Color Spaces Analysis For Luminance & Chrominance Signals AS NTSC-TV System

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Abstract

There are many regulations related to television and video broadcast signals in various countries around the world, especially the developed countries in technology and communication systems including the United States, Japan and the two together using (NTSC) system . So this system was chosen in research to analyze the space of colors in which to enables us to know the nature of this system and the possibility to convert to other working systems (PAL, SECAM ,...) to ensure the exchange of information and video signals through systems of the global direct broadcasting and the Internet. The research has included analysis of the colors according to an international standard (International Commission on Illumination), which represents the evolution of Maxwell triangle to the process of mixing colors and thus determine the color space for this system for parameters (I,Q,Y) and calculate the values of quantitative color as well as the value of grayscale according to mathematical equations and illustrations of this, After that simulate those results in the image have been selected for the test to be analyzed according to the matlab program as it has proved assess the pattern of color change correct outcomes of the application in the analysis provided and the color that fits the selected image.

Keywords : color’s system , Commission International (CIE) , National Television System Committee (NTSC).

تحليلات فراغات الألوان لإشارات الإضاءة والتلوين لنظام التلفاز NTSC

الخلاصة

هناك أنظمة كثيرة تخص البث ألتلفازي والإشارات الفديوية العاملة في مختلف دول العالم وبالأخص الدول المتطورة تقنيا في منظومات الاتصالات و منها الولايات المتحدة الأمريكية و اليابان و الاثنان معا تستعمل نظام (NTSC) . لذا في هذا البحث تم اختيار هذا النظام لتحليل فضاء الألوان فيه ليمكننا من معرفة طبيعة عمل هذا النظام وإمكانية تحويله إلى الأنظمة العاملة الأخرى (بال , سيكام ,...) لضمان تبادل المعلومات والإشارات الفديوية عبر منظومات البث العالمي المباشر وشبكة الانترنت. تضمن البحث تحليل الألوان وفق مقياس دولي (معيار لجنة الإضاءة الدولية) الذي يمثل تطور لمثلث ماكسويل لعملية خلط الألوان وبالتالي تحديد الفضاء اللوني الخاص بهذا النظام لمعاملات (I, Q ,Y) و حساب القيم الكمية للألوان الرئيسية وكذلك قيمة التدرج الرمادي وفق المعادلات الرياضية والرسومات الإيضاحية الخاصة بذلك, وبعد ذلك محاكاة تلك النتائج على صورة مختبريه تم اختيارها لتكون الصورة المعنية بالاختبار لتحليلها وفق برنامج الماتلاب

حيث اثبت تقييم تغير نمط الألوان صحة نواتج التطبيق في تحليلات اللون المقدّمة والتي انطبقت على صورة الاختبار المختارة.

List of symbols and abbreviations:

CIE Commission International d’ Éclairage.
CVBS Color Video Baseband Signal.
C_λ Color of wavelength λ.
E(λ) Spectral composition.
FCC Federal Communications Commission.
HSB Hue-Saturation- Brightness.
NTSC National Television System Committee .
RGB Three primary colors Red ,Green and Blue.
QAM Quadrature Amplitude Modulation.
VSB Vestigial Sideband Modulation.
XY Z Tri-incentive spectral colors in CIE system.
YUV Composite color video standards.
YIQ color space is derived from the *YUV* and is optionally used by the NTSC.
YCbCr Offset version of the YUV color space.
Y Luminance

1.Introduction

Light as an electromagnetic radiation at a particular wavelength, depending on the wavelength, light can be visible or invisible to the eye ,it has three primary properties. They include frequency or wavelength, intensity or brightness, and polarization or direction of wave oscillation[1].

Technically, light is carried or transported by photons. Photon is a term used by physicists to define the elementary particle responsible for electromagnetic phenomena. It is the transporter of all wavelengths of electromagnetic radiation including gamma rays, x-rays, ultraviolet light, microwaves, and radio waves. the photon interacts with matter by transferring the amount of energy (E) as follows , $E = h \times c / \lambda$ where h is Planck’s constant($h = 6.626 \times 10{-}34$ J· s) ,c is the speed of light and λ is the wavelength. The frequencies and wavelengths of the major components of the spectrum and then focusing attention upon visible and invisible light. The top portion of (Figure.1) illustrates a large portion of the electromagnetic spectrum in terms of the frequency and wavelength of its major components. In the lower portion of (Figure 1) visible light is “exploded” in terms of its wavelength in nanometers[1].

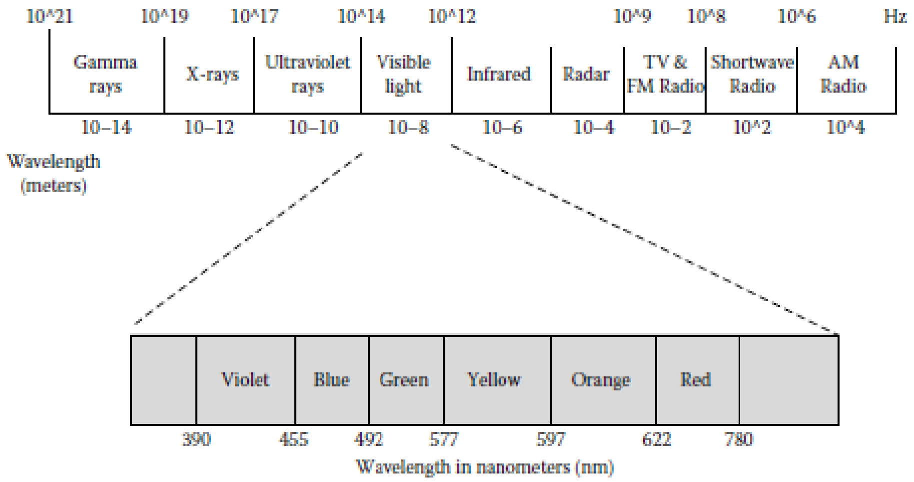
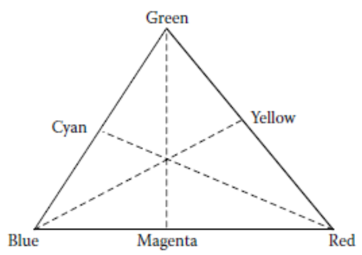


Figure (1) The electromagnetic spectrum and visible light[1].

In discussing color, it's important to understand the system defined by the Commission Internationale de L'Echairage (CIE). This system can be described as an evolution of the well-known Maxwell triangle[Figure.2(a)], and provides an easy-to-use method to define color mixing. The three primary colors R,G,B (red, green and blue) are placed at the vertices of an equilateral triangle). Along the sides of a Maxwell triangle, mixing of two of the three primary color components occurs in every possible proportion, as you travel toward the center of the triangle the third primary color becomes increasingly important, with the center of the triangle having a true white color. If we route a line through the center from each primary color vertex to the opposite side, we obtain the positions where cyan, yellow, and magenta occur.

The spectral locus shown in [Figure.2(b)] indicates that although the primary colors are the most intense obtainable, their additive mixtures cannot be used to produce the entire color spectrum, to get around this problem, the CIE used primaries that are not found in the spectrum. In doing so, the CIE selected three primaries that they called *X*, *Y*, and *Z*, which are theoretically defined as supersaturated colors; they reside outside the bounds of the spectral locus[2].



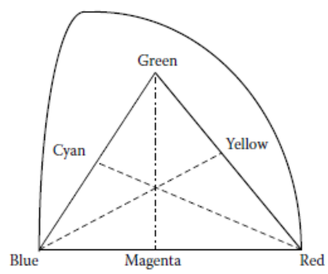


Figure 2(a).The Maxwell triangle. ***Figure 2 (b). The spectral locus [2].***

2. CIE Theoretical Primaries.

Through the use of the three aforementioned imaginary primaries, we obtain a method that makes the coordinate system simpler . Figure 3 illustrates the CIE X , Y and Z theoretical primaries and their relationship to the spectral locus. Note that through the use of X, Y, and Z, we can now define a color of wavelength λ as follows:

$$C_\lambda = xX + yY = zZ \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where x, y, and z are the amounts of the primaries X, Y, and Z. These three values represent relative proportions that can be normalized to obtain the values of X, Y, and Z as follows:

$$x = X/(x + y + z),\ y = Y/(x + y + z),\ z = Z/ (x + y +z)$$

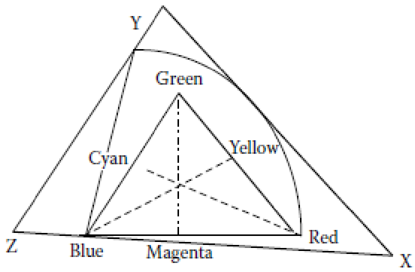


Figure (3) The CIE theoretical primaries and their relationship to the spectral locus[2].

The values of x and y are known as chromaticity coordinates, as they are limited to containing hue and saturation information(HSB). The y value was modified to carry luminosity, so that any color can now be represented by using its chromaticity values x ,z and y, resulting in the CIE chromaticity chart (Figure 4). The CIE chromaticity that shown in the figure characterizes colors by a luminance parameter (Y) and two color coordinates (X and Y) which specify a point on the chart[3].

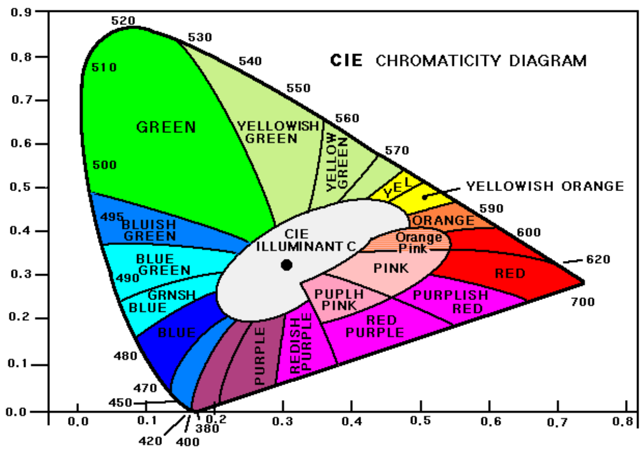


Figure (4) Chromaticity diagram [3].

Luminance (Y)

It is a weighted sum of the three colors of light used in color television and computer displays , which are RGB at a given point on the screen .A stronger Luminance signal indicates a more intense brightness of light at a given spot on the screen. It is given by[4]:

Y =0,299R + 0,587G + 0,1145B the luminance signal………………….……...….(2)

Chrominance

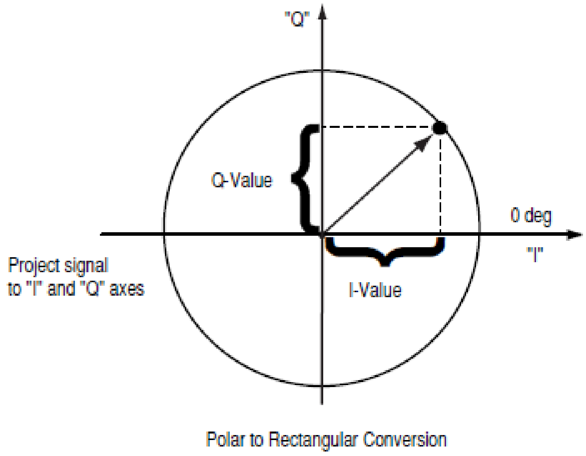
The Chrominance signal specifies what color is to be shown at a given point on the display as well as how saturated or intense the shade of color that is shown and given by[4]:

U =0.493(B−Y) is called the blue chrominance ……………………….……......... (3)

V = 0.877(R –Y) is called the red chrominance …………………………..……..… (4)

I/Q formats

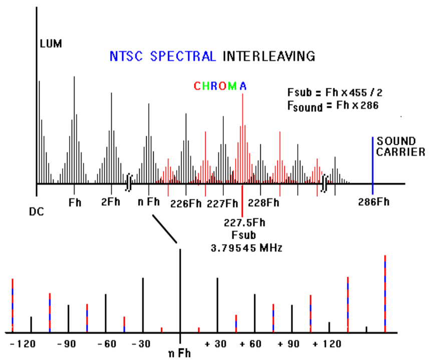
This is a rectangular in digital communications, modulation is often expressed in terms of I and Q, this is a rectangular representation of the polar diagram. On a polar diagram, the I axis lies on the zero degree phase reference, and the Q axis is rotated by 90 degrees. The signal vector’s projection onto the I axis is its “I” component and the projection onto the Q axis is its “Q” component(Figure 5) . Most digital modulation maps the data to a number of discrete points on the I/Q plane .These are known as constellation points. As the signal moves from one point to another, simultaneous amplitude and phase modulation usually results. To accomplish this with an amplitude modulator and a phase modulator is difficult and complex. Alternatively, simultaneous AM and phase modulation is easy with an I/Q modulator [5].

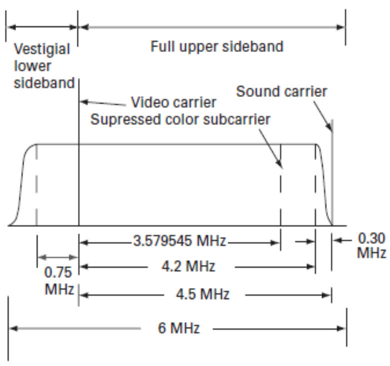


Figure(5) "I-Q" Format [5].

3. NTSC Color System

The image in NTSC Television is transmitted using three components .The first and most important is the Luminance (Y). As described above, Luminance specifies how bright a given spot on the display, and is the only signal used on black and white displays or receivers[6] .The broadcast signal has a much lower resolution than the luminance signal.The number of lines of horizontal resolution in NTSC broadcast video is about (333) lines across the screen. It able to display a maximum of (166.5) pairs of alternating black and white stripes, drawn vertically on the screen . That's the horizontal luminance resolution , so it only covers the resolution of the black and white detail of the image so this system uses a line - locked subcarrier at (3. 79545 MHz) (Figure 6) [7] . NTSC system uses (VSB) amplitude modulated with a suppressed carrier (Figure 7) following two orthogonal axes by two signals, I (in phase) and Q (quadrature), carrying the chrominance information[8].





Figure(6) NTSC spectral[7] **Figure(7)Vestigial Sideband Modulation[7]**

In this system instead of transmitting the red, blue, and green (RGB) signals on an equal basis, three linear combinations are used , one of these , the luminance signal (Y) , is chosen to be the brightness signal that would have been produced by a monochrome camera the other two linear combinations(I&Q) are given by [9] :

$$I = 0.74(R-Y) - 0.27(B-Y) \quad \text{…(5)}$$

$$Q = 0.48(R-Y) + 0.41(B-Y) \quad \text{… (6)}$$

Red, green, and blue are three primary additive colors and are represented by a three-dimensional, Cartesian coordinate system, all of the color spaces (YUV , YIQ , YCbCr , HSV , XYZ…and another)can be derived from the RGB information supplied by devices such as cameras and scanners ,from equation (3) yields:

$$R-Y=R-(0.299R+0.587G+0.114B) =0.701R-0.587G-0.114B \quad \text{…(7)}$$

$$B-Y=B-(0.299R+0.587G+0.114B) = -0.299R-0.587G+0.886B \quad \text{… (8)10}$$

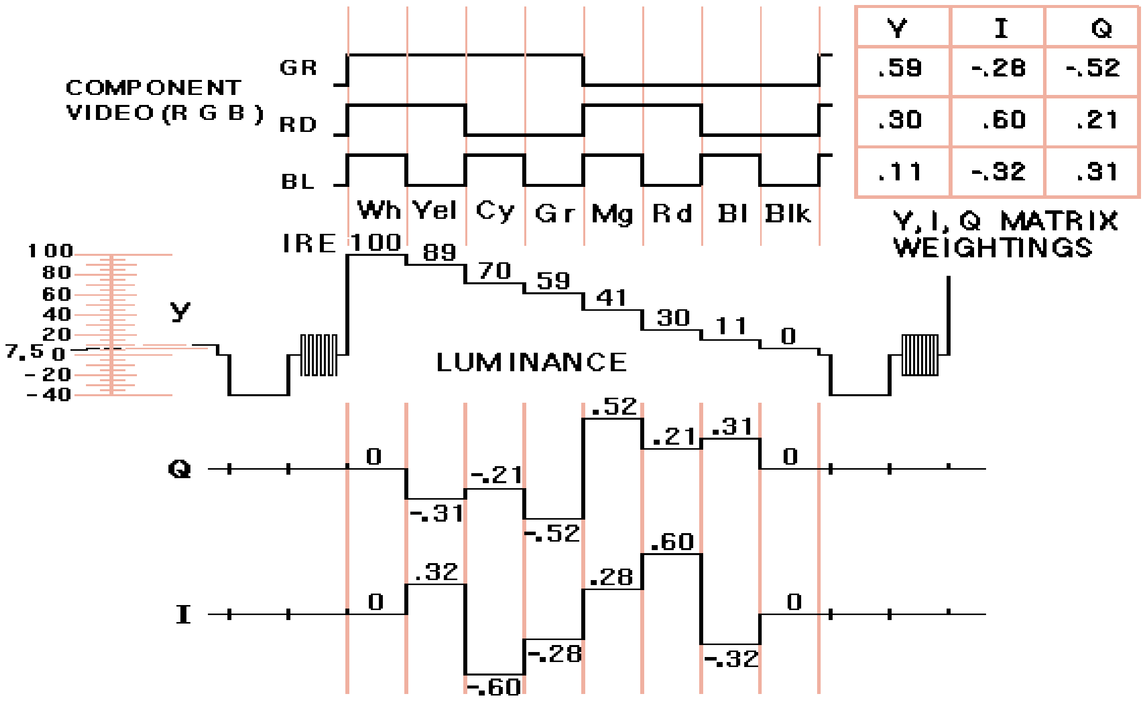
Rearranging equations (3,6,7,8, 9) yields the matrix:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.595716 & -0.274453 & -0.321263 \\ 0.211456 & -0.522591 & 0.311135 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad \text{… (9)}$$

Then, the inverse matrix becomes:

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} 1 & 0.9563 & 0.6210 \\ 1 & -0.2721 & -0.6474 \\ 1 & -1.1070 & 1.7046 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix} \quad \text{…(10)}$$

Two things to note regarding the RGB transformation matrix, the top row is identical to that of the Y,U and V (equal Y, I and Q) because the YIQ color space is derived from the YUV color space(Figure 8) . The additional components transmitted are "I" and "Q", these contain combinations of the Red, Green and Blue information to describe the color or chrominance that should appear on the given spot on the screen [10].



Figure(8) The Y, I and Q matrix with (RGB) representation in NTSC[10].

4. Matlab Evaluation

The application called Color Spaces used for television colorimetric and various color spaces analysis . it contains RGB representation and television resolute on (256 x 256 pixels and 24 bit color depth) . The input test picture (Waterfall Gali _Ali beeg) with desired color space RGB (Figure 9) can be converted into luminance Y (Figure 9 a) , the in- phase chrominance I (Figure 9 b) and the quadrature chrominance Q (Figure 9 c) , then the output picture NTSC representation with signals Y , I and Q inverse again to (RGB) representation (Figure 10a , b & c). The simulation results were compared to measurement results to evaluate the performance of analysis test picture , and proved the results are fitting together (Appendex. 1) .

Figure(9) Test picture (Waterfall Gali _Ali beeg) with Full color (RGB).

Figure 9 a) Luminance Y.

Figure10 a) inverse Luminance Y.

Figure 9 b) Chrominance Q.

Figure10 b) inverse Chrominance Q.

Figure 9 c) chrominance I.

Figure10 c) inverse chrominance I.

5. Conclusions

Any three independent parameters can be used to specify colors . One system that is convenient because it relates to easily observed properties is CIE color space. Color space refers to the dominant color in chromaticity and Luminance , it is quantified by passing a line from white to the color point out to the spectral curve . The International Commission on Illumination were established for the purpose of analyzing the space of colors for the various systems of television, including the NTSC system , which can be represented include the value of lighting which according to the parameter (Y) as character color so represented in accordance with parameters (I, Q), so we can calculate the default values for those parameters to enable us to conversion to other operating systems such as PAL or SECAM and vice versa.

6. Future recommendations

Development of research to include other television systems (Pal ,Secam ,…) .

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Appendex 1:

Matlab simulation program flow chart