MEASUREMENT OF CIE TRISTIMULUS VALUES XYZ 
BY COLOR VIDEO IMAGES

—Development of Video Colorimetry—

カラービデオ画像によるCIE表色系三刺激値XYZの測定
—ビデオ測色法の開発—

Yoshiaki UETANI *
上谷芳昭

A new colorimetry technique by color video images is developed and named "Video Colorimetry". A digital camera is colorimetrically calibrated using a colorimeter, a xenon lamp, and color samples. The calibration describes the device dependent characteristics of the camera as a series of regression functions. In the actual measurement, the calibration functions transfer the video signal values RGB on a digital color image into the absolute values of the CIE 1931 tristimulus values XYZ pixel by pixel. The XYZ values of each pixel are transferred into the absolute values of color coordinates xy. For light sources, correlated color temperature is also calculated. The accuracy of the video colorimetry is validated by comparison with the colorimeter.

Keywords: Color, Colorimetry, Video image, CIE XYZ, Tristimulus values, Digital camera
色彩，測色，ビデオ画像，CIE XYZ，三刺激値，デジタルカメラ

1. INTRODUCTION
To evaluate the color in the interior or exterior of buildings, the spatial distribution of color in a visual field should be colorimetrically measured. Visual colorimetry using the Munsell color samples is often adopted in color surveys of scenery. Colorimeters are sometimes employed for studies in which quantitative colorimetric data are required. Though a conventional colorimeter can measure the color of a field point by point, it takes a long time to finish a scanning and the obtained distribution could be too coarse to analyze the spatial distribution of color.

In the field of photometry, there have been also needs to measure the luminance distribution of visual field. The film photographic photometry \textsuperscript{19} met the demand and have been utilized for the study of daylighting and luminous environment. To improve the time-consuming process of photographic development and measurement by an expensive densitometer, the photographic film was replaced by video images captured by CCD (Charge Coupled Device) \textsuperscript{20}. Since then, a number of researchers have developed video photometers for research and application of lighting and architectural design \textsuperscript{21}, \textsuperscript{22}, \textsuperscript{23}, \textsuperscript{24}, \textsuperscript{25}, \textsuperscript{26}, \textsuperscript{27}.

Recently, a CCD-based colorimetry system has been developed \textsuperscript{28}. It is capable of measuring the distribution of luminance, color coordinates and correlated color temperature of the visual field. The system is composed of a 16-bit monochrome CCD camera, three RGB color filters mounted on a wheel, an interface device to connect the camera to a PC, and a control software. Considering the specification, the system is expected to be accurate and useful for the colorimetry of artificial lighting and building interior where the illuminating condition is stable. On the other hand, the time lag to capture three RGB images sequentially by rotating the color filter wheel may affect the accuracy for the colorimetry of daylighting and exterior of buildings when the daylight source is unstable due to weather condition.

There are other colorimetric calibration techniques to measure not only the tristimulus values but also the spectral reflectance or transmittance of objects using video images. One method requires the video system's spectral transfer functions \textsuperscript{29} which are usually unavailable from the manufacturers of digital cameras. Another uses the specially made multichannel CCD camera with 6 color filters \textsuperscript{30} which requires multiple captures changing filters. These laboratory instruments might be overspec for the architectural research and application which do not always require spectral properties but tristimulus values of visual objects.

For the research and application of colorimetry in the field of...
architecture, the author has developed the video colorimetry systems using color video images. The first system was composed of a CCD color video camera and a video capture board with a desktop PC. It was colorimetrically calibrated with a colorimeter. The RGB values of each pixel on a color video image were converted into the CIE color coordinates xy. The color coordinates were transferred into the correlated color temperature (CCT) for the measurement of the CCT distribution of the sky to estimate the cloud cover.

The second system was composed of a precision color CCD camera and the interface board with a desktop PC. The system was also colorimetrically calibrated with a colorimeter. The RGB values of each pixel on a color video image were converted into the CIE color coordinates xy for the colorimetry of building interiors and exteriors.

This paper describes the third system, in which the colorimetric calibration technique is applied to a digital camera. The latest video colorimetry system measures the absolute values of CIE tristimulus values XYZ of each pixel on a captured color image. The XYZ values are converted into the absolute luminance and color coordinates Yxy. For light sources, correlated color temperature is also calculated.

Compared to the laboratory instruments, the author's system has advantages of affordability, easy operation, and instant measurement. It is simply composed of an image processing software on a note-type PC and an inexpensive digital camera available as a consumer product. To capture a video image and convert it into an array of the XYZ values are as easy as to take a digital picture and send it to a printer. Because one measurement takes just a moment to capture a color video image, not only the building exteriors under unstable daytime light source, but also moving objects (e.g., driving cars) are able to be measured.

2. METHODOLOGY
This section describes the basic concept which is common and applicable to most digital cameras. The device dependent details are explained in the following section as a case study using a digital camera.

2.1 Basic formula
The CIE 1931 tristimulus values \((X, Y, Z)\) and \((R, G, B)\) are related by the following equations,

\[
\begin{align*}
X &= 2.7689 R + 1.7517 G + 1.1302 B \\
Y &= 1.0000 R + 4.5907 G + 0.0601 B \\
Z &= 0.0000 R + 0.0565 G + 5.5943 B
\end{align*}
\]

(1)

where the value \(Y\) is identical with the luminance, which has the unit of candela per square meter \(\text{cd/m}^2\).

The National Television System Committee (NTSC) in USA recommended the color television standards in 1953. Countries as USA, Canada, Japan, and Mexico adopted this standard. Many other countries have chosen different system as SECAM or PAL. The transformation equations from the normalized RGB video signals \((Rv, Gv, Bv)\) of the NTSC system to the normalized CIE tristimulus values \((Xn, Yn, Zn)\) for the illuminant C are expressed by the well known equations as,

\[
\begin{align*}
Xn &= 0.6067 Rv + 0.1736 Gv + 0.2001 Bv \\
Yn &= 0.2998 Rv + 0.5868 Gv + 0.1144 Bv \\
Zn &= 0.0000 Rv + 0.0661 Gv + 1.1150 Bv
\end{align*}
\]

(2)

The transformation equations for the illuminant D\(_\text{65}\) are given as follows,

\[
\begin{align*}
Xn &= 0.5880 Rv + 0.1789 Gv + 0.1828 Bv \\
Yn &= 0.2998 Rv + 0.6056 Gv + 0.1043 Bv \\
Zn &= 0.0000 Rv + 0.0679 Gv + 1.0201 Bv
\end{align*}
\]

(3)

The parameters in the transformation equations were decided by the colors of CRT phosphors when the NTSC system was proposed a half century ago. Recent TV systems tend to adopt the new standards by the Society of Motion Picture and Television Engineers (SMpte) or the European Broadcasting Union (EBU) which propose closer colors to modern phosphors.

The NTSC formulae are so popular that a lot of image analysis software and hardware have utilized them to convert RGB images to device independent CIE XYZ images. However, mere usage of these formulae provides no more than relative XYZ values, e.g. an integer between 0 and 255, though the absolute values are essential to the colorimetry for research and application of architecture. The new method described here converts the RGB values of each pixel on a color image into the absolute XYZ values by the colorimetric calibration of a digital camera.

2.2 Colorimetric Calibration
The purpose of the colorimetric calibration is to obtain the calibration functions that convert the normalized values of RGB signals captured by a digital camera into the absolute values of CIE tristimulus values XYZ. If the same objects were measured by a reference colorimeter under the same condition of illumination, the measured XYZ values would give good agreement with the results by the video colorimetry.

In the colorimetric calibration of the former studies by the author, captured video values \((Rv, Gv, Bv)\) are transferred into the normalized CIE tristimulus values \((Xv, Yv, Zv)\) by the NTSC formula (2) or (3) at first. Then the regression analyses were applied between the normalized values \((Xv, Yv, Zv)\) and the absolute values \((X, Y, Z)\) measured by the reference colorimeter. This straightforward calibration was accurate but not efficient in collecting sample data. For the color chips of high chroma (e.g. pure red, green, blue, etc.), if any of the captured video values \((Rv, Gv, Bv)\) are saturated beyond the range of digitization, all the normalized values \((Xv, Yv, Zv)\) calculated by the formula (2) or (3) must be discarded.

To improve the efficiency of the calibration work, a new technique "the Inverse Matrix Colorimetric Calibration" is developed as follows.
2.2(a) Normalized values of video signals
A digital camera captures the color video images of color samples illuminated by a reference lamp at various illumination levels. The settings of exposure and white balance control must be recorded for each color video image. The exposure is generally the function of shutter speed, f-stop of the lens, and gain control of the CCD. The white balance function controls the balance of RGB signals to represent the white and other colors properly based on the correlated color temperature of the light source (e.g. Daylight, Incandescent lamp, Fluorescent lamp, etc.). Most digital cameras including full automatic ones keep such information in the header of each image file.

The normalized values of video signals (Rv, Gv, Bv) of each color sample on captured color video images are read numerically by image analysis software. These values are expressed by a fraction between 0 and (2^N-1)/2^N, where N is the bit depth of digitization. Most digital cameras have 8-bit depth, some cameras for professional photographers have 12-bit, and a number of precision digital cameras for laboratories have 16-bit.

2.2(b) Absolute tristimulus values and reference video signal values
A reference colorimeter measures the absolute values of CIE tristimulus values (Xs, Ys, Zs) of each color sample under the same illumination as the color video images. The inverse functions of equations (3) convert the absolute values of (Xs, Ys, Zs) into the reference video signal values (Rvs, Gvs, Bvs) as follows.

\[
\begin{align*}
R_{vs} &= 1.971 Xs - 0.549 Ys - 0.297 Zs \\
G_{vs} &= -0.954 Xs + 1.936 Ys - 0.027 Zs \\
B_{vs} &= 0.064 Xs - 0.129 Ys + 0.982 Zs
\end{align*}
\]  

2.2(c) Regression functions
The regression analysis between (Rvs, Gvs, Bvs) and (Rv, Gv, Bv) decides the set of regression functions \( f_s, f_r, \) and \( f_r \).

\[
\begin{align*}
R_{vs} &= f_s(Rv, E, W) \\
G_{vs} &= f_r(Gv, E, W) \\
B_{vs} &= f_r(Bv, E, W)
\end{align*}
\]  

where \( E \) and \( W \) are the parameters of exposure and white balance controls of the digital camera. Though most digital cameras have the functions of automatic controls, the video colorimetry described here requires a digital camera that has repeatable manual controls of white balance and exposure.

2.3 Video colorimetry in practice
In the actual video colorimetry, a digital camera captures color video images of objects or light sources. An image analysis software reads normalized video signal values (Rv, Gv, Bv) of the images pixel by pixel. Then the values (Rv, Gv, Bv) are converted to the reference video signal values (Rvs, Gvs, Bvs) by the regression functions (5), and finally obtains the absolute values of CIE tristimulus values (X, Y, Z) by the transformation equations (3). The value \( Y \) is the luminance [cd/m^2] of each pixel. The values (X, Y, Z) are transferred into the color coordinates (x, y) as follows,

\[
\begin{align*}
x &= X / (X + Y + Z) \\
y &= Y / (X + Y + Z)
\end{align*}
\]  

If the object is a light source and the color coordinates (x, y) are close to the Planckian locus, the approximate value of correlated color temperature \( T [K] \) is calculated as follows \(^1\),

\[
T = 1437 n^3 + 3601 n^2 - 6861 n + 5514.31
\]  

where, \( n = (x - 0.3320) / (y - 0.1858) \).

3. COLORIMETRIC CALIBRATION AS A CASE STUDY
The colorimetric calibration depends on the functions of individual camera, therefore the form of regression functions may vary according to the characteristics of optics, CCD, firmware, etc. In this section, a digital camera is calibrated as a case study for the colorimetry of building interior and exterior.

3.1 Instruments
The digital camera (Nikon, E2n, Figure 1) is capable of capturing a 24-bit color images of 1280 by 1000 pixels through a conventional still camera lens. Each of the RGB signals of a pixel is expressed by an 8-bit integer between 0 and 255 (= 2^8 - 1).

The white balance is manually fixed to 'CLOUDY' position, which corresponds to 6500K in CCT according to the user's manual \(^2\). The NTSC equations (3) for the illuminant D65 is selected through the preliminary calibration from the NTSC (C), NTSC (D65), SMPTE, EBU, and HDTV standards \(^3\).

The shutter speed, and f-stop are manually controlled and unified to the exposure value \( E_v \) as a parameter of the brightness.

\[
E_v = \log_a(F/S)
\]  

where, \( F \) is the f-stop value of the iris, \( S \) is the shutter speed [sec]. The images are stored in a PC card. The image format is TIFF or JPEG(Fine).

![Figure 1: The spectra-colorimeter (left) and the digital camera with the zoom lens](image)
The digital camera is equipped with a zoom lens (Nikon, AF Zoom Nikkor 35-70/2.8D, Figure 1). In the preliminary study, the digital camera with the zoom lens captured the uniformly illuminated screen. The video signal levels over the whole image were verified to be nearly flat.

The colorimetric reference for the calibration is a spectrachrometer (Photo Research, PR650, Figure 1). The 24 chips of color samples (Macbeth, ColorChecker, Figure 2) including 6 monochromatic samples were illuminated by a Xenon lamp (Ushio, UXL-500D) at the incident angle of 0 degree in a dark room at Fukuaya University. The illuminance values on the color samples were changed from 353 lx to 4867 lx by controlling the distance to the lamp. The digital camera and colorimeter measured the colors chips at the reflection angle of 45 degrees. Theoretically, the video colorimetry is valid within the triangle of the NTSC phosphors shown in Figure 2.

The digital camera captured color samples at the widest end of the zoom lens. The image size of each color sample was about 100 by 150 pixels. An image analysis software (NIH, NIH Image) on a note-type PC (Apple, PowerBook 1400c) read the normalized video signal values \((R_v, G_v, B_v)\) by taking the averages of 50 by 50 pixels square at the center of each color sample. If the normalized video signal value is larger than 0.975 or smaller than 0.025, it is discarded because of over or under exposure. Figure 3 shows the scatter diagrams of the \(R_v-R_v, G_v-G_v, \text{and } B_v-B_v\). The valid pairs of \(R_v-R_v\) were 893 cases, \(G_v-G_v\) were 927 cases, and \(B_v-B_v\) were 953 cases. The minimum values of \(X, Y, \text{and } Z\) measured by the colorimeter were 3.3, 3.3 and 3.5 cd/m² respectively. The maximum values were 1496, 1496 and 1563 cd/m². These are considered as the valid range of calibration.

3.2 Regression functions

In the video photometry, the forms of the regression functions varied according to the video devices. Some device fitted to the logarithmic function \(^5\), and another fitted to the quadratic polynomial function \(^6\). The regression analysis tried several functions and resulted in the equations (9) and the parameters shown in Table 1. In most cases, the correlation coefficients \(r\) beyond 0.9. The regression functions are also drawn in Figure 3.

\[
\begin{align*}
R_v & = a_1(E_v) + a_2(E_v)R_v + a_3(E_v)R_v^2 \\
G_v & = a_1(E_v) + a_2(E_v)G_v + a_3(E_v)G_v^2 \\
B_v & = a_1(E_v) + a_2(E_v)B_v + a_3(E_v)B_v^2
\end{align*}
\]

By the following equations (10), the reference RGB signal values \((R_v, G_v, B_v)\) are converted into the absolute values of CIE tristimulus values \((X, Y, Z)\) pixel by pixel.

\[
\begin{align*}
X & = 0.5880 R_v + 0.1789 G_v + 0.1828 B_v \\
Y & = 0.2998 R_v + 0.6056 G_v + 0.1043 B_v \\
Z & = 0.0000 R_v + 0.0679 G_v + 1.0201 B_v
\end{align*}
\]

The equations (6) and (7) transfer the values \((X, Y, Z)\) of each pixel into the color coordinates \((x, y)\) and the correlated color temperature \(T\). The regression functions and parameters are coded as a macro program on the image analysis software.
Table 1 Parameters for the regression functions for the colorimetry of buildings

| Ev | $a_0(Ev)$ | $a_1(Ev)$ | $a_2(Ev)$ | $b_0(Ev)$ | $b_1(Ev)$ | $b_2(Ev)$ | $r$ | $n$ | $a_0(Ev)$ | $a_1(Ev)$ | $a_2(Ev)$ | $b_0(Ev)$ | $b_1(Ev)$ | $b_2(Ev)$ | $r$ | $n$ |
|----|-----------|-----------|-----------|-----------|-----------|-----------|-----|-----|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----|-----|
| 8.5 | 1.65e+0   | -1.17e+1  | 4.38e+1   | 0.959     | 27        | 1.21e+0   | -6.45e+0 | 3.57e+1 | 0.712     | 36        | 1.33e+0   | 1.62e+1   | 2.85e+1   | 0.763     | 37   |
| 9.5 | 1.95e+0   | -6.82e+0  | 6.75e+1   | 0.952     | 50        | -4.59e-1  | 3.59e+0   | 5.77e+1 | 0.789     | 60        | 2.90e-1   | 1.05e+1   | 4.94e+1   | 0.866     | 62   |
| 10.5| 5.67e+0   | -2.23e+1  | 1.41e+2   | 0.965     | 73        | -4.12e+0  | 2.98e+1   | 9.12e+1 | 0.832     | 84        | 1.67e+0   | 9.35e+0   | 1.11e+2   | 0.888     | 86   |
| 11.5| 9.06e+0   | -3.76e+1  | 2.85e+2   | 0.984     | 95        | 5.03e+0   | 1.70e+1   | 2.31e+2 | 0.895     | 103       | 2.92e+0   | 1.17e+1   | 2.42e+2   | 0.928     | 105  |
| 12.5| 6.07e+0   | -4.98e+0  | 4.93e+2   | 0.991     | 109       | 4.11e+0   | 6.60e+0   | 5.19e+2 | 0.940     | 117       | 6.85e+0   | 7.31e+0   | 5.47e+2   | 0.987     | 118  |
| 13.5| 7.44e+0   | 2.06e+1   | 8.74e+2   | 0.994     | 120       | 8.79e+0   | 2.73e+0   | 9.97e+2 | 0.965     | 123       | 1.34e+1   | 3.85e+1   | 1.06e+3   | 0.990     | 123  |
| 14.5| 1.93e+1   | 1.98e+1   | 1.92e+3   | 0.994     | 124       | 9.94e+0   | 1.30e+2   | 1.92e+3 | 0.977     | 127       | 1.54e+1   | 9.97e+0   | 2.15e+3   | 0.991     | 123  |
| 15.5| 2.26e+1   | 1.89e+2   | 3.53e+3   | 0.993     | 123       | 8.90e+0   | 4.56e+2   | 3.33e+3 | 0.974     | 117       | 8.09e+0   | 5.21e+2   | 3.71e+3   | 0.982     | 123  |
| 16.5| 2.55e+1   | 6.62e+2   | 5.90e+3   | 0.989     | 98        | 2.69e+0   | 1.24e+3   | 5.10e+3 | 0.971     | 91        | 5.76e+0   | 7.50e+2   | 6.55e+3   | 0.970     | 99   |
| 17.5| -2.40e+1  | 3.01e+3   | 7.11e+3   | 0.990     | 49        | -7.29e+0  | 4.60e+3   | 2.43e+3 | 0.968     | 49        | -7.85e+0  | 3.04e+3   | 9.46e+3   | 0.979     | 51   |
| 18.5| -1.15e+2  | 8.67e+3   | 2.68e+3   | 0.974     | 25        | -1.54e+2  | 1.05e+4   | -4.99e+3 | 0.956     | 24        | -1.92e+2  | 6.10e+3   | 2.42e+4   | 0.939     | 26   |

3.3 Practical video colorimetry of a building

The video colorimetry technique was applied to measure the luminance and the color coordinates on the interior (Figure 4) and exterior (Figure 5) of the university hall at Fukuyma University on February 16, 1998. The color images captured by the digital camera are transferred to the PC. The macro program on the image analysis software reads the RGB values pixel by pixel, and convert them into the absolute values of the CIE XYZ, and the color coordinates x, y. Figure 4 and 5 show the interactive interface of the macro program.

For the validation, the XYZ values were measured by the spectral-colorimeter. Figure 6 and Figure 7 show the comparison of the XYZ values and color coordinates measured by the video colorimeter and the colorimeter. The results show that the video colorimetry has a reasonable accuracy. For light blue colors in Figure 7, there are some difference. There are also some overestimates of the value Z in Figure 6. These might be because the Z values exceeded the valid range of calibration. The other reason could be the change of daylight condition under the partly cloudy sky. There were some time difference in shooting video images by the digital camera and measuring XYZ data by the colorimeter.
4. CONCLUSION

A new colorimetry technique is developed. The system is simply composed of a digital camera, a note-type PC, and a macro program on an image analysis software. The digital camera is calibrated with a colorimeter. In the actual measurement, the color image of the scene captured by the digital camera is transferred to the PC. The macro program converts the RGB values on color images into the absolute values of CIE XYZ pixel by pixel. The XYZ values are also transferred to the color coordinates and the correlated color temperature.

As a case study, a digital camera was colorimetrically calibrated. The practical colorimetry of the building interior and exterior showed reasonable accuracy by comparison with a colorimeter. The results also showed some errors due to the calibration range. This problem will be solved if brighter light source is utilized in the colorimetric calibration.

Because the basic concept of the video colorimetry technique is independent of a specific digital camera, it is able to be applied to most digital cameras. If recent high class digital cameras with 12-bit or 16-bit depth of digitization are colorimetrically calibrated, the accuracy is expected to be comparable to genuine colorimeters for research. If the technique is applied to low cost 8-bit digital cameras found in most class rooms and design offices, color science will become more familiar to architectural students, designers, and engineers.

Finally, the author names this new colorimetry technique as "Video Colorimetry".

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NOMENCLATURE

| X, Y, Z  | absolute values of the CIE tristimulus values XYZ. |
| R, G, B  | absolute values of the CIE tristimulus values RGB. |
| Xn, Yn, Zn | normalized values of the CIE XYZ. |
| Rv, Gv, Bv | normalized values of the video signals RGB. |
| Xv, Yv, Zv | absolute values of the CIE XYZ measured by the reference colorimeter. |
| Rvs, Gvs, Bvs | reference values of the video signals RGB as the inverse functions of Xv, Yv, Zv. |
| N        | bit depth of digitization. |
| E        | parameter of exposure control. |
| W        | parameter of white balance control [K]. |
| x, y     | color coordinates. |
| T        | correlated color temperature [K]. |
| Ev       | exposure value. |
| F        | f-stop value of the iris. |
| S        | shutter speed. |

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和文要約

1. 序論
建築の内部空間および外観の色彩を評価するためには測色が欠かせない。一般には色票による視感測色や色彩計による物理測色が行われるが、建築環境の色彩構成は複雑なので逐次測色には多大の労力と時間を要する。

測光の分野では、視感の輝度分布を測定するために写真測光法やビデオ測光法が開発され、照明や建築の研究及び応用に利用されている。

著者は、建築の測色のために、色彩計で較正した画像処理用カラー画像データで色度を計測するビデオ測色システムを開発してきた。本論文では、デジタルカメラによってCIE三刺激值XYZの絶対値を計測する方法を述べる。この新たに開発された手法によれば、視眼内の輝度と色度の分布に加え、光源の相関色温度も測定することが出来るので、さまざまな研究や実務への応用が期待される。

2. 方法
2.1 基本式
CIE（国際照明学会）が1931年に定めたRGB表色系とXYZ表色系の各三刺激値は（1）式で相補に変換される。

カラーテレビの正式放送は、米国で1953年に開始された。その後、NTSC（National Television System Committee）方式と呼ばれ、1960年に正式放送を開始した日本もこれを採用した。一方、ヨーロッパではPAL方式やSECAM方式などが採用されている。

NTSC方式では、正規化されたCIE XYZ表色系の三刺激値（Xn, Yn, Zn）とビデオ信号（Rv, Gv, Bv）は、白色として標準の光Cを選ぶと（2）式により、あるいは標準の光D65を選ぶと（3）式により相補に変換される。

2.2 色彩較正
色彩較正の目的は、デジタルカメラのビデオ信号をCIE XYZ表色系の三刺激値の絶対値に変換する較正関数を求めることがある。

暗室において、基準光源により様々な照度レベルで照明した様々な色票を、デジタルカメラで撮影する。画像を生成し、色彩計で三刺激値を計測し、これを（3）式に逆関数である（4）式で変換すると、ビデオ信号の基準値（Rv, Gv, Bv）に変換する。

3. 色彩較正の事例
較正関数（5）は、個々のデジタルカメラの光学系、C C D、組み込みソフトなどの特性に依存する。本論文では、色彩較正の事例として、デジタルスチルカメラ（Nikon, E2n）にズームレンズ（Nikon, AF Zoom Nikkor 35-70/2.8D）を装着したものを利用した（Figure 1）。

Nikonのホウイットパラメータの色相知度6500Kに固定した。絞り FとシャッタースピードSをマニュアルで設定し、（8）式による青色EVを較正関数のパラメータとした。PCカードに保存される画像を、ノートパソコン上で読み込み、画像処理ソフト（NIH, NIH Image）でデータ処理をした。

測定の結果として分光色彩計（Photo Research, PR650, Figure 1）を用いた。暗室で24色の色票（Macbeth, ColorChecker, Figure 2）に、キセノンランプ（Ushio, UXL-500D）の直射光を照射した。ランプと色票の距離を変化させて、色票面の照度を467lxから353lxまで変化させた。

デジタルカメラによるビデオ信号（Rv, Gv, Bv）と分光色彩計によるビデオ信号の基準値（Rv, Gv, Bv）の散布図をFigure 3に示す。

回帰分析の結果、較正関数（9）式と較正関数（10）式により表色計（Table 1）が得られた。

実際のビデオ測色では、カラー画像の各画素のビデオ信号（Rv, Gv, Bv）は、（9）式と（10）式によりCIE XYZの三刺激値（X, Y, Z）に変換され、さらに色票及び（7）式により色度（xy）及び相関色温度Tに変換される。

ビデオ測色法を、福山大学の大学会館の内部（Figure 4）および外観（Figure 5）の輝度および色度の測定に応用した。なお、比較のために分光色彩計で三刺激値XYZを同時に測定した。三刺激値XYZの測定結果をFigure 6に、色度の測定結果をFigure 7に示すが、いずれもおおむね一致している。ビデオ測色法がやや過大に見積もっていることもあるが、これは輝度レベルが較正の範囲を超えたこと、及び天候条件の変化に起因すると考えられる。

4. 結論
カラー画像画像による測色法を新たに開発した。システムは、分光色彩計で較正されたデジタルカメラとノートパソコン上の画像処理ソフトで構成されている。画像処理ソフト上のマクロプログラムにより、画像処理上の各画素のRGB信号値はCIE三刺激値XYZの絶対値に変換され、さらに色度と相関色温度に変換される。

この「ビデオ測色法」は特定の機器の機能に依存しないので、高性能機から普及機まで様々なデジタルカメラに適用可能であり、色彩の研究、設計実務、教育などへの応用が期待される。

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