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AN ERROR OF TRANSMITTING A COLOUR BY VIDEO PATH AFTER USE OF A RANDOM SPECTRAL DISTRIBUTION OF LIGHT AND END-PATH DEVICE

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ABSTRACT

This work is aimed at studying the colour rendering parameter in telecommunication paths. The authors present an analysis of the existing problem, which may occur when introducing machine vision and artificial intelligence training systems. An important feature that is discussed in this paper is the influence of the light source and the parameters of the final equipment. The authors also discuss a comparative analysis of the influence of various light sources, and those differing from the reference spectral characteristics of the camera. Conclusions are made about the possibility of eliminating colour rendering errors in telecommunication paths. Recommendations are presented to show how to reduce the impact on colour rendering quality.

Keywords: colour constancy, colour rendering, image quality, colour appearance model, uniform colour space, adaptive television, multimedia systems.

INTRODUCTION

The current trends in the development of technologies in the field of artificial intelligence give rise to new, higher requirements for the information received, such as photo and video information. In [1-4], the authors address the problem of the correctness of transmitting video information, taking into account the properties of human perception. It should be noted that references [1-4] are fundamental to this topic, and are also the beginning of the progress of the field of knowledge. The authors point to the multifunctional dependence of the properties of perceptions, as well as offer an analytical apparatus to account for all properties.

This direction is parallel to existing colour correction algorithms that exist in the form of various filters and adaptation to brightness. However, the distinctive feature of such algorithms is the lack of the ability to dynamically adapt the image to the desired quality level, while also considering the spectral characteristics. This work aims to study the possibility of dynamic adaptation of the image to conditions on the transmitting and receiving ends.

LITERATURE

Modern tools for assessing quality are aimed at using metrics in colour spaces such as Lab and Luv [5]. These tools should be attributed to the former colour space. However, during the appearance of the system, they were not widely used due to the complexity of changes in the equipment of receivers of that time. The next colour perception model, the CIECAM97, was a follow up to the Lab and Luv colour spaces and took into consideration more properties of human perception [6]. It produced a more comprehensive colour appearance model, and had a more uniform colour space. It was designed for three types of viewers, those with small, medium and large colour differences. It should be noted that this system is taken as a basis for the construction of subsequent modifications.

Since the CIECAM97 model had complex mathematical requirements for the technical capabilities of that time and resulted in several inaccuracies. Hence, a simplified and more augmented model was developed, the CIECAM02 model [7]. It later became the basis for the construction of subsequent colour perception models. The CIECAM02 model, however, did not solve the problem when negative values of cone reactions were obtained at low brightness values, which physically cannot be, this phenomenon was traced in the direct and inverse transforms [7].

A number of refinements and improvements are reflected in the CAM06 colour vision model, which was derived from the iCAM model developed by Fairchild and Johnson [8]. The advantage of this model is to produce a more uniform colour chart in the field of red and blue colours. Despite this uniformity, however, inaccuracy could manifest itself on the boundary conditions of the functional dependencies of the model. These inaccuracies were considered in the CAM16 model [9]. Fairchild [10], the author of the iCAM perception model, claims that, in the coming years, a fundamentally new model will not appear. Fairchild has further proposed to use the CAM16 model in further studies.

Nevertheless, these models are still aimed at the average viewer, and for other features that may occur, they may not be reflected by the specified colour perception model. Since adaptation algorithms should be used to account for all possible characteristics of the viewer, this is beyond the scope of this article. Instead, this work uses the CAM16 model to study the magnitude of the change in colour coordinates depending on various factors affecting colour reproduction. It further reflects on the factors that cannot be excluded by traditional video transmission

ARPN Journal of Engineering and Applied Sciences

systems. The purpose of the article is to provide a solution aimed at reducing the amount of colour distortion.

Factors Influencing the Through Route Using the Adaptive Model

To effectively provide a solution for reducing the amount of colour distortion, several factors need to be considered for assessment as unacceptable distortions. More information about the criteria for assessing the quality of colour perception can be found in [11-13].

The colour rendering quality can be influenced by several factors and their number may vary depending on various shooting or playback conditions. The main factors, including those presented in Figure-1, are:

a) The brightness level (Y): a physical limitation is caused by limitation by the dynamic range of brightness transmitted by multimedia systems;

b) The background brightness (Y_b): it is a factor that adapts vision; its influence does not have a significant effect as shown by Gofaizen and Pilyavskiy in [14]. Combined with other influences, however, it can lead to unacceptable distortions;

c) The spectral distribution of light sources ($P(\lambda)$): it is a random factor since the spectral distribution of two of the same type of light sources may differ; studies are underway in this direction [15];

d) The spectral distribution of cameras (x_{10}, y_{10}, z_{10}): it is also a quasi-random factor, since not all manufacturers adhere to international standards [16] and calculations [17]. Hence, there are no standards for spectral characteristics in ITU standards, for example;

e) The spectral characteristics of the sensitivity of human vision (x_c, y_c, z_c): it is a random process since the spectral characteristics of vision vary for different people and differ from one eye to another;

f) The spectral characteristics of reproducing devices (x_d, y_d, z_d) deserve a separate study due to the wide range of varieties of reproducing devices. These characteristics can be divided into self-luminous, projecting, and holographic. Another characteristic that is to be included is the number of primary colours and their spectral attributes [18].

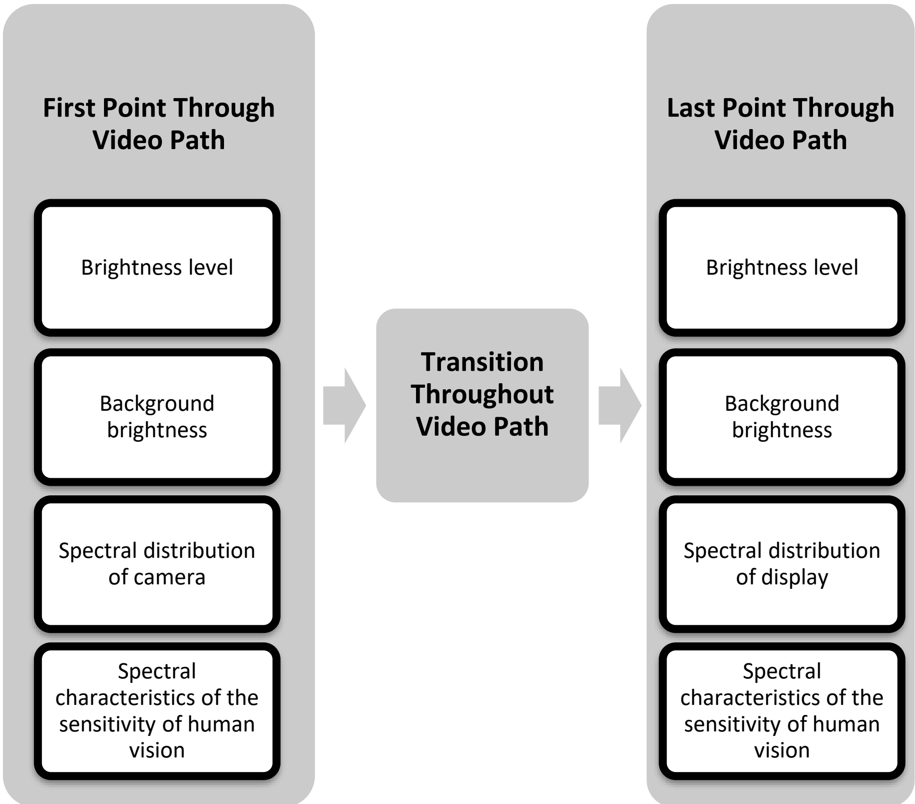


Figure-1. Factors affecting colour rendering quality.

In Gofaizen's research [19], an orthogonal grid was presented for evaluating the colour rendering quality, but its disadvantage is that it could not evaluate equal colour points. This drawback leads to complex estimation difficulties when it comes to colour distortion of a given saturation. To this effect, the article proposes to use a radial grid as a tool for evaluating colours of equal hue.

Construction of a Radial Grid

The radial grid was built based on the characteristics of colour perception and the required accuracy. Based on the characteristics of colour perception, a distance of 5 CIE units was selected for the space between adjacent radial colours. This distance is estimated to be "noticeable, but acceptable distortion". The number of radial lines chosen was 20, based on the unwanted clutter of the picture. For real conditions of measurement, however, the values used would be significantly higher.

The set of colours used is shown in Figure-2, where the colours are presented in an equidistant space (a space in which the distance between the colours has equal values). The colour set is presented in the CAM16 coordinate system. While the colours have the same lightness, namely 50 units, the conditions under which the colours were built are average, as is the brightness of the vision adaptation of 50 cd/m^2.

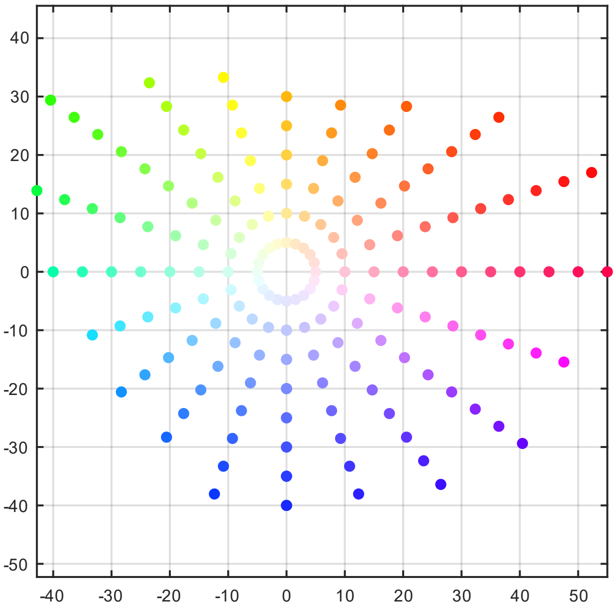
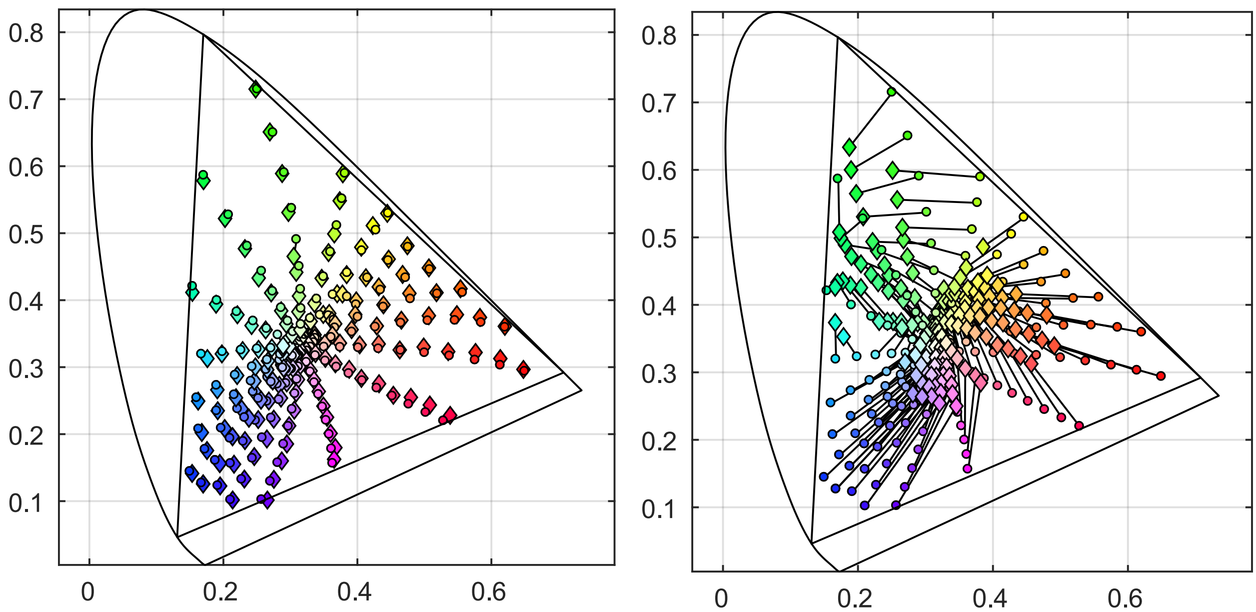


Figure-2. A set of colours in the coordinates of the model CAM16-UCS, LA = 50, VC = average, grid type = radial, ΔE = 5, lightness = 50, set of radial line = 20.

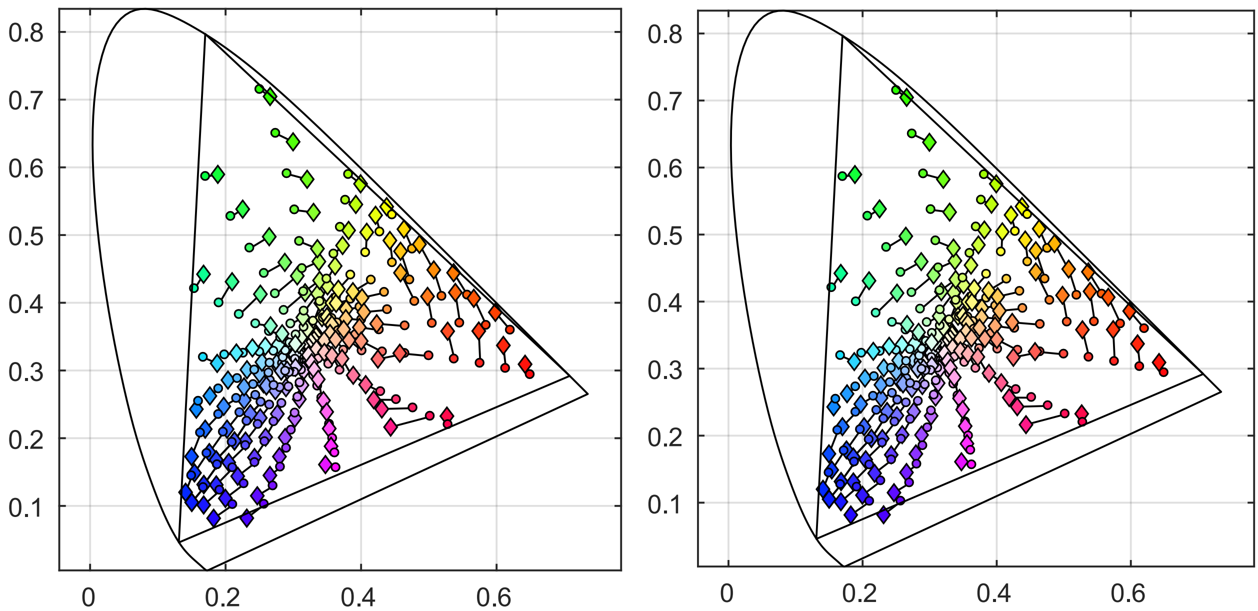
The research implemented used light sources of the type F315, F1 (fluorescent light sources), HP1 (high-pressure lamp), D65 (the light source used for studio lighting), and A (warm light used for domestic street lighting, and in-house lighting in the form of light bulbs). The spectral characteristics of the camera are also used [20]. These characteristics differs from flawless ones and can serve as an example of the influence of real camera characteristics on the colour rendering quality. Figure 3 to 6 show the results of the study.

Visually, you can evaluate the colour rendering quality. In the figures, the circle represents the value of the measuring colour, the rhombus represents the colour obtained after the influence of one or a combination of factors. Colours are connected by a line for a visual vector of colour coordinate changes. This data is presented in *xyz* coordinates, which are generally accepted and are currently being used. Despite that, the *xyz* coordinate system cannot be used due to the unevenness of its colour space.



(a) (b)

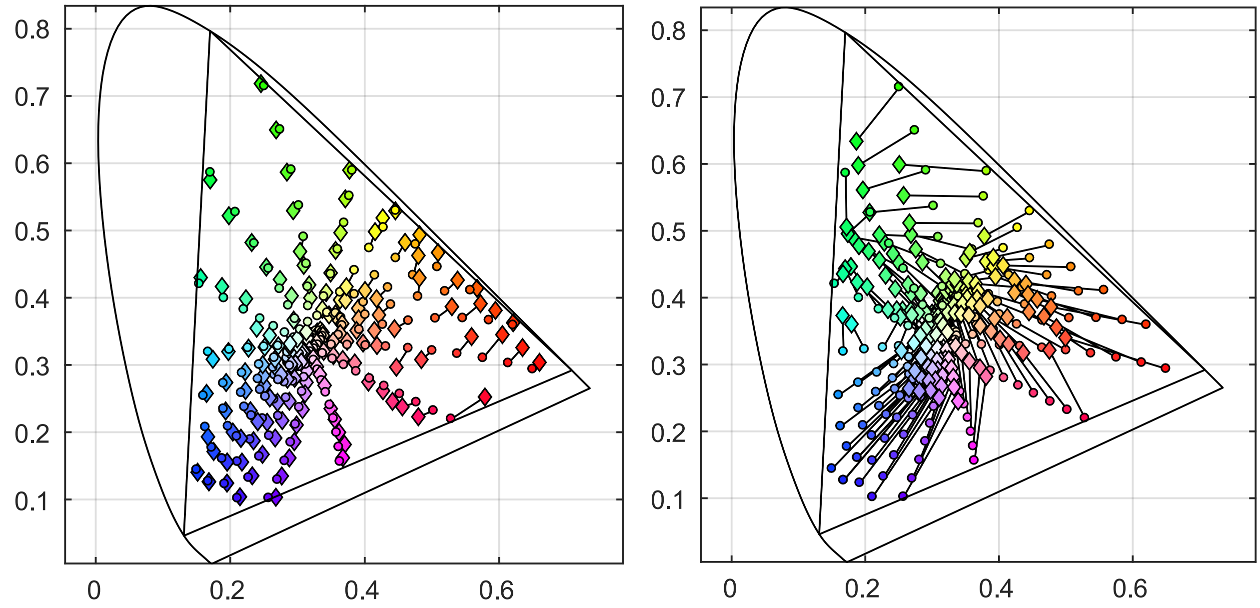
Figure-3. Effect on the colour rendering of the D65 (a) light source in conjunction with the BaslerAG camera (b).



(a) (b)

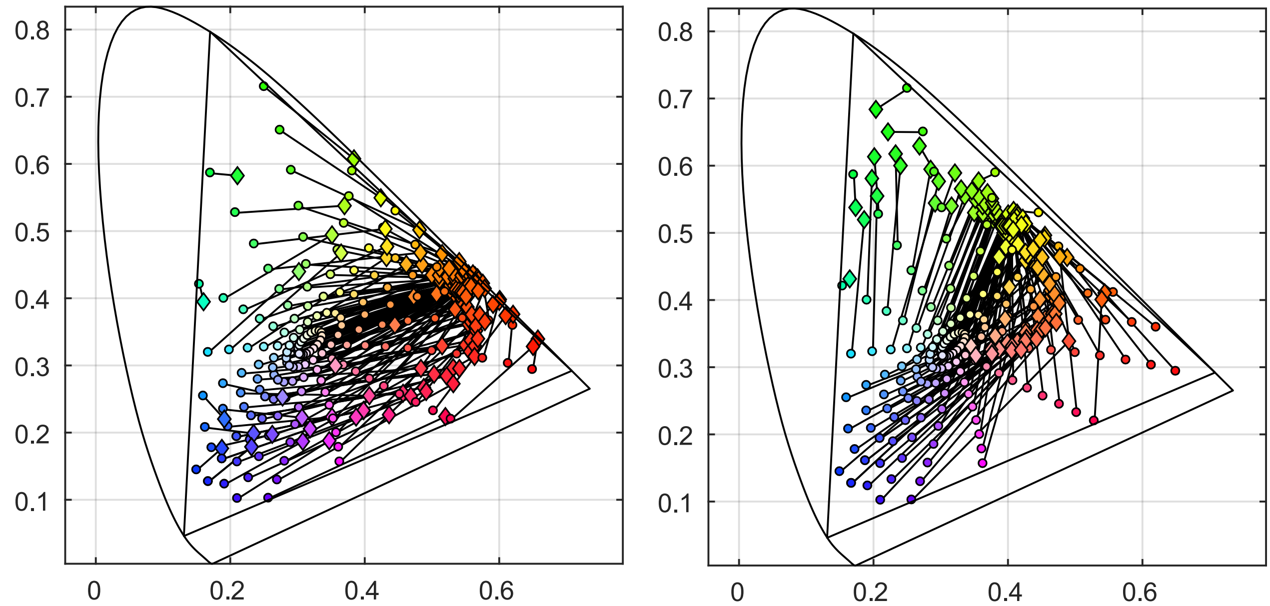
Figure-4. Effect on the colour rendering of the F1 (a) light source in conjunction with the BaslerAG camera (b).

ARPN Journal of Engineering and Applied Sciences



(a) (b)

Figure-5. Effect on the colour rendering of the F315 (a) light source in conjunction with the BaslerAG camera (b).



(a) (b)

Figure-6. Effect on the colour rendering of the HP1 (a) light source in conjunction with the BaslerAG camera (b).

Error Measurement Algorithm

Based on the research conducted above, the error ΔE can be represented as a sum of errors that are obtained as a result of the influence of factors presented in Figure-1. The record can be represented as Formula (1):

$$\Delta E = \Delta E_{\mathrm{Y}} + \Delta E_{\mathrm{Yb}} + \Delta E_{\mathrm{P(l)}} + \Delta E_{\mathrm{x10,y10,z10}} + \Delta E_{\mathrm{xc,yc,zc}} + \Delta E_{\mathrm{xd,yd,zd}} + \cdots + \Delta E_{\mathrm{N}}, \quad (1)$$

where N is the set of factors (i) that may occur in colour rendering, $N \in (0, \infty)$.

Moreover, ΔE_{i} can be written as an expression (2).

$$\Delta E_i = \left[\left(a_{M_{i_{etalon}}} - a_{M_{i_{out}}}\right) + \left(b_{M_{i_{etalon}}} - b_{M_{i_{out}}}\right) + \left(J_{i_{etalon}} - J_{i_{out}}\right)\right]^{1/2} \quad (2)$$

Where a_{Mi}, b_{Mi}, and J_{i} are the chromaticity coordinates of the equidistant coordinate system CAM16, i_{etalon} is the test point of a set of colours is presented in Figure 2, and i_{out} is the point that is obtained at the output of the system, reproducing device, orperceived by a person.

Modelling Results

The result of the simulation is the amount of colour rendering error, which must be taken into account to achieve the correct colour reproduction. Colour-correction can be performed at any point on the path, provided that ΔE is present. Figures 7 and 8 present the error values that occur when using the spectral characteristics of the camera and light sources.

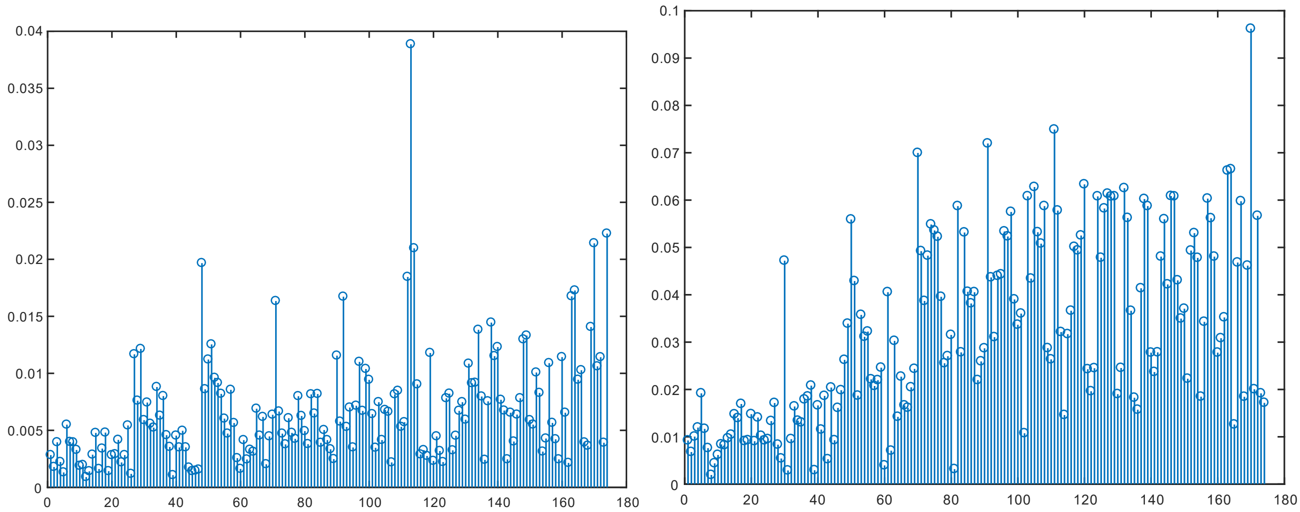
The correction factors can be calculated based on the error ΔE and presented in the form of Formula (3):

$$\{J_{cor}, a_{M_{cor}}, b_{M_{cor}}\} = \{J_{out}, a_{M_{out}}, b_{M_{out}}\} - \Delta E \qquad (3)$$

where J_{cor}, a_{Mcor}, b_{Mcor} are the colour coordinates after colour correction.

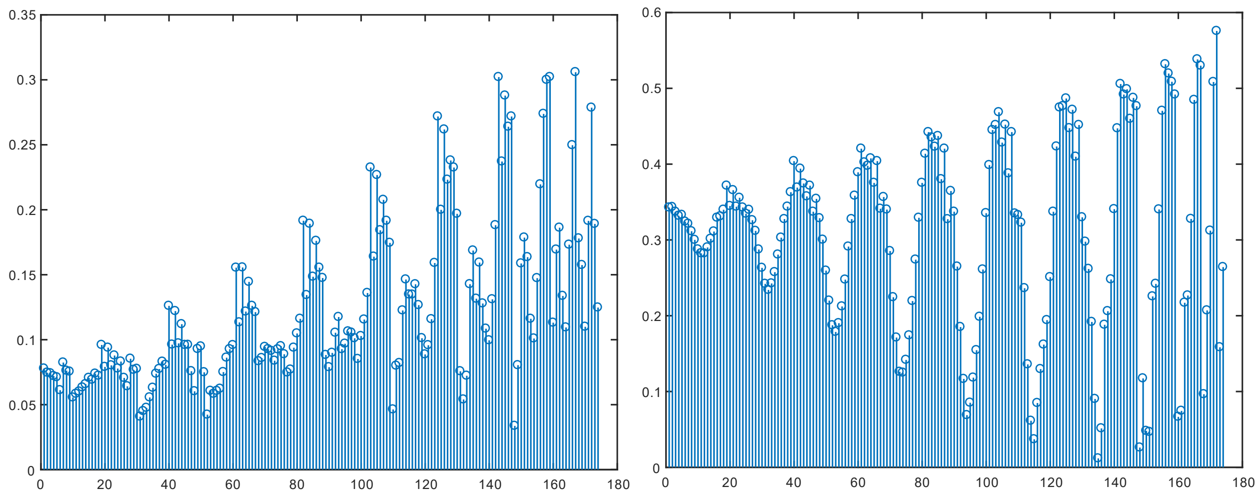
Formula (4) may also be used as a means to go to the the more widely used coordinate system:

$$\left(J_{cor}, a_{M_{cor}}, b_{M_{cor}}\right)_{iCAM16} \Rightarrow XYZ \qquad (4)$$



D65 F1

Figure-7. The error ΔE when using a real camera and a light source such as D65 and F1.



F315 HP1

Figure-8. The error ΔE when using a real camera and a light source such as F315 and HP1.

CONCLUSIONS

The paper presented an analysis of existing colour perception models that can be used to obtain an estimate of the influence of various factors, the main of which were shown in Figure-1. In the course of the research, it was shown that the spectral distribution of light sources to varying degrees affects the quality of colour reproduction. The magnitude of the influence is expressed by a vector with its orientation and length for varying points of the colour chart, as shown in Figures 3 to

6. It also deduces from the figures that, with different lighting sources, the effects are manifested in different ways. Therefore, it is not possible to know in advance the effect on a certain colour, where this should happen dynamically, in the form of an algorithm. Estimating the magnitude of the influence, and based on the evaluation criteria [14,21], the distortions have inadmissible values.
The distortion value fluctuates several times, in comparison with the ideal camera rendering, when the values shown in figures 3-6 (a) are assessed against the values in figures 3-6 (b)

In conclusion, this work proposed analytical expressions that allow a viewer to adjust the magnitude of the effect, in the presence of the calculated value of the error vector on the transmitting side. Formulas 1-4 are based on the equal-colour model of CAM16 colour perception. Therefore, the estimates obtained in this work are designed to account for the properties of human vision. For greater convenience and to allow for the possibility of applying the algorithm to the currently existing systems, the same values are presented in the *xyz* coordinate system.

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