Research of the chromaticity coordinates and color spectrum calibration using tristimulus sensors and eigenspectrum method

Mang Ou-Yang[a], Ting-Wei Huang[a], Yao-Fang Hsieh[*a], and Yi-Ting Kuob [b,c]
[a]Dep. of Optics and Photonics, National Central Univ., Jhongli City, Taoyuan County , TAIWAN
TEL:+886-34227151 Ext:65280 , FAX:+886-32807026, Email:oym@dop.ncu.edu.tw
[b]Institute of Applied-Arts , National Chiao-Tung Univ., Hsihchu city, Taiwan
[c]Jen-Teh Junior College of Medicine, Nursing and Management, Miaoli County, Taiwan

ABSTRACT

The purpose of color measuring instrument is judging the color information by scientific method, which may instead of the human's eyes. Generally, the instruments of color measuring have two kinds, spectrophotometer and color meter. The former measures spectrum by usage of prism or grating to separate the light, this could achieve high accuracy but with a higher price. The latter obtains tristimulus from color filter; however there is no spectrum information with it. This article establishes a color measuring system and uses eigenspectrum method to correct the average inaccuracy. The measuring system includes tristimulus sensors which were made by color filter, and Xenon lamp as light source. The advantage of this measuring system is the higher accuracy and the lower cost. The eigenspectrum method can correct the average inaccuracy in less eigenvector, which can save the time. This method used singular value deposition to obtain basis function of spectrum set, which can be obtained by measuring. Because the range of the spectrum set was 380nm to 780nm, the eigenvector per nanometer from 380nm to 780nm can be obtained. In general, the color spectrum can be obtained with less eigenvector. This article establishes a color measuring system, which has three sensors and uses Xenon lamp as light source, to acquire the color spectral reflectance. This article also uses the eigenspectrum methods to correct the average color difference in L*a*b* color space,which from 31.2398 down to 4.8401, and reconstructs the spectrum information.

Keywords: color temperature conversion, correlated temperature, center of gravity method, isotemperature

1. INTRODUCTION

The color is an art, lets us be able to appreciate this beautiful world, the artists applies the color in the fine arts aspect expresses its thought and the emotion, but the people appreciate the fine arts work by its vision, regardless of being the construction, the carving, the drawing or the technological design. It's outward appearance must express by the different color its represents the spirit, and makes beautiful boundary to expand to in-depth domain. In daily life, people also express its innermost feelings by the different color that regardless of being goes out every day puts on clothes' color, or the women use the cosmetics cosmetics, may see the trifle because of the color the clue. But the color lies in business application, may because of different color matching, impetus the consumer to this commodity purchase desire, for example black honored, red excited, blue color eternal…and so on, as long as undergoes suitable matching, may achieve the suitable addition effect. The nature scenery is also flooding the rich color, however these will defer to the four seasons as well as sooner or later fluctuate, but will have our different feeling, so long as therefore realized attentively can discover periphery the scenery will not have when will not be changing, they will defer to the bright light differently to take to the human the different feeling [1].

The color is a science, how to make good use of the color character, how will the correct judgment color and define, becomes the most important base element. In this paper will introduce how to distinguish the color and the method of color measurement. Speaking of the human, the vision brings the impression, far compared to the sense of hearing and the sense of taste. The product purchase desire, also will rely on the feeling of color and distinguish food cleanly the quality or not. But solely will rely on the subjective impression easy to create the mistake and the error. The external environment photo source will be different, the angle, the position not same level will have the possibility to create the differernce. if can quality and quanty the color, take the value as the distinction of color, then may reduce the subjective

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consciousness, avoids having the identical object color actually to have the infinite many kinds of possible adjectives. Furthermore, the color measuring instrument also by the widespread application in the display industry [2-3], the display industry raise in recent years a wave revolution unrest, however this unrest also caused between the country and the country executes the test of strength mutual competition respectively. However how to construct a set to conform to color of appraisal standard for all display actually not to achieve the comprehensive mutual recognition, and used to appraise this standard essential to admire a set of accurate color gauging system as well as the gauging standard. The color measuring instrument may also the suitable application situation in the appraisal environment light, spread out the color, promotes effect of the photo source, and lifting efficiency. However says by the present environment, color measuring instrument's use underused, its reason because often the price has not been able to cause the populace to accept causes, therefore how by a low end installment cell design set of standard color measuring system, and enables it to obtain the universal application, promotes its value added that for this reason research main purpose[4-6].

2. METHODOLOGY

2.1 The effect of spectrum to color signal

Measurement of spectrum by color sprectrum measuring instrument the color using the dispersion spectrum already be widespread application place in each kind of measurement. It has high precision and high spatial resolution, however it still has the high price problem. Therefore the color meter arouses everyone's interest, its low price and the system manufacture is easy. Generally the precisely color meter uses the sensor which three input characters and CIE1931 color match function closely. Use this kind of technique is emphatically in the colore filter's make. If we hope that can more match with color match function, it needs higher cost. If it can use the less precise sensor, it may lose the sensitivity to be unable to match the color match function, but the cost can be down. Use the mathematical method to revise the error enables the value of exports to match with CIE1931 color match function. Using the relationship between value of exports, the spectrum, and the sensor sensitivity, and then use the mathematical method to reconstruct the spectrum.

If we use three color sensors, we can from color measurement to obtain three output, as (1) show,

$$v_1 = \sum_{\lambda=380nm}^{780nm} T_1(\lambda)R(\lambda)S(\lambda)C(\lambda)$$
$$v_2 = \sum_{\lambda=380nm}^{780nm} T_2(\lambda)R(\lambda)S(\lambda)C(\lambda)$$
$$v_3 = \sum_{\lambda=380nm}^{780nm} T_3(\lambda)R(\lambda)S(\lambda)C(\lambda) \quad (1)$$

where the v_1, v_2, v_3 represent the different output values of different sensors , T_1, T_2, T_3 represent the transmittance of different color filters, R represents the response of optical receiver and, TR (λ) is the sensitivity of combination of light filter and the optical receiver , S (λ) represents the lighting spectrum, C (λ) represents the object spectrum of reflection, λ is set from 380nm to the 780nm, and take 1nm as the interval, then indicates (1) by the matrix way, as (2) .

$$[v]_{i\times 1} = [TR]_{i\times j} \bullet [SC]_{j\times 1} \quad (2)$$

, where i=3, j=401. If the number of measured color ticket is k, we can obtain k set output.

$$[v]_{i\times k} = [TR]_{i\times j} \bullet [SC]_{j\times k} \quad (3)$$

When $[TR]_{i\times j}$ can conform to CIE 1931 definition CMF of (Color Matching Function), then may obtain conforms to the CIE standard output three stimulus value, then the transformation is the CIE color coordinate. if it is unable to conform to the CIE 1931 standards, then may use of mathematical method of section 2.2 to reconstruct spectrum to obtains more approximately tri-stimulus values..

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2.2 Eigenspectrum reconstruct

$$[SC]_{j,k^{th}} = \sum_{m=1}^{i} a_{j,m,k^{th}} [B]_{j,m} \quad (4)$$

(4) represents reconstruct k^{th} spectrum, i=3, j=401 and k is the sum of measured spectrum. If the number of measurement is 922, (4) can be represented as (5)

$$[SC]_{j\times k} = \left[\sum_{m=1}^{i} a_{j,m,1} [B]_{j,m}, \sum_{m=1}^{i} a_{j,m,2} [B]_{j,m}, \ldots, \sum_{m=1}^{i} a_{j,m,k^{th}} [B]_{j,m}, \ldots, \sum_{m=1}^{i} a_{j,m,k} [B]_{j,m} \right] \quad (5)$$

By (5), when we measure k reflection spectrum, the 401 points which from 380nm to 780nm in three eigenvector, indicated by the $[B]_{j\times i}$. If also for known $[TR]_{i\times j}$, when wants to measure an unknown reflection spectrum $[SC]_{j,x}$,that the output of by the sensor is $[v]_{I,x}$. Then we can use (6) and (7) to obtain $[a]_{i,x}$, that x represents the illumination light illumination in the random color ticket.

$$[v]_{i,x} = [TR]_{i\times j} \bullet \sum_{m=1}^{i} a_{m,x} [B]_{j,m} = [TR]_{i\times j} \bullet [B]_{j\times i} \bullet [a]_{i,x} \quad (6)$$

$$[a]_{i,x} = ([TR]_{i\times j} [B]_{j\times i})^{-1} [v]_{i,x} \quad (7)$$

$$[SC]_{j,x} = [B]_{j\times i} \bullet [a]_{i,x} \quad (8)$$

$$[XYZ]_{3,x} = [CMF]_{3\times j} \bullet [SC]_{j,x} \quad (9)$$

So, when the $[B]_{j\times i}$ and $[TR]_{i\times j}$ are known, the $[SC]_{j,x}$ of unknown ticket and the $[XYZ]_{3,x}$ can be calculated.

2.3 Measurement

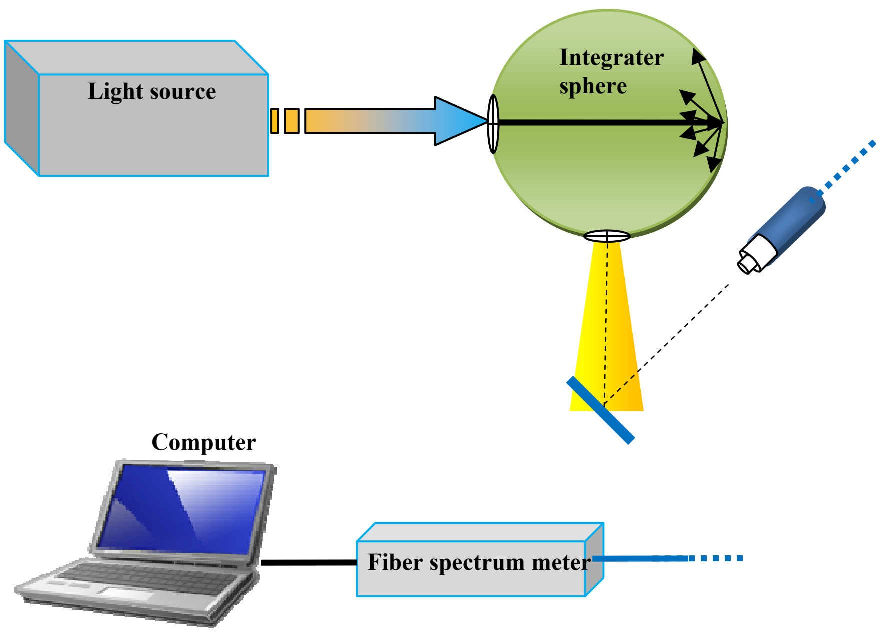

Fig. 1: This figure represents the measurement setup. The measurement has two types light source, which is tungsten and xenon. The color ticket has 922. The fiber spectrum meter can measure flux.

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3. RESULTS

3.1 The measurement of tungsten light source and xenon light source

The v_1, v_2, v_3 are measured as 25717.63, 57328.49 and 148640.1, that are the tri-stimulus values. The calculated chromaticity coordinate (x_s,y_s) is (0.111,0.2474). The measured chromaticity coordinate by color meter (x_p,y_p) is (0.1627,0.1019). The error between the calculation and measurement is as

$$\Delta xy = \sqrt{(x_p - x_s)^2 + (y_p - y_s)^2} \tag{10}$$

When the measured color ticket has N (N=922) number, the error can be represented as

$$\Delta xy_N = \frac{\sum_{n=1}^{N} \sqrt{(x_{pn} - x_{sn})^2 + (y_{pn} - y_{sn})^2}}{N} \tag{11}$$

$$\Delta u'v'_N = \frac{\sum_{n=1}^{N} \sqrt{(u'_{pn} - u'_{sn})^2 + (v'_{pn} - v'_{sn})^2}}{N} \tag{12}$$

If the color space is transferred to uniform color space, The error can be represented as

$$\Delta E_{abN} = \frac{\sum_{n=1}^{N} \sqrt{(L_{pn} - L_{sn})^2 + (a_{pn} - a_{sn})^2 + (b_{pn} - b_{sn})^2}}{N} \tag{13}$$

The measurement results are showed in the latter.

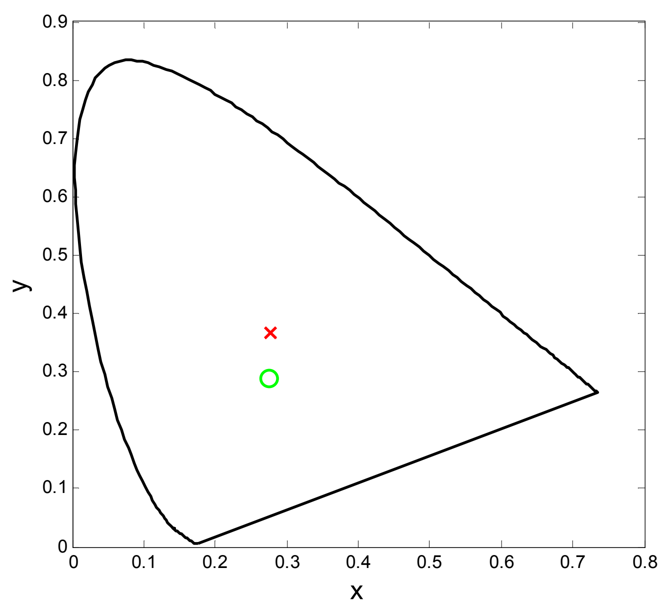

Fig. 2: The light source is tungsten. This figure is the color point distribution in xy chromaticity coordinate when the error is 0.078. The cross represents the measurement by sensor. The circle represents the measurement of spectrum meter.

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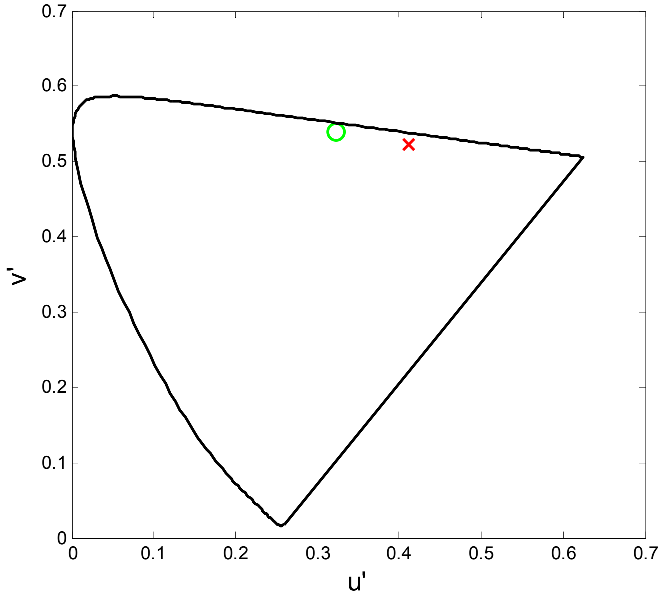

Fig. 3: The light source is tungsten. This figure is the color point distribution in u'v' chromaticity coordinate when the error is 0.091. The cross represents the measurement by sensor. The circle represents the measurement of spectrum meter.

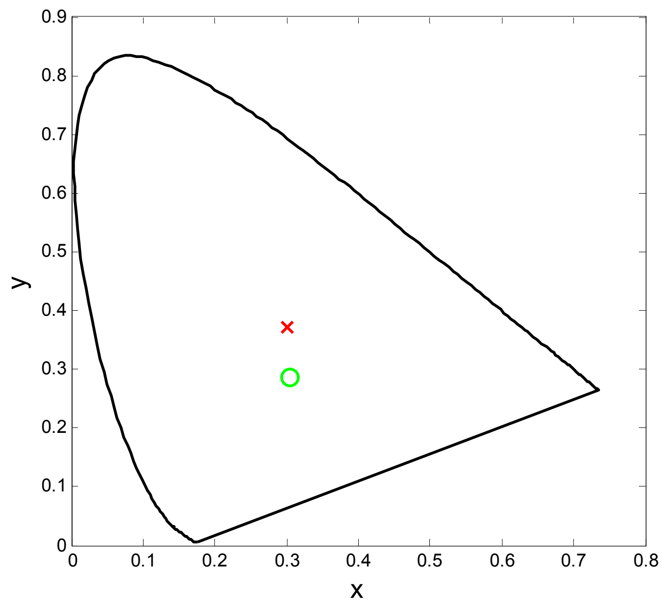

Fig. 4: The light source is xenon. This figure is the color point distribution in xy chromaticity coordinate when the error is 0.084. The cross represents the measurement by sensor. The circle represents the measurement of spectrum meter.

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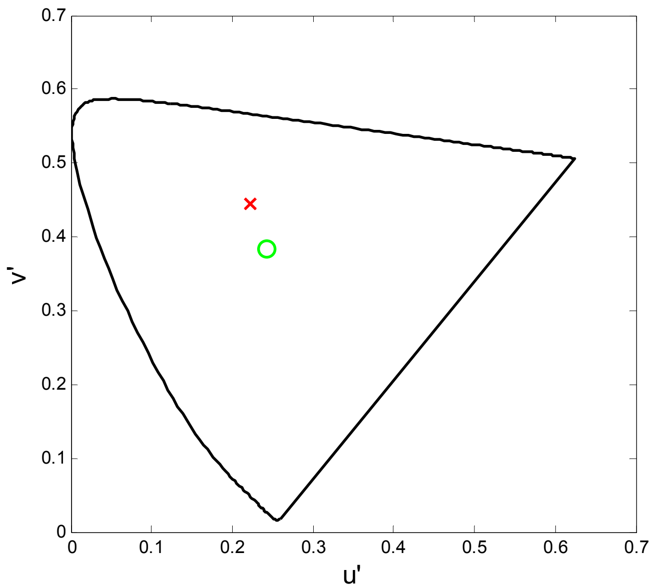

Fig. 5: The light source is xenon. This figure is the color point distribution in u'v' chromaticity coordinate when the error is 0.065. The cross represents the measurement by sensor. The circle represents the measurement of spectrum meter.

3.2 The spectrum reconstruct results by eigenspectrum reconstruct

We use the method before section to correct the spectrum, and compare the calculation and the measurement.

$$\Delta\left[SC\right]_{j,x} = \sqrt{\frac{\sum_{n=1}^{j}(SC_{pn} - SC_{sn})^2}{j}} \tag{14}$$

In the tungsten case, before correction the ΔE_{ab922}=39.01742, after correction the ΔE_{ab922}=6.4818, and the $\Delta[\mathrm{SC}]_{\mathrm{j,k^{th}}}$ is 0.064566. The result is as the Fig. 6.

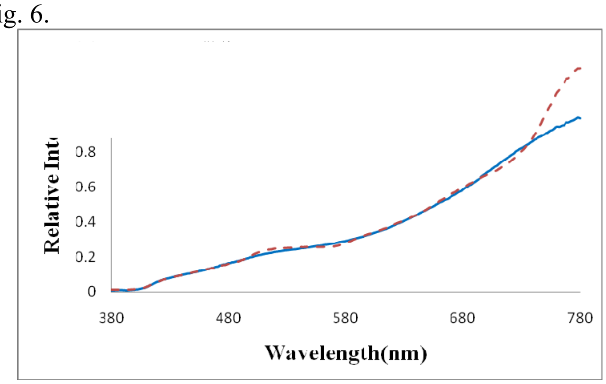

Fig. 6: This figure uses the method of eigenspectrum reconstruct to reconstruct the tungsten spectrum. The solid line represents the measurement by spectrum meter. The dash line represents the spectrum reconstruct.

In the Xenon case, before correction the ΔE_{ab922}=31.2398, after correction the ΔE_{ab922}=4.84013, and the $\Delta[SC]_{j,k^{th}}$ is 0.29744. The result is as the Fig. 7.

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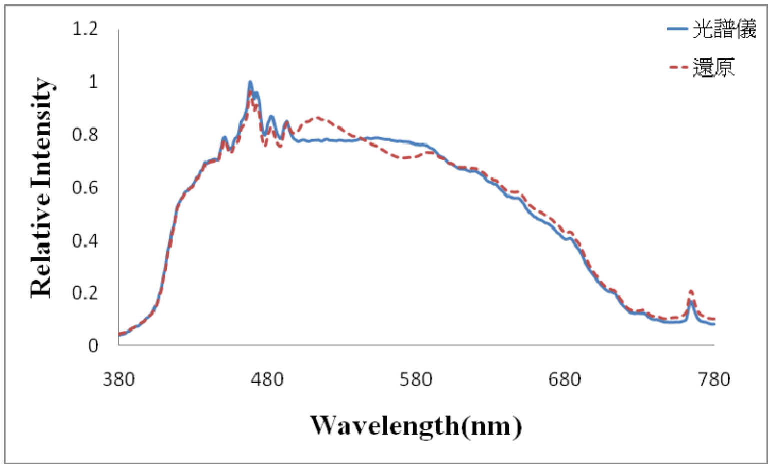

Fig. 7: This figure uses the method of eigenspectrum reconstruct to reconstruct the xenon spectrum. The solid line represents the measurement by spectrum meter. The dash line represents the spectrum reconstruct.

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4. CONCLUSION

The color measuring instrument may replace the human eye to do for the objective color determination criterion. Human's eye is complex and sensitive; a good color measuring instrument must be able to substitute for the eye completely. In this research has used three sensitive spirit different light sensors. The sensitivity and CIE 1931 schedule CMF $\bar{x}$、$\bar{y}$、$\bar{z}$ of definition, the existence relative difference, but its price is relatively speaking more inexpensive can cause the manufacture cost to reduce largely. After corrected by eigenspectrum reconstruct method, the error of uniform color space can be reduced and the ΔE_{ab922} reduces to 4.8401. And can the use optical fiber color meter and spectrum of information as well as the sensor measuring output of the storage but of reflection spectrum reduced color ticket. And after the reconstruct to the original spectrum, the error between the calculation and the measurement $\Delta[SC]_{j,k^{th}}$ is 0.029744.

5. REFERENCE

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