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# COLOR CORRECTION IN IMAGE TRANSMISSION WITH MULTIMEDIA PATH

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## ABSTRACT

The paper proposes to use the color rendering parameter as a criterion for the color constancy parameter for evaluation. The method for determining color rendering is proposed to be based on an objective evaluation method using an extended color set. The color set is proposed to be formed in an equidistant coordinate system of the equal-contrast coordinate system CAM16. In the paper, the estimation of color consistency is based on the spectral distribution of light sources and colors.

**Keywords:** image processing, quality assessment, multimedia tract, color consistency, colorimetric evaluation, color rendering ratio.

## 1. INTRODUCTION

The rapid introduction of video technology into modern systems of automation, machine vision, artificial intelligence, database creation, etc., is first and foremost progress, but at the same time, it raises questions that need to be addressed.

One of these questions is the color rendering factor, but if it is an image as a whole then the concept of color constancy should be used. The main works include [1], where the authors propose to use the color rendering index $R_a$ to evaluate the color rendering quality. The color rendering index means a vector in space that expresses the relative distance between two colors. The use of a color rendering parameter makes it possible to objectively estimate the quality of color rendering, and the various refinements [2] of this parameter lead to a difference in the values of one parameter and, accordingly, to the different criteria for the evaluation of the color rendering factor.

However, the image may be of many colors and cannot be estimated by each. For this reason, you should use the algorithm to determine the acceptable values of color change. Adaptation algorithms have been proposed in several papers [3-7] and it remains unclear how the video signal is controlled. The work is dedicated to this area.

## 2. PURPOSE AND OBJECTIVES

The aim is to develop an algorithm for adapting the video to light sources with arbitrary spectral distribution based on the use of a set of reference colors. Tasks to be solved:

- determine the number of colors needed for the optimal operation of the algorithm;
- extend the algorithm to arbitrary video resolution.

## 3. DEFINITION OF A COLORS SET

To determine the color set, the criterion for color separation is chosen, namely the threshold at which a person notices two colors differently. The following will be a summary of the color differentiation criterion.

### 3.1 Color Rendering Criteria

In [8], the relationship between the magnitude $\Delta E$ (1), which characterizes for video applications the discrepancy between the colors of the transmitted scene and its image, distortions can reach levels from barely perceptible to unacceptable.

$$\Delta E = \sqrt{(J_1' - J_2')^2 + (a_{M1}' - a_{M2}')^2 + (b_{M1}' - b_{M2}')^2} \quad (1)$$

$J', a_M', b_M'$ are color coordinates in an evenly contrasted (and a system where the distance between colors is the same) coordinate system, indices 1 and 2 indicate adjacent color coordinates.

This estimate compares the data of [9, 10] as presented in Figure-1.

Comparison of the $\Delta E$ estimates [11] indicates that, under independently changing conditions, the image environment and the brightness of the adaptation, when shooting on the transmitting side and reproducing on the receiving side, can lead to distortions of color transfer from the level of imperceptible or barely perceptible to the level of unacceptable lower image quality.

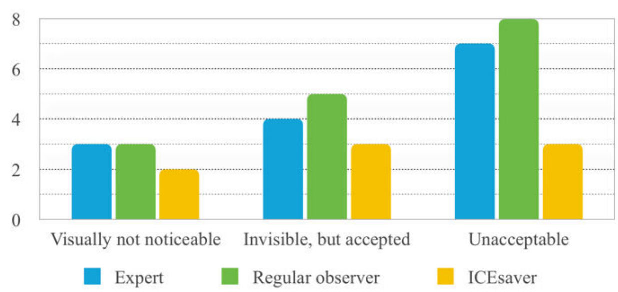


**Figure-1.** Criteria of evaluation of color differences.

To select a set of test colors, you should be guided by the color discrepancy parameter. Taking into account that the vast majority of observers are not specifically trained in color differences, and given that the multimedia image is dynamically selected to construct a color set, the distance between colors is 5 units. CIE. The

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choice of this distance is due to the calculated capabilities and the time it takes to complete the work.

### 3.2 Color Set

Since the shooting and observation conditions may be different, a color perception model should be used to build a set of test colors. It should be noted that the base model is CAM97 [12] and its modifications CAM02 [13], CAM06 [14], iCAM16 [15]. Significant progress has been made in taking into account the physiological features of vision. If necessary, color perception can be simulated in different ambient conditions, such as the background brightness, the surroundings, as well as the color coordinates of the light source. This model is relevant and can be effectively used after the light-to-converter but does not work at the spectral level, and adapting it to multimedia applications remains an urgent task.

Applying the criterion defined in the previous paragraph and assuming that the conditions of adaptation on the transmitter and receiver sides are the same: light $J = 30$, which corresponds to the relative brightness of the image $Y \approx 0.2$, the shooting and observation conditions are average (assumed to be daytime illumination), the distance between adjacent colors $\Delta E = 5$.

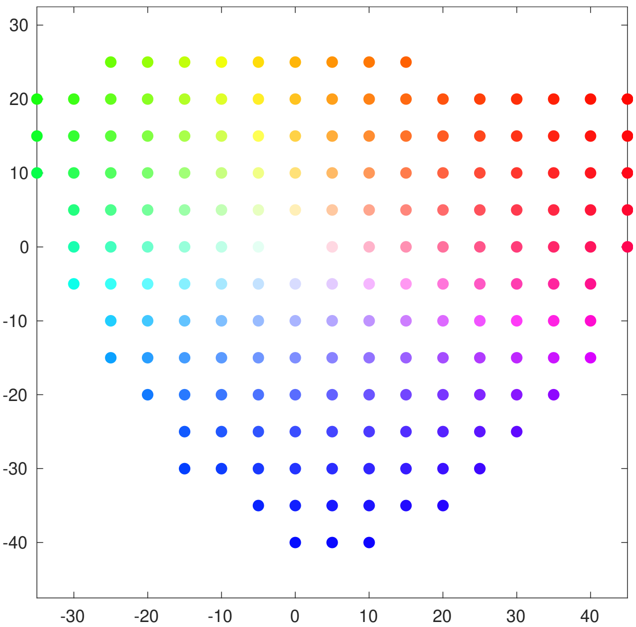


**Figure-2.** Color set for $J = 30$, Viewing Conditions = average, $L_A = 50\frac{cd}{m^2}$, $\Delta E = 5$.

The presented set of colors Figure-2 (modeling is made using the environment of Matlab simulation [16]) in the coordinates of the equidistant system has some limitations and should be separated:

- limitations due to the characteristics of the video system - limited dynamic range in brightness, spectral characteristics of sensitivity [17, 18];
- the limitations caused by the color perception properties of different adaptive factors - observation conditions, image brightness, background brightness, adaptation brightness.

For other input parameters, the color set is shown in Figure-2 may be different, so the algorithm presented in [5] should be used for the recalculation.

#### A. Find the optimal spectra for the given color coordinates

Each color $C$ of the set shown in Figure-2, we can map the distribution of the even-energy spectrum in the range $\lambda \in (360 \ldots 720)$ nm, which represents one part of the spectrum with a certain level $k$,

$$C = \begin{cases} k & for \quad \lambda \in (\lambda_1 \ldots \lambda_2) \\ 0 & for \quad \lambda \in (360 \ldots \lambda_1) \& \lambda \in (\lambda_2 \ldots 720) \end{cases},$$

and two sections of the spectrum,

$$C = \begin{cases} k & for \quad \lambda \in (360 \ldots \lambda_1) \& \lambda \in (\lambda_2 \ldots 720) \\ 0 & for \quad \lambda \in (\lambda_1 \ldots \lambda_2) \end{cases}.$$

To find the values $(\lambda_1, \lambda_2)$ the problem of finding the minimum is solved, where the main criterion is the minimum discrepancy between the given coordinates $X_O, Y_O, Z_O$ (Figure-2) and the coordinates obtained after solving the problem of finding the minimum $X_C, Y_C, Z_C$. In this case, to calculate the reference colors shown in Fig. In Figure-2, the energy spectrum $P(\lambda)$ was used as well as the standardized CIE spectral characteristics of vision $(\bar{x}, \bar{y}, \bar{z})$.

$$\{X_C, Y_C, Z_C\} = \sum P(\lambda) C(\lambda_1, \lambda_2) \{\bar{x}, \bar{y}, \bar{z}\} \tag{2}$$

This is a crucial parameter $\Delta$,

$$\Delta = |\{X_O, Y_O, Z_O\} - \{X_C, Y_C, Z_C\}|.$$

For all the set $N$ of existing values $(\lambda_1, \lambda_2)$ there is a set of values $\Delta$ which must correspond to the expression $\lim_{N\to\infty} \Delta \to 0$. The initial value for further calculations is $C(\lambda_1, \lambda_2)|_{\Delta\to\infty}$.

#### B. Effect of different light sources on color rendering

Using (2), we can calculate the values of $X_L, Y_L, Z_L$ for a light source with an arbitrary spectral distribution $P(\lambda)$. In this case, the determination of $\Delta E$ will be obtained using (1) according to the scheme presented in Figure-3.

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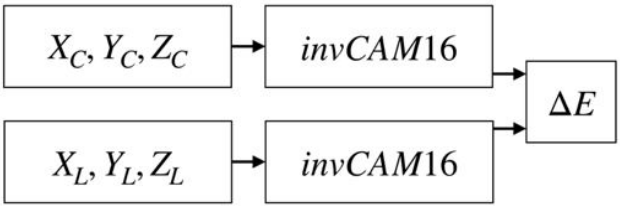


**Figure-3.** Determination of the value of the vector of change of color coordinates.

Figures 4-7 present the change of color coordinates using the spectral distribution of light sources type A, F1, F315, HP1 [19]. The figures show + - color coordinates that uniformly fill the area of the transmitted color, Figure-2, and • - color coordinates after illumination of optical samples by a light source with an excellent spectrum.

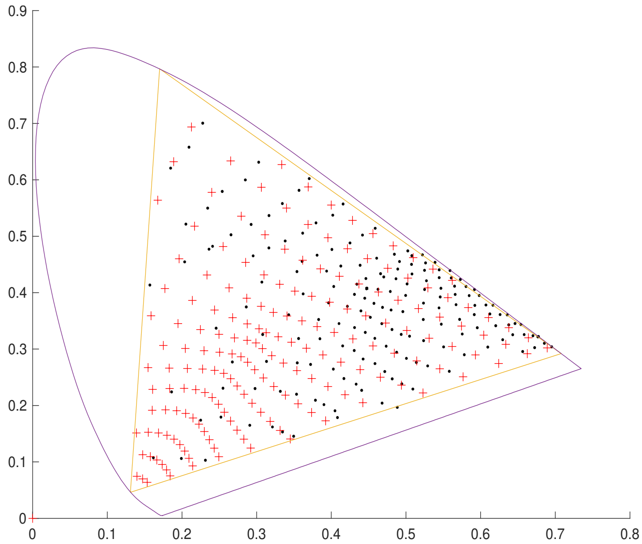

**Figure-4.** Color point variable when illuminated by a type A lighting source.

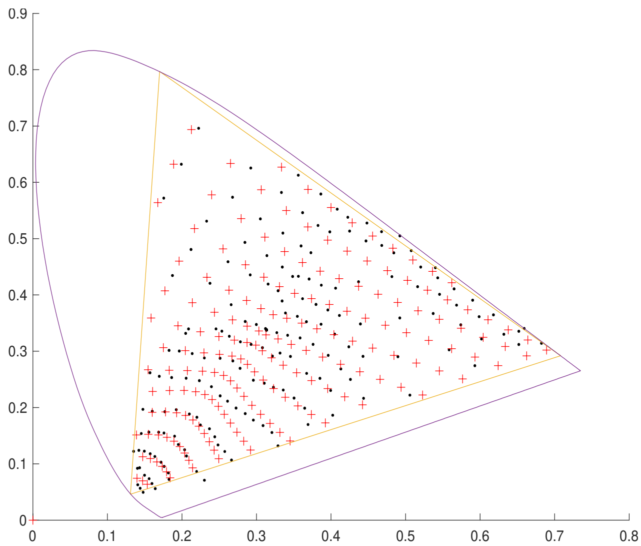

**Figure-5.** Color point variable when illuminated by a type F1 lighting source.

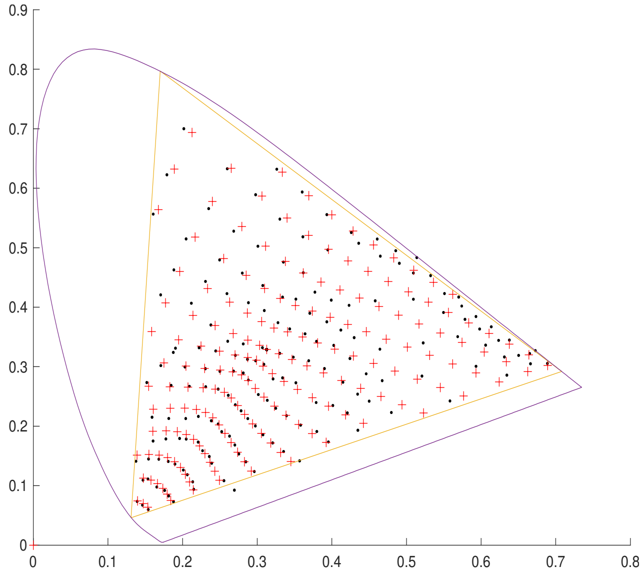

**Figure-6.** Color point variable when illuminated by a type F315 lighting source.

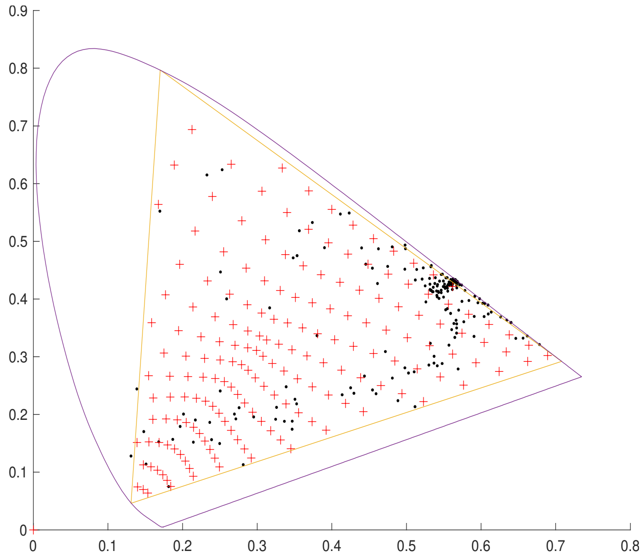

**Figure-7.** Color point variable when illuminated by a type HP1 lighting source.

The results presented show that the algorithm can operate with an arbitrary spectral distribution of light sources. It also lets to determine the magnitude of the color coordinate vector. It should be noted that some of the points are beyond the boundaries of the color triangle, these points are obtained under different conditions of adaptation to one side of the multimedia path. This color was perceived by man as if the system could reproduce it.

### 3.3. Determination of Correction Coefficients

The correction factor is the inverse of the vector of change of color coordinates $1/_{\Delta E}$, expressed in the coordinates of the color space. Given that the values of the color coordinates in the image are $n \times m$, where $n$ is the number of activity counts per line and $m$ is the number of

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rows, the number of correction coefficients is equal to the number of image.

The coefficients are calculated using the reference colors $X_O, Y_O, Z_O$ and the resulting illumination by an arbitrary light source $X_C, Y_C, Z_C$. The coefficients are calculated using the formulas,

$$k_1 = {}^{X_O}/_{X_C},\ k_2 = {}^{Y_O}/_{Y_C},\ k_3 = {}^{Z_O}/_{Z_C}. \qquad (3)$$

It should be noted that for different points the magnitude of change has different magnitude, respectively, and the coefficients $k_1, k_2, k_3$ will also have different values. The values of the coefficients belong to the interval $k_{\{1,2,3\}} \in (0 \dots 1)$.

Theorem. For arbitrary $\mathrm{X_i}, \mathrm{Y_i}, \mathrm{Z_i}$ multimedia image coordinates, there are $\mathrm{X_O}, \mathrm{Y_O}, \mathrm{Z_O}$ coordinates, such that the difference between them (Δ) is zero.

If the theorem holds, then the values of the correction coefficients 〖$k_{1_i}, k_{2_i}, k_{3_i}$, and the correction coefficients are calculated by the formula,

$$\begin{pmatrix} X_{O_i} \\ Y_{O_i} \\ Z_{O_i} \end{pmatrix} = \begin{pmatrix} k_{1_i} & & \\ & k_{2_i} & \\ & & k_{3_i} \end{pmatrix} \begin{pmatrix} X_i \\ Y_i \\ Z_i \end{pmatrix}.$$

if the value $\Delta E_i$ does not exceed the threshold of impermissible changes, Figure-1, such coordinates need not be multiplied by the correction coefficients. Visually, the algorithm is presented in Figure-8.

## 4. DISCUSSION OF RESULTS

The criteria for estimating the magnitude of color changes were systematized and presented, and these criteria are presented in Figure-1. Using the criteria, the distance between colors in an even-contrast system was determined and a grid of equidistant grid of color coordinates was constructed, which is presented in Figure-2. Color grid step 5 units selected CIE as the distance identified by the ordinary observer as acceptable changes. To take into account the magnitude of the effect of light sources on color, an algorithm for constructing optimal spectra was proposed. Thanks to the obtained spectra it was possible to determine the magnitude and nature of the influence, Figures 4-7 propose an algorithm for calculating the offset coefficients. It should be noted that the accuracy of determining the coefficients depends primarily on the number of colors in the set. On the other hand, increasing the color set increases the calculation time.

In Fig. Figure-8 presents an algorithm for taking into account the influence of an arbitrary spectral distribution of a light source. It is also proposed to reduce the calculation time of the original color values by determining the coefficients only for the points where the parameter $\Delta E \geq 5$.

## 5. CONCLUSIONS

In the work, we proposed an algorithm that allows us to adapt multimedia images to conditions when the illumination has an arbitrary spectral distribution. First of all, the operation of the specified algorithm was made possible by the use of an even-contrast model of color perception and algorithms of spectral adaptation.

This algorithm is extended to use in multimedia systems with an arbitrary resolution of the transmitted image.

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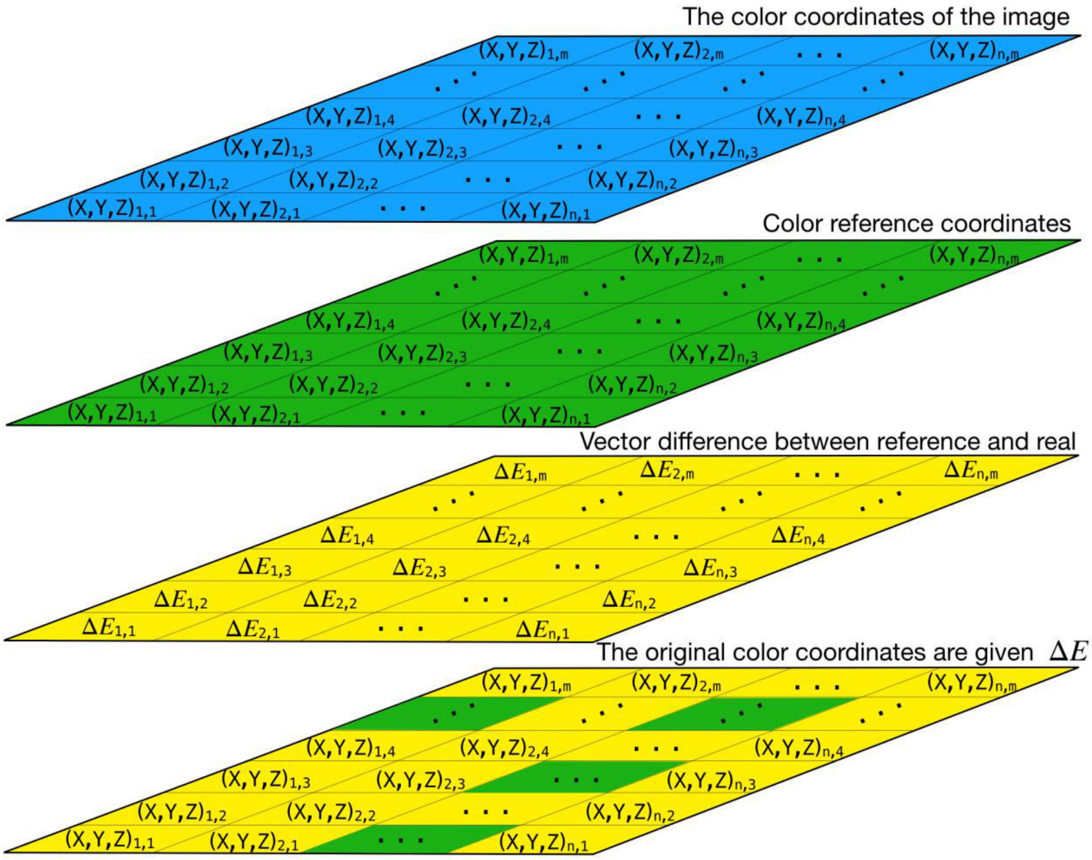


**Figure-8.** Picture of the algorithm for correction of multimedia images when illuminated by a light source with an arbitrary spectral distribution.

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