
| LCD / Double Modulation | The double modulation is first by the backlight and second by the liquid crystal (for example for 'dynamic black' or HDR[4]). This modifies the electro-optic response curve of the display, temporally and sometimes locally. |
| Single DMD / White peaking | Some Single DMD displays include a white segment in their color wheel for luminous output increase. This segment is managed internally as a fourth color channel, mixing up color proportions. This feature should be disabled to use the model |

***Table 2.*** *Applicability*

[3] DMD: Digital Micro-mirror Device, a Texas Instrument technology.

[4] HDR: High Dynamic Range

## Model Description

The model description will start with a paragraph defining the color data set measured to characterize the display (section *Characterization data set*), then some notations and normalizations are defined (section *Notations and normalizations*) and then the proposed 2D and 1D transforms are derived (section *Inverse transform: XYZ to RGB*).

## *Characterization data set*

A set of color measures is necessary to characterize a projector. These measures give the *RGB-XYZ* correspondence for a restricted number of *RGB* triplets. The model controls the generalization of this data set to the entire input color space.

The data set has a part of the measures used for determining the 2D transform and a part for the 1D transform.

The measurement data set so includes two subsets:

- The "L" data subset: a grey ramp for the luminance variation characterization
- The "C" data subset: samples on three color planes for colorimetry characterization

The "L" data subset covers the whole range of luminance variations, while the "C" data subset covers the whole range of color variations. Figure 1 represents this data set. The black dashed line is the "L" data subset and the three colored planes are the "C" data subset.

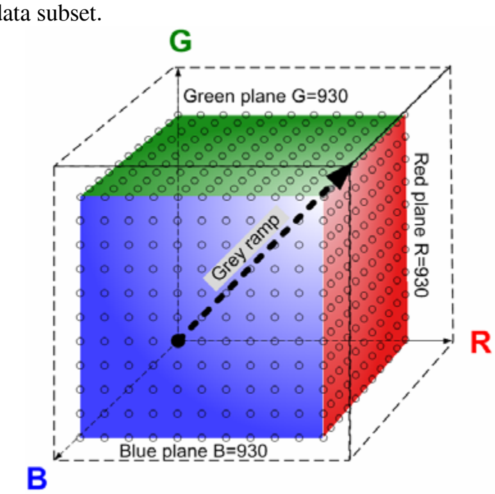


***Figure 1.*** *Characterization data set*

For the model testing, a specific data set has been defined: RGB varying from 0 to 1023 in the application context, its characteristics are the following:

The luminance "L" data subset is a uniform grey ramp from 0 to 1023 with step 11.

The chromaticity "C" subset is composed of 3 planes in the *RGB* cube defined by:

$$"C" \text{ subset} = \begin{cases} \text{Sampling of plane } R = REF \\ \text{Sampling of plane } G = REF \\ \text{Sampling of plane } B = REF \end{cases}$$

*REF=930* was chosen and the sampling of planes *R, G* and *B* is uniform with step *93* (*11x11* samples). Double points and the triple point are pruned.

## Notations and normalizations

The first point is to guarantee the correct data exploitation. Most particularly, to cancel light leakage effect at low levels, the black $XYZ_{black}$ level (corresponding to input $R=G=B=0$) is subtracted to all *XYZ* measures.

This done, the above hypothesis of independent light intensity variation / color variation can be expressed by using a normalized representation for *RGB* on one side and for *XYZ* on the other side. While various choices are possible, the following have been made in the context of the *XYZ* to *RGB* transform model.

<u>*XYZ* normalization:</u>

*S*, *x* and *y* are defined as:

$$S = X + Y + Z \quad x = \frac{X}{S} \quad y = \frac{Y}{S}$$

A *XYZ* triplet can univocally be represented by the triplet (*x, y, S*). *x* and *y* are the same as the CIE 1931 *x* and *y* chromaticity coordinates.

<u>*RGB* normalization:</u>

*Σ, r* and *g* are defined as:

$$\Sigma = R + G + B \quad r = \frac{R}{\Sigma} \quad g = \frac{G}{\Sigma}$$

A *RGB* triplet can univocally be represented by the triplet (*r, g, Σ*).

The light intensity vs color independence hypothesis can be expressed by:

1. *(r, g)* depend only on *(x, y)*, independently of *S* and *Σ*.

Or, said another way, a given *(x, y)* color has a stable proportion of *R, G* and *B* for every value of *S*.

2. For a given *(x, y), Σ* depends only on *S*.

## Inverse transform: XYZ to RGB

While both the forward - *RGB* to *XYZ* – and the inverse - *XYZ* to *RGB* – transforms are of interest to characterize a display, the inverse transform is of higher importance when we want to render accurately specific colors on the considered display. This inverse transform is often combined with, in example, a forward film emulation transform to create a film look on the target display. The inverse transform - *XYZ* to *RGB* - is used to predict what *RGB* input is required to generate a given *XYZ* color on the screen.

The following paragraphs describe first the colorimetric computation (section 2D transform) and then the luminance computation (section 1D transform).

### *Colorimetric computation / 2D transform*

The goal of the *XYZ* to *RGB* transform is to determine a $(RGB)_{out}$ output triplet corresponding to a $(XYZ)_{in}$ input triplet.

In the *XYZ* to *RGB* transform, an input *XYZ* triplet is first normalized into the corresponding (*x, y, S*) triplet. After *XYZ* normalization, the measured data set provides a collection of sextuplets: *(x, y, S, R, G, B)*.

The 2D transform is in two steps:

- **First step**: Building a 2D mesh
- **Second step**: Interpolating in this mesh

The <u>**first step**</u> of the processing is to build a 2D mesh in the *(x, y)* plane, entirely paving the useful part of this space with triangles. The vertices of these triangles are the measured points (of the "C" data set) identified by their *x* and *y* coordinates.

This mesh is stored as reference during the characterization phase. Each node of the mesh stores four elements: $S=X+Y+Z$ value and the corresponding *R, G* and *B* values from the characterization data set.

Figure 2 represents such mesh: each *(x,y)* point stores the corresponding *(SRGB)* data measured and acquired for the "C" data set.

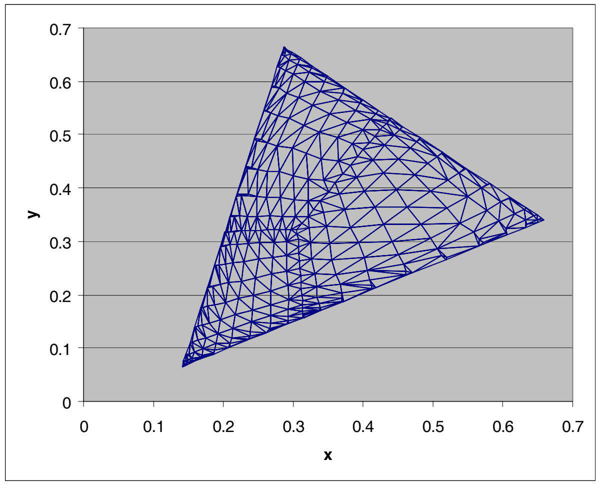


***Figure 2.*** *2D mesh in the (x,y) plane. Each vertex stores (SRGB) information.*

The <u>**second step**</u> consists in interpolating *S, R, G* and *B* for an input $(XYZ)_{in}$.

From the above reference mesh, a $(SRGB)_{REF}$ quadruplet can be interpolated for each input $(XYZ)_{in}$ triplet:

- For this, first $x_{in}$ and $y_{in}$ are computed from $(XYZ)_{in}$.
- Then the triangle containing this $(x_{in}, y_{in})$ point is found in the reference mesh.
- Thirdly, the $S_{REF}$, $R_{REF}$, $G_{REF}$ and $B_{REF}$ values for this point are interpolated from the values stored at the vertices of the found triangle.

The interpolation in the mesh triangles is basically a "flat" (or linear) interpolation implemented using as weighting factors the surface of the sub-triangles created by the insertion of the input point.

**The $(SRGB)_{REF}$ quadruplet is the output of the 2D transform.**

This quadruplet represents the color point belonging to one of the three "reference" planes and having the same *(x, y)* coordinates as the $(XYZ)_{in}$ input color.

Below Figure 3 shows an example of such interpolation for the *G* component:

The white lines indicate the color gamut. The red, green and blue circles are respectively the R, G and B points in the "reference" planes.

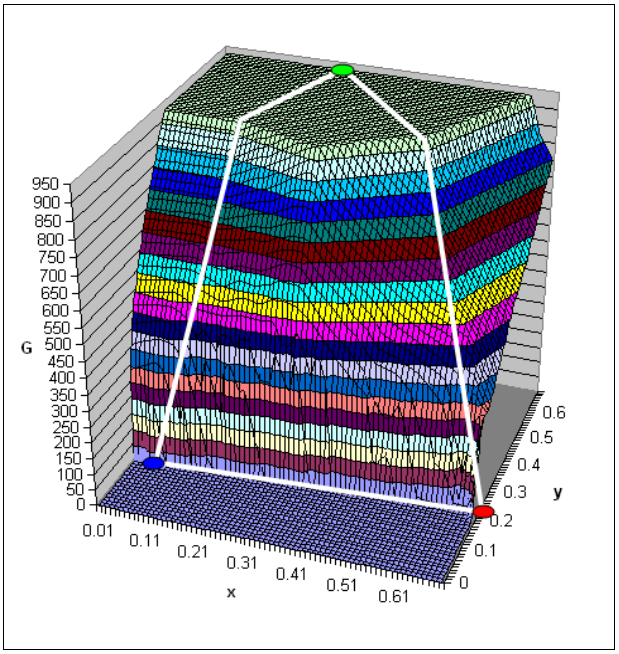


***Figure 3.*** *G component interpolation (3D view)*

### *Luminance computation / 1D transform*

**Position of the problem:**

We are looking for the color point $(RGB)_{out}$ corresponding to $(XYZ)_{in}$.

The above 2D transform allows to determine a point $(RGB)_{REF}$ of the $RGB$ cube giving a visual color of $(x_{in}, y_{in})$ chromaticity identical to the $(XYZ)_{in}$ input point.

For this $(RGB)_{REF}$ point the $S_{REF} = X_{REF} + Y_{REF} + Z_{REF}$ value is known as interpolated by the 2D transform process.

As stated above, the colorimetry independence with regard to luminance implies that all colors sharing the same $(x,y)$ have the same proportions of $R$, $G$ and $B$ in their composition.

$(RGB)_{REF}$ and $(RGB)_{out}$ share the same $(x_{in}, y_{in})$ coordinates and consequently have the same proportions of $R$, $G$ and $B$.

In other words, $(RGB)_{out}$ and $(RGB)_{REF}$ are linked by a multiplicative factor:

$$(RGB)_{out} = k \cdot (RGB)_{REF} \quad \Leftrightarrow \quad \begin{cases} R_{out} = k \cdot R_{REF} \\ G_{out} = k \cdot G_{REF} \\ B_{out} = k \cdot B_{REF} \end{cases}$$

As $(RGB)_{out}$ corresponds to $(x_{in}, y_{in}, S_{in})$ and $(RGB)_{REF}$ corresponds to $(x_{in}, y_{in}, S_{REF})$, the factor $k$ only depends on $S_{in}$ and $S_{REF}$.

It is this luminance dependence we want to determine in the following paragraph.

**Luminance dependence:**

The curves on Figure 4 represent the response to a Red, Green, Blue and White ramp on a Digital Projector.

- The horizontal axis is $S=X+Y+Z$ in Cd/m² (or nits).
- The vertical axis is $\Sigma = R+G+B$.

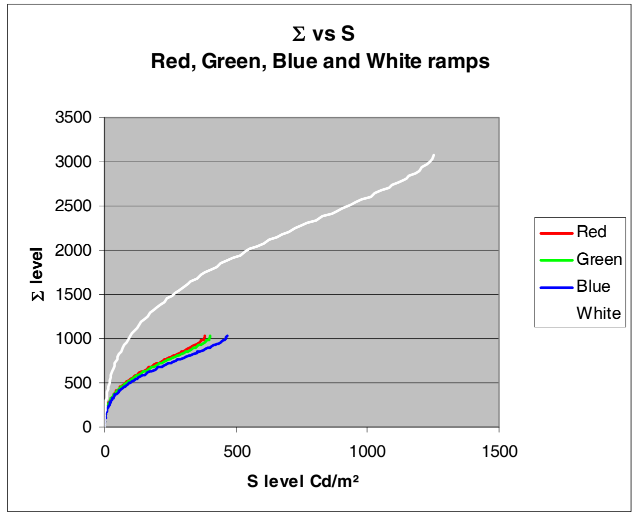


***Figure 4.*** *Sum of RGB vs. sum of XYZ for Red, Green, Blue and White ramps*

Similar curves are obtained for other input color ramps with constant $RGB$ proportions.

The principles of independence between light intensity and color explained in the above paragraph can be verified on this example by normalizing these curves by their values at a given level. This level can be the maximum of $\Sigma$, or preferably a proportion of this maximum to avoid saturation problems. Practically we are using $(Max(\Sigma).930)/1023$ in order to have the same reference level as in the mesh construction above.

Normalizing consists in computing for each curve:

$$\Sigma_{REF} = (Max(\Sigma).930)/1023 \qquad \Sigma_n = \frac{\Sigma}{\Sigma_{REF}} \qquad S_n = \frac{S}{S_{REF}}$$

Where $S_{REF}$ is the $S$ level corresponding to $\Sigma_{REF}$

Normalization gives the following curves:

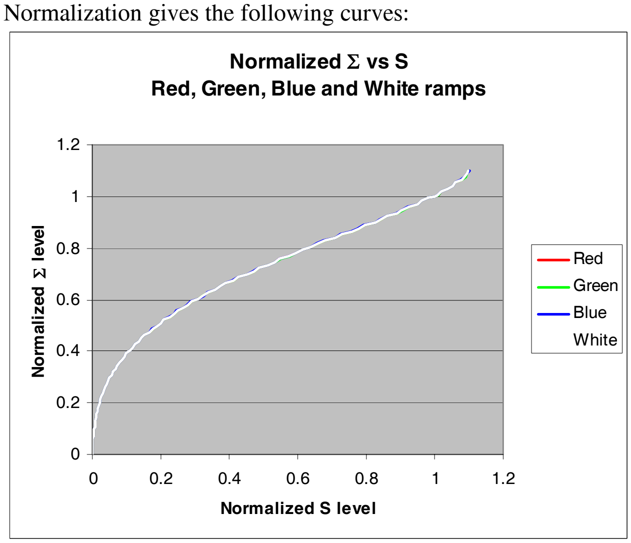


***Figure 5.*** *Normalized $\Sigma$ vs S curves*

These curves are superimposed as predicted in the model.

From this, a common 1D transform can be identified linking normalized $\Sigma$ (i.e. $\Sigma_n$) to normalized $S$ (i.e. $S_n$).

Naming $f$ the function representing this common 1D transform, we have:

$$\Sigma_n = f(S_n)$$

This 1D transform can be represented by a number of measurement points with a linear or higher order interpolation, or by a mathematical function representing this curve.

***RGB**$_{out}$* **computation:**

The input sum $S_{in}$ and the quadruplet $(S_{REF}, R_{REF}, G_{REF}, B_{REF})$ resulting from the 2D transform are exploited to find the $RGB_{out}$ triplet corresponding to the $XYZ_{in}$ input point.

First a normalized $S_n$ value is computed by dividing $S_{in}$ by $S_{REF}$:

$$S_n = \frac{S_{in}}{S_{REF}} .$$

Secondly, $\Sigma_{out} = R_{out}+G_{out}+B_{out}$ is computed using the 1D transform:

$$\Sigma_{out} = f(S_n) ,$$

$\Sigma_{REF} = R_{REF}+G_{REF}+B_{REF}$ is evaluated from the quadruplet.

Finally, $R_{out}$, $G_{out}$, and $B_{out}$ are computed by:

$$R_{out} = \frac{R_{REF}.\Sigma_{out}}{\Sigma_{REF}} \qquad G_{out} = \frac{G_{REF}.\Sigma_{out}}{\Sigma_{REF}} \qquad B_{out} = \frac{B_{REF}.\Sigma_{out}}{\Sigma_{REF}}$$

**$RGB_{out}$ is the output of the model corresponding to the $XYZ_{in}$ input point.**

# Results

## Instrumentation and Measures

Measurements have been performed using an automated application specifically developed for projectors and direct view displays characterization.

Using X-RITE / Gretag-Macbeth's Eye-One Probe as a measurement device, this application can automatically measure characterization and verification datasets of several hundreds of values, and apply the parametric characterization model and the verification procedures.

## Verification method and error indicators

The verification "V" data subset is composed of a 5x5x5 uniform sampling of the *RGB* cube. With 10 bit dynamic, *R*, *G* and *B* take all combinations of the five following values:

{104, 312, 520, 728, 936}.

Verification consists in measuring the actual *XYZ* of each $RGB_{in}$ triplet of the "V" data subset. Therefore, we have a list of 125 triplet pairs:

$\{RGB_{in} \rightarrow XYZ_{meas}\}$

With the parametric model, we can estimate *RGB* for each measured $XYZ_{meas}$. We so have a wider correspondence list:

$\{RGB_{in} \rightarrow XYZ_{meas} \rightarrow RGB_{est}\}$

From this list, we can compute an *RGB* error between the corresponding *RGB* input and *RGB* estimate:

$\{RGB_{error} = dist^5(\mathrm{RGB_{in}} - \mathrm{RGB_{est}})\}$

A global error $\Delta_{RGB\%}$ can be computed by taking the average of these relative *RGB* errors over the entire verification data set (*N=125* measures):

$$\Delta_{RGB\%} = \frac{1}{Max(RGB)} \frac{1}{N} \sum_{i=1}^{N} RGB^i_{error} \quad {}^6$$

However, as the *RGB* color space is far from being uniform in terms of color difference visibility, we prefer to evaluate also the error in the visual domain. For this we use the CIE1976 *L*a*b** color space that is meant to be more uniform. So, the estimated *RGB* list is measured and we obtain a four triplets list of the form:

$\{RGB_{in} \rightarrow XYZ_{meas} \rightarrow RGB_{est} \rightarrow XYZ_{est}\}$

We can then compute an *XYZ* error between the initial *XYZ* measure $(XYZ_{meas})$ and the *XYZ* measure of the $RGB_{est}$ estimation $(XYZ_{est})$. For this, respective *L*a*b** colors $Lab_{meas}$ and $Lab_{est}$ are computed from $XYZ_{meas}$ and $XYZ_{est}$ using the standard formulae (recalled in [5]). The global error in this space will be:

$$Avg.\Delta E_{Lab} = \frac{1}{N} \sum_{i=1}^{N} dist\left(Lab^i_{meas} - Lab^i_{est}\right)$$

The model comparison of the next paragraph uses these global measures for each display and each characterization model used. The maximum of $\Delta E_{Lab}$ $(Max.\Delta E_{Lab})$ error over the verification set is given as complementary indicator as well as the 95th percentile value of $\Delta E_{Lab}$ $(95^{th}.\Delta E_{Lab}$ = value below which 95% of errors fall).

## Model comparison

To evaluate the quality of the proposed parametric model, a reference needs to be chosen. It is the purpose of this paper to show that a better quality than a simple linear model (3x3 matrix) and more complex non-linear model (Splines and Tetrahedral) can be achieved. For the simple additive model, the reference chosen is, for example, the IEC 61966 standard [6] proposing to link *RGB* and white normalized *XYZ* (noted *X'Y'Z'*) by a constrained 3x3 matrix:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = S_{3x3} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

where $$S_{3x3} = \begin{pmatrix} x_R/y_R & x_G/y_G & x_B/y_B \\ 1 & 1 & 1 \\ z_R/y_R & z_G/y_G & z_B/y_B \end{pmatrix} \begin{pmatrix} S_R & 0 & 0 \\ 0 & S_G & 0 \\ 0 & 0 & S_B \end{pmatrix}$$

With $S_R$, $S_G$, $S_B$, solution of the equation:

$$\begin{pmatrix} x_R/y_R & x_G/y_G & x_B/y_B \\ 1 & 1 & 1 \\ z_R/y_R & z_G/y_G & z_B/y_B \end{pmatrix} \begin{pmatrix} S_R \\ S_G \\ S_B \end{pmatrix} = \begin{pmatrix} x_W/y_W \\ 1 \\ z_W/y_W \end{pmatrix}$$

This later equation formulates the additivity constraints.

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5 *dist()*: Euclidian distance in each color space.

6 *Max(RGB)* = 1023 for a 10 bit dynamic signal

For the non-linear model, standard 3D lattice-based interpolation technique (thin plate splines and tetrahedral) is used. For the characterization, *R, G, B* values in a regular lattice (7x7x7) are measured to obtain corresponding *X, Y, Z* tristimulus values. Thin plate splines interpolation algorithm is used for the forward mapping (*RGB* to *XYZ*) and a tetrahedral interpolation of the oversampled dataset is used for the inverse mapping (*XYZ* to *RGB*).

Comparison results are shown in the following tables for two target displays: NEC NC800C digital cinema projector and Sony BVM 32" CRT.

The NEC NC800C projector was used with different settings:

- ITU Rec.709 mode
- Cinema mode 1 – DCI P3
- Cinema mode 2 – P7v2 telecine - Secondaries (Cyan, Magenta and Yellow) reinforced

| **NEC NC800C Projector ITU Rec. 709 mode** | | | |
|---|---|---|---|
| Error type | 3x3 linear model | 3D non-linear model | Parametric model |
| *Avg.* $\Delta E_{Lab}$ | 1.39 | 1.04 | 0.86 |
| $95^{th}$. $\Delta E_{Lab}$ | 2.97 | 2.81 | 1.65 |
| *Max.* $\Delta E_{Lab}$ | 3.51 | 4.58 | 2.26 |
| $\Delta_{RGB\%}$ | 1.27% | 2.41% | 1.84% |

| **NEC NC800C Projector Cinema mode 1 – DCI P3 - (SMPTE 431-2)** | | | |
|---|---|---|---|
| Error type | 3x3 linear model | 3D non-linear model | Parametric model |
| *Avg.* $\Delta E_{Lab}$ | 2.44 | 1.27 | 1.16 |
| $95^{th}$. $\Delta E_{Lab}$ | 5.34 | 3.26 | 2.74 |
| *Max.* $\Delta E_{Lab}$ | 6.43 | 5.00 | 6.14 |
| $\Delta_{RGB\%}$ | 5.53% | 3.24% | 3.32% |

| **NEC NC800C Projector Cinema mode 2 – P7v2 telecine - Secondaries reinforced** | | | |
|---|---|---|---|
| Error type | 3x3 linear model | 3D non-linear model | Parametric model |
| *Avg.* $\Delta E_{Lab}$ | 8.32 | 1.47 | 1.00 |
| $95^{th}$. $\Delta E_{Lab}$ | 16.95 | 3.01 | 2.50 |
| *Max.* $\Delta E_{Lab}$ | 19.18 | 5.23 | 3.29 |
| $\Delta_{RGB\%}$ | 7.29% | 3.57% | 3.38% |

| **Sony BVM 32" CRT** | | | |
|---|---|---|---|
| Error type | 3x3 linear model | 3D non-linear model | Parametric model |
| *Avg.* $\Delta E_{Lab}$ | 4.10 | 0.82 | 0.68 |
| $95^{th}$. $\Delta E_{Lab}$ | 6.24 | 2.02 | 1.40 |
| *Max.* $\Delta E_{Lab}$ | 7.16 | 2.95 | 2.58 |
| $\Delta_{RGB\%}$ | 3.69% | 0.89% | 0.78% |

***Table 3.*** *Results*

Results in the above tables show that the proposed two step parametric model can significantly outperform the simple linear model (3x3 matrix) and perform slightly better over the complex non-linear model (splines and tetrahedral). We see most specifically the case of P7v2 telecine mode where non-additive color variations can be correctly estimated by the 2D step of the proposed parametric model.

## References


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[3] R. Bala, *Device Characterization*, Chapter 5 of *Digital Color Imaging Handbook*, edited by G. Sharma, CRC Press, 2003.

[4] W. Xiong and B. Funt, "Nonlinear RGB-to-XYZ mapping for device calibration," *Proc. of the 13th Color Imaging Conference: Color Science, Systems & Applications*, Scottsdale, AZ, pp. 200-204, Nov. 2005.

[5] http://www.brucelindbloom.com/ "Math" page: Useful Color Equations, XYZ to Lab.

[6] IEC International Standards 61966, Part 3, 4, 5, 6 (Colour Measurement and Management of equipment using CRT, LCD panels, PDP and FPD)


## Authors Biography

*Laurent Blondé is graduate engineer of the Institut d'Optique (1985). Hired as a research engineer for THOMSON R &D, he participated in more than a few R&D projects including: Infrared Image Synthesis, Special Effects and Virtual Studio, Display processing, Anti-Camcorder and Color Management for Cinema applications. Supporting both of the Technicolor and Grass Valley businesses, Blondé is currently Technical Advisor. His research interests involve all domains of image processing and synthesis for the media industry.*

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