OBJECTIVE ASSESSMENT OF COLOURS' WARMTH

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Broadcast television systems are initially designed for human image perception under transmission conditions in a limited spectrum range therefore, broadcast television is consistent with the parameters of the human visual system and does not exceed them. In turn, applied television systems, which include, among other things, radiography, bolometry and remote sensing of the Earth, are designed to register specific objects. At the same time, the sources of recorded radiation are sunlight outside the non-visual range, X-rays, infrared rays, the range and conditions of propagation of which are significantly different from visible sunlight. To register this radiation accurately, television systems with parameters that differ significantly from the human visual system are needed. In this article, the possibility of colour contrast in applied television systems with a wide dynamic range is considered and a method for assessing the perception of the warmth of colour shades is proposed. To do this, at the first stage, a colour space is selected that specifies a coordinate system for colour shades. Next, a selection of colours is formed in the colour space, participating in further studies to assess the perception of colour warmth. The scientific work also discusses the creation of a test trial. An algorithm is presented for a web program that conducts a survey of the subject. Subject survey data is stored on a separate server and is available for further processing. The following is an example of processing preliminary data for 18 colour shades, but it is proposed to further expand the number of colour shades to 36.

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Introduction

Today there are many applied television systems, the parameters of which differ from the parameters of conventional broadcast television. Broadcast television systems are initially designed for human image perception under transmission conditions in a limited spectrum range therefore, broadcast television is consistent with the parameters of the human visual system and does not exceed them. In turn, applied television systems, which include, among other things, radiography, bolometry and remote sensing of the Earth, are designed to register specific objects. At the same time, the sources of recorded radiation are sunlight outside the non-visual range, X-rays, infrared rays, the range and conditions of propagation of which are significantly different from visible sunlight. To register this radiation accurately, television systems with parameters that differ significantly from the human visual system are needed. The dynamic range is one such parameter that is particularly important [1, 12].

The inconsistency of dynamic ranges in television and visual systems forces to use image post-processing. For example, the dynamic range can either be compressed or colour contrast methods can be applied to the image, increasing the information content of the image due to the fact that a person sees more colours than gradations of brightness (a million shades [1] versus 200 gradations of brightness [2,3]).

This scientific work is based on previous [4,5,6] works, in which the problems of choosing a colour space were solved [4], distributing a sample of colours shades [5] in the colour space, which will later represent interpolation nodes, and preliminary assessment psychophysical perception of the warmth of colour shades [6] for a section of CIE LCH space at the brightness point L=0, all points of which have brightness L=0. In this work, the perception of colour warmth will be assessed for the entire CIE LCH three-dimensional space. The nodes obtained in [5] will be used as interpolation nodes.

Color contrast

One possible way to increase the contrast of an image is color contrast. Color contrast - increasing the information content of an image by replacing gradations of brightness with color tones. A person sees about 200 gradations of brightness [1, 2]. At the same time, a person can distinguish about a million shades of colors [3]. Thus, luminance gradations in an image with a high dynamic range can be translated into chromaticity gradations, which will increase the information content of this image.

The principle of the color contrast method is as follows.

Let's take an image of a linearly increasing black and white signal from minimum to maximum, shown in the figure...

Let's divide the amplitude range of the input signal into 6 sections. Each section of the input signal must be assigned its own range of colors on the color triangle R, G, B, that is, in the level range of the first section I, we must submit three signals to the three-beam kinescope, varying according to a given law. In this case, it should be taken into account that colors (hue and brightness) are not repeated in more than one area. If the assigned colors lie in the plane of Maxwell's color triangle, then the brightness of the areas of the colored black and white image will be the same. Here, the sum of the potentials on the electrodes of the kinescope must be constant over the entire brightness range of the black and white image, that is

$$u_R + u_G + u_B = const \qquad (1)$$

If condition (1) is not satisfied, then in addition to changing the color tone, the brightness of the painted areas will also change, which corresponds to color triangles lying in different planes of the primary color coordinate system. This coloring algorithm gives a large range of visually distinguishable colors and is therefore preferable to the first.

Choice of colour space

Nowadays, there are many colour spaces that serve different purposes. Television uses three-colour colour spaces similar to CIE 1931[4]. However, this colour space has a factor that significantly influences the solution of the problem [3]. This factor is the McAdam ellipses. McAdam ellipses are areas in colour space within which colour characteristics do not change. In terms of the goals of amplitude colour contrast, this means that several gradations of brightness will correspond to the same colour shade [5]. As a result, the information component of the processed image will decrease.

To solve this problem, it is necessary to choose a colour space in which McAdam ellipses are either absent or have a minimal area, that is, they meet the condition of equal contrast.

The first option for such a color space is CIE Lab. This color space was developed to eliminate the non-linearity of the CIE XYZ model. L means lightness (from 0 to 100), A is the position between green and magenta, B is the position between blue and yellow. In this case, McAdam ellipses are transformed into circles of the same size.

The disadvantage of CIE LAB is the difficulty in working with the coordinates of an individual shade. This plays an important role because, as will be seen later, to assess the warmth and coldness of colors and shades, it is necessary to form a sample of points. However, the CIE LAB space, like its slices, has a complex shape, which makes it difficult to form a color sample.

Based on this, it is necessary to choose a color model that will be simple both for the sampling task and for translation into CIE LAB. Such a space is CIE LCH. This space, like its slices, has a simple shape, which makes it possible to effectively solve the problem of sampling. CIE LAB is converted to CIE LCH using the formulas:

$$L = L$$

$$C = \sqrt{a^2 + b^2} \qquad (2)$$

$$H = \begin{cases} \arctan\left(\frac{b}{a}\right), если \ \arctan\left(\frac{b}{a}\right) \geq 0 \\ \arctan\left(\frac{b}{a}\right) + 360°, если \ \arctan\left(\frac{b}{a}\right) \leq 0 \end{cases}$$

Despite its simplicity, using the CIE LCH space to construct a traversal path has its drawbacks, since the McAdam ellipses have an irregular shape (Fig. 1), which impairs the linearity of the perception of color contrast.

However, in this space it is possible to form a selection of colors to assess the warmth and coldness and set key points for the traversal path. Once the warm-coolness has been estimated for a sample of colors and shades, the sample can be converted to CIE LAB.

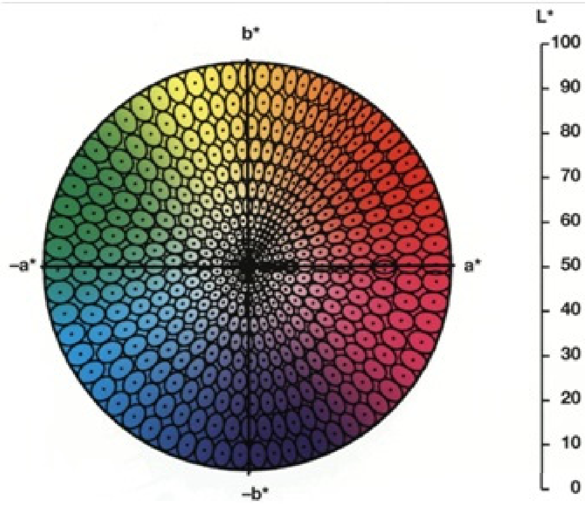

Fig. 1. CIE LCH color space slice with MacAdam ellipses

Overview of traversal algorithms

There are many algorithms for constructing a traversal path, each of which has both advantages and disadvantages [10, 11]. For example, the stigma-shaped algorithm has high performance, and the spiral-triangular algorithm has a wide coverage of colour space shades.

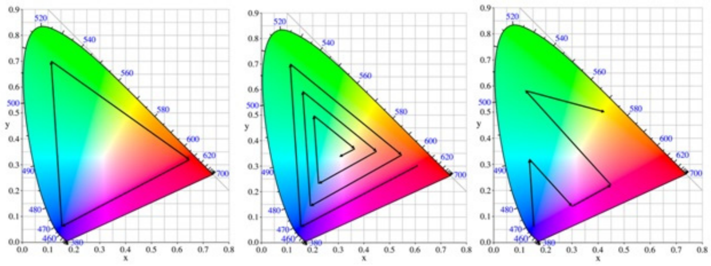

Fig. 2. Algorithms for traversal paths. Triangular algorithm, spiral-triangular algorithm, stigma-shaped algorithm

However, the considered algorithms either cover a small number of shades or are not intuitively clear, which can negatively affect the operator's interpretation of the results of the processed image.

One of these methods is a method based on the quantum hypothesis of colour vision [11, 12], developed by Mazurov A.I. and Denisov A.K. [2]. Using this method allows to obtain a psychological compatibility of the coloured image that is close to the original one.

In the quantum hypothesis colour is determined by the following parameters: the number of photons absorbed by the visual system, or brightness (F), the total energy of these photons (E or $F\overline{\varepsilon}$) and its dispersion $F\overline{\varepsilon^2}$. ε – is the average photon energy, ε^2 – is the square of the average photon energy.

Psychological compatibility is ensured by preserving the brightness image of the original photograph and the continuity and monotony of the colour scale trajectory by F, $F\overline{\varepsilon}$ и $F\overline{\varepsilon^2}$. This is accomplished using the following equations:

$$\begin{aligned}
&\frac{F}{F_b} = L_R * U_R + L_B * U_B + L_G * U_G \\
&\frac{E}{E_b} * \epsilon_b = L_R * U_R * \epsilon_R + L_B * U_B * \epsilon_B + L_G * U_G * \epsilon_G \\
&\frac{D(E)}{D(E)_b} * \epsilon_b^2 = L_R * U_R * \epsilon_R^2 + L_B * U_B * \epsilon_B^2 + L_G * U_G * \epsilon_G^2
\end{aligned} \tag{3}$$

where F, E, D(E) – brightness, energy and energy dispersion at points of the colour scale; F_b, E_b, $D(E)_b$ – the same values in white; L_R, L_B, L_G – brightness coefficients of the red, blue and green colours of the monitor; U_R, U_B, U_G – voltage at the input of the red, blue and green channels of the monitor; (ϵ_R ϵ_R^2), (ϵ_B ϵ_B^2), (ϵ_G ϵ_G^2), (ϵ_b ϵ_b^2) – chromaticity coordinates of the monitor's red, blue, green and white colours in the FED(E) colorimetric system [14, 15].

Computer modelling of colorization of radiographic images in accordance with this system of equations showed the psychological compatibility of the original and processed images [16].

Colour contrast is calculated using the following formula:

$$K = K_B \pm K_C = \frac{\Delta \overline{F}}{F_f} \pm \left(\frac{\Delta \overline{\epsilon}}{\overline{\epsilon_f}} + \frac{\Delta \overline{\epsilon_f}}{\epsilon_f^2} \right) \tag{4}$$

where K_B – brightness contrast, K_C – chromaticity contrast.

Scientific work carried out by Shi Xie-Qi and co-authors, Moon Suh Park et al. and Elliot Varney and Andrew Smith [8] showed that the colour scale can provide additional information in the field of medical radiography to make a more accurate diagnosis. In a study [9], colour contrast was used in conjunction with neural network processing, which increased the accuracy of the neural networks.

Blinov N.N. and Mazurova A.I. in their research on the importance of colour sensation and psychological perception of colour. Colour perception increases the perception of gradation resolution and facilitates the perception of three-dimensional images.

A method for objective perception assessment of colour shades warmth

This research paper presents a test to evaluate the perceived warmth of colour shades from a sample of colour in a colour space, followed by the creation of a colour contrast algorithm. This will allow us to further develop an intuitive algorithm that covers the maximum possible number of shades. To do this, it is necessary to add to the algorithm a parameter that will help human perception. Since the work solves the problem of colour contrast, we can choose the warmth of colour as such a parameter for human perception. This option is used in some application television systems. For example, it has become widespread in the processing of barometric images, as can be seen in Figure 2 [8].

Fig. 3. Barometric image with colour contrast

As can be seen in Figure 3, the brightness levels responsible for cold temperatures correspond to “cool colours”, and for warm ones – “warm”.

A person’s perception of colour warmth refers to a parameter that affects the perception of a hue as “warm” or “cold” depending on hue and saturation [9]. The perception of the warmth of colour shades is a subjective parameter used mainly in the artistic field [2].

The book [9] examines the warmth of colour from the point of view of colour temperature for the black body model (Fig. 3).

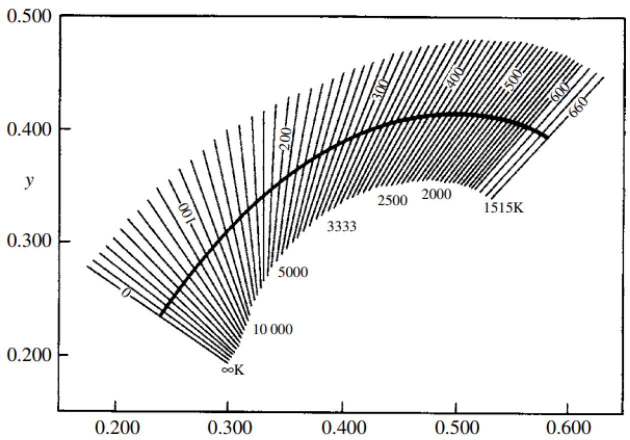

Fig. 4. The Planck locus with isothermal lines marked on it

Thin lines in Figure 4 mark isothermal lines - lines indicating the correspondence of a set of colours for a certain temperature. The model is actively used for light sources. Matching a colour source to a specific colour temperature does not mean that the source is heated to that temperature that its glow only matches the given colour [13].

However, it is worth noting that this model reflects a physical parameter, not a psychophysiological one. From a physics point of view, when heated, the body changes its colour from red to blue (Fig. 4). However, from the point of view of psychophysiology, blue is “colder” than red.

That is why, it is necessary to measure the psychophysiological “warmth” of colours to build a palette for a colour contrast algorithm. There is no objective assessment of the perception of colour warmth, but the objectivity of the measurement can be improved by conducting a statistical study.

First, tests must be conducted in which subjects will compare colours with each other according to the parameter of perception of the warmth of colour shades. The more the subjects, the more reliable the results. It is planned to involve about 100 people in the tests. The subjects will be given two colour shades, from which they must choose the "warmest" or "coolest". After this, this shade will be compared with the next one. This test will be named the stage of the test element.

The result of the comparison will be a two-dimensional table containing the compared pairs of colours and the winning colour of the pair. The number of items also affects the accuracy of the final result, however, a test trial with many items can negatively affect the accuracy of the assessment, as test takers may become fatigued and make more errors. Therefore, it is necessary to count the maximum possible number of elements.

Thus, the test program must present two different colours from a predetermined list to the reviewer in the program window, and then take into account the reviewer's response in the form of an increase in the values in the "Votes for Colour 1" or "Votes for Colour 2" cells corresponding to the element. For convenience of data collection, the program was implemented as a web application with access via the Internet. The algorithm for software implementation of a test can be presented in (Fig. 5).

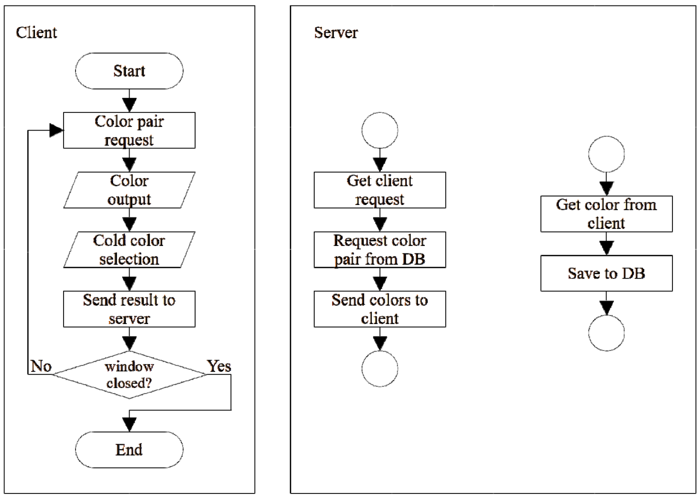

Fig. 5. The software algorithm of the test

The program interface is shown in the figure below (Fig. 6).

Fig. 6. The program interface

Table 1

Example of a test trial summary table with 5 colours and 10 reviewers

Colour 1	Colour 2	The “warmest” colour of the pair	Overweight of the votes for the coolest colour (Δ)
#BE5079	#978319	#BE5079	13
#BE5079	#C05530	#BE5079	13
#A05AC0	#807655	#A05AC0	13
#A05AC0	#976A78	#A05AC0	13
#A05AC0	#2D8825	#A05AC0	13
#A05AC0	#C05530	#A05AC0	13
#A05AC0	#978319	#A05AC0	13
#A05AC0	#BE5079	#A05AC0	13
#978319	#C05530	#978319	12
#976A78	#C05530	#976A78	13
#976A78	#BE5079	#976A78	13
#976A78	#978319	#976A78	11
#807655	#BE5079	#807655	13
#807655	#976A78	#807655	12
#807655	#978319	#807655	12
#807655	#C05530	#807655	13
#687899	#2D8825	#687899	13
#687899	#976A78	#687899	13
#687899	#157FE0	#687899	12
#687899	#4D8176	#687899	13
#687899	#1EA8C8	#687899	12
#687899	#249B88	#687899	13
#687899	#807655	#687899	12
#687899	#BE5079	#687899	13
#687899	#C05530	#687899	12
#687899	#A05AC0	#687899	13
#687899	#978319	#687899	13
#4D8176	#2D8825	#4D8176	13
#4D8176	#976A78	#4D8176	13
#4D8176	#807655	#4D8176	12
#4D8176	#249B88	#4D8176	12
#4D8176	#BE5079	#4D8176	11
#4D8176	#A05AC0	#4D8176	13
#4D8176	#C05530	#4D8176	13
#4D8176	#978319	#4D8176	13
#2D8825	#C05530	#2D8825	13
#2D8825	#BE5079	#2D8825	13
#2D8825	#976A78	#2D8825	13
#2D8825	#807655	#2D8825	13
#2D8825	#978319	#2D8825	13
#249B88	#807655	#249B88	13
#249B88	#976A78	#249B88	12
#249B88	#BE5079	#249B88	12
#249B88	#A05AC0	#249B88	13
#249B88	#978319	#249B88	13
#249B88	#C05530	#249B88	13
#249B88	#2D8825	#249B88	13
#1EA8C8	#BE5079	#1EA8C8	13
#1EA8C8	#C05530	#1EA8C8	13
#1EA8C8	#976A78	#1EA8C8	13
#1EA8C8	#978319	#1EA8C8	12
#1EA8C8	#4D8176	#1EA8C8	13
#1EA8C8	#249B88	#1EA8C8	12
#1EA8C8	#807655	#1EA8C8	12
#1EA8C8	#2D8825	#1EA8C8	12
#1EA8C8	#A05AC0	#1EA8C8	13
#1EA8C8	#157FE0	#1EA8C8	15
#157FE0	#BE5079	#157FE0	12
#157FE0	#C05530	#157FE0	13
#157FE0	#249B88	#157FE0	12
#157FE0	#A05AC0	#157FE0	13
#157FE0	#2D8825	#157FE0	13
#157FE0	#978319	#157FE0	13
#157FE0	#4D8176	#157FE0	12
#157FE0	#807655	#157FE0	12
#157FE0	#976A78	#157FE0	12

According to ITU BT.500-15 [6], the total test time for television image tests should not exceed 30 minutes in order to avoid fatigue of the reviewers and, consequently, the occurrence of false answers. The total number of test elements will be:

$$K = \sum_{1}^{35} n = 630 \qquad (5)$$

where K – is the total number of elements (pairs).

Given that the estimated time required for one element is 2-3 seconds, the total test time will be:

$$T = 630 * 3 = 1890\ sec = 31{,}5\ min \qquad (6)$$

Which is comparable to the required time according to ITU BT.500-14.

To illustrate this was simulated a test with fewer colours and fewer reviewers. In the case of 10 reviewers and 12 colours, the final test results take the form of a Table 1.

The results of the table can be treated the following way. The first and the second columns are the shown colors. The third column is the color, that was chosed dusing the test session. The fourth column is number of participants, that preferred this color as colder one. When using the results of many participants, statistics of the colder-warmer colors can be gathered with every color ranked (or sorted) according to the overweight of the votes. Degree of overweight should also be taken into account as statistically insignificant differences should be treated as equal temperature colors.

Table 2

Approximate colour interpretation

Colour	Describtion
#BE5079	Light raspberry
#A05AC0	Light lilac
#978319	Dark golden
#976A78	Pale burgundy
#807655	Dark yellow-brown
#687899	Gray-blue
#4D8176	Ultramarine gray
#2D8825	Dark green
#249B88	Pale ultramarine
#1EA8C8	Blue
#157FE0	Light blue
#C05530	Pale orange

Discussion

The first two columns of the table contain test elements, presented as a pair of compared colour shades. The third column contains the sum of votes for the first colour (in the first column), and the fourth – for the second (in the second column). The fifth column contains the total number of votes in each element, and the sixth column contains the winner of the pair based on the total number of votes.

The actual table of test results contains K = 630 rows, which corresponds to the assessment of 36 colours for the elements of the test. The generated table contains an assessment of the “coldness” of colour shades from the sample, which can be calculated by the total number of wins in each element of the test trial (in all rows for a specific colour). The obtained data will be needed for further processing. For example, summarizing the results for interpolation or nonlinear regression to find perceived colour warmth values for other shades, visually testing workaround methods, and so on.

$$Z_i = \frac{\sum_i \Delta_i}{\sum_j \Delta_j} \tag{7}$$

where $\sum_i \Delta_i$ – is the sum of the advantage for one specific colour over the others from Table 1, $\sum_j \Delta_j$ – is the sum of all the advantages from Table 1.

In this work, two-dimensional cubic spline interpolation was performed [7]. Splines are found using the formula:

$$S(x,y) = a_t Z b_u^T \tag{8}$$

Where:

$$Z = \begin{pmatrix} Z_{i,j} & Z_{i+1,j} & \mu_{i,j}^{(x)} & \mu_{i+1,j}^{(x)} \\ Z_{i,j+1} & Z_{i+1,j+1} & \mu_{i,j+1}^{(x)} & \mu_{i+1,j+1}^{(x)} \\ \mu_{i,j}^{(y)} & \mu_{i+1,j}^{(y)} & \mu_{i,j}^{(xy)} & \mu_{i+1,j}^{(xy)} \\ \mu_{i,j+1}^{(y)} & \mu_{i+1,j+1}^{(y)} & \mu_{i,j+1}^{(xy)} & \mu_{i+1,j+1}^{(xy)} \end{pmatrix}$$

$$a_t = \left[\varphi_1(t) \quad \varphi_2(t) \quad h_i\varphi_3(t) \quad h_i\varphi\ (t)\right]$$

$$b_u = \left[\varphi_1(u) \quad \varphi_2(u) \quad l_j\varphi_3(u) \quad l_j\varphi_4(u)\right]$$

$$h_i = x_{i+1} - x_i;\ l_j = y_{j+1} - y_j \tag{9}$$

$$\varphi_1(\xi) = (1-\xi)^2(1+2\xi)$$

$$\varphi_2(\xi) = \xi^2(3-2\xi)$$

$$\varphi_3(\xi) = \xi(1-\xi)^2$$

$$\varphi_4(\xi) = -\xi^2(1-\xi)$$

$$t = \frac{x - x_i}{h_i};\ u = \frac{y - y_j}{l_j}$$

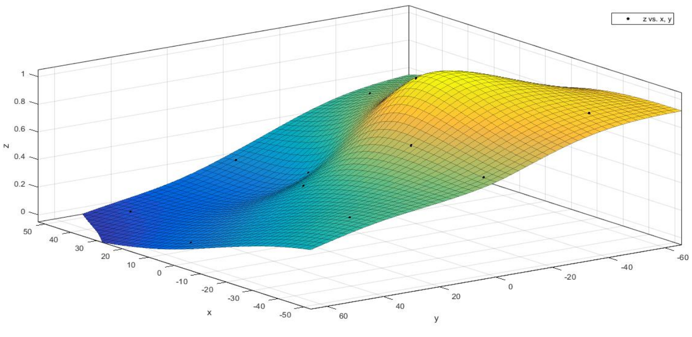

Fig. 7. Illustration of a CIE LCH slice, with the Z axis marking human perception of the warmth of hues

Conclusion

In this article, a method for assessing the perception of the warmth of colour shades was developed. An implementation of the method was also developed in the form of a web application with the ability to access via the Internet. The method can be used to conduct large database of test results. On the other hand, processing over Internet can lead to broken results, thus special diagnostics should be implemented to remove anomaly test results and the large amount (more than a 100) of participants should be used. Still a small test session of experiments shows that the method can give statistically significant results.

References

1. *Mozhaeva A.I., Vlasuyk I.V., Potashnikov A.M., Cree M.J., Streeter L.* The Method and Devices for Research the Parameters of the Human Visual System to Video Quality Assessment // 2021 Systems of Signals Generating and Processing in the Field of on Board Communications, 2021, p. 50.
2. Potashnikov A., Mazin V., Stepanov N., Smirnov A., Mozhaeva A. Analysis of Modern Methods Used to Assess the Quality of Video Sequences During Signal Streaming. 1-4. 2022. 10.1109/IEEE-CONF53456.2022.9744294.
3. *Mozhaeva A., Vashenko E., Selivanov V., Potashnikov A., Vlasuyk I., Streeter L.* Analysis of current video databases for quality assessment. T-Comm: Телекоммуникации и транспорт. 2022. Vol. 16. No. 2, pp. 48-56. DOI 10.36724/2072-8735-2022-16-2-48-56.
4. Color in Trademark and Tradedress Disputes. Date Views 01.12.2021 www.visualexpert.com/Resources/color.html.
5. CIELAB color space. Wikipedia : [site]. URL: https://en.wikipedia.org/wiki/CIELAB_color_space (date: 10.02.2022).
6. Recommendation ITU-R BT. 500-15: Methodologies for the subjective assessment of the quality of television images. 2023, p. 112.
7. *Vlasuyk I.V., Potashnikov A.M., Romanov S.G., Balobanov A.V.* Synthesis of the Perceptionally Linear Color Space Using Machine Learning Methods // 2019 Systems of Signals Generating and Processing in the Field of on Board Communications, SOSG 2019, Moscow, 20-21 march 2019. P. 8706823. DOI 10.1109/SOSG.2019.8706823
8. *Shi X.-Q., Sällström P., Welander U.* A color coding method for radiographic images // Image and Vision Computing. 2002. Vol. 20. No. 11, pp. 761-767.
9. *Smith A., Varney E.* A New Opportunistic Bone Density Screening Method Based on Colored CT Images of the Spine // Radiology and Medical Diagnostic Imaging. 2019. Vol. 2019. No. 2, pp. 1-3.
10. *Potashnikov A.M., Vlasuyk I.V., Ivanchev V.V., Balobanov A.V.* The Method of Representing Grayscale Images in Pseudo Color Using Equal-Contrast Color Space // 2020 Systems of Signals Generating and Processing in the Field of on Board Communications, 2020, pp. 1-6, doi: 10.1109/IEEECONF48371.2020.9078584.
11. *Balobanov A.V.* Digital methods for generating and converting signals of color components from black and white images // Infokommunikacionnye Tehnologii. 2011. Vol. 9. No. 4, pp. 81-86.
12. Certificate of state registration of a software № 2021661887 Russian Federation. Special software for research of spatio-temporal and color characteristics of the human visual system "PViTsKhZ". Version 1.0 : № 2021661046 : declared 12.07.2021 : published 19.07.2021 / I. Vlasuyk, A. Balobanov, A. Potashnikov, S. Romanov, A. Uzeev; declarant: Red banner of labour federal state budget educational institution of higher education "Moscow technical university of communications and informatics".
13. *Mozhaeva A., Streeter L., Vlasuyk I., Potashnikov A.* Full Reference Video Quality Assessment Metric on Base Human Visual System Consistent with PSNR // 2021 28th Conference of Open Innovations Association (FRUCT), Moscow, Russia, 2021, pp. 309-315, doi: 10.23919/FRUCT50888.2021.9347604.
14. *Liangliang Li, Jia Ren, Peng Wang, Zhigang Lü, Mengyu Sun, Xiaoyan Li, Hui Gao.* An adaptive enhancement method for generic multi-modal high-bit RAW grayscale image displaying on low-bit monitors // Displays, pp.102491, 2023.
15. *Xin Cheng, Jingmei Zhou, Jiachun Song, Xiangmo Zhao.* A Highway Traffic Image Enhancement Algorithm Based on Improved GAN in Complex Weather Conditions // IEEE Transactions on Intelligent Transportation Systems, vol. 24, no. 8, pp. 8716-8726, 2023.
16. *Wenjing Han, Chang Zhang, Cheng Wang, Luqin Yin.* Constructing a Forest Color Palette and the Effects of the Color Patch Index on Human Eye Recognition Accuracy // Forests, vol. 14, no. 3, p. 627, 2023.

ОБЪЕКТИВНАЯ ОЦЕНКА ТЕПЛОХОЛОДНОСТИ ЦВЕТОВ

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Аннотация

В данной статье рассматривается возможность цветового контрастирования в системах прикладного телевидения с большим динамическим диапазоном и предлагается метод оценки восприятия теплоты цветовых оттенков. Для этого на первом этапе выбирается цветовое пространство, задающее систему координат для цветовых оттенков. Далее на цветовом пространстве формируется выборка цветов, участвующих в дальнейших исследованиях по оценке восприятия теплоты цвета. Также в научной работе рассматривается создание тестового испытания. Представлен алгоритм вэб-программы, которая проводит опрос испытуемого. Данные опроса испытуемых хранятся на отдельном сервере и доступны для дальнейшей обработки. Далее представлен пример обработки предварительных данных для 18 цветовых оттенков, однако

Ключевые слова: *обработка изображений, цветовое контрастирование, динамический диапазон, цветовые пространства, теплохолодность.*

Литература

1. *Mozhaeva A.I., Vlasuyk I.V., Potashnikov A.M., Cree M.J., Streeter L.* The Method and Devices for Research the Parameters of the Human Visual System to Video Quality Assessment // 2021 Systems of Signals Generating and Processing in the Field of on Board Communications, 2021, pp. 50.
2. *Potashnikov Aleksei, Mazin Vladimir, Stepanov N., Smirnov A., Mozhaeva Anastasia.* Analysis of Modern Methods Used to Assess the Quality of Video Sequences During Signal Streaming, 2022, pp. 1-4. 10.1109/IEEECONF53456.2022.9744294.
3. *Mozhaeva A., Vashenko E., Selivanov V., Potashnikov A., Vlasuyk I., Streeter L.* Analysis of current video databases for quality assessment // T-Comm: Телекоммуникации и транспорт, 2022. Vol. 16, No. 2, pp. 48-56. DOI 10.36724/2072-8735-2022-16-2-48-56
4. Color in Trademark and Tradedress Disputes. Date Views 01.12.2021 www.visualexpert.com/Resources/color.html.
5. CIELAB color space. Wikipedia : [сайт]. URL: https://en.wikipedia.org/wiki/CIELAB_color_space (дата обращения: 10.02.2022).
6. МСЭ-R BT.500-15. Методики субъективной оценки качества телевизионных изображений. Женева: Электронная публикация, 2023. 112 с.
7. *Vlasuyk I.V., Potashnikov A.M., Romanov S.G., Balobanov A.V.* Synthesis of the Perceptionally Linear Color Space Using Machine Learning Methods // 2019 Systems of Signals Generating and Processing in the Field of on Board Communications, SOSG 2019, Moscow, 20-21 марта 2019. P. 8706823. DOI 10.1109/SOSG.2019.8706823
8. *Shi X.-Q., Sallstrom P., Welander U.* A color coding method for radiographic images // Image and Vision Computing. 2002. Vol. 20. № 11, pp. 761-767.
9. *Smith A., Varney E.* A New Opportunistic Bone Density Screening Method Based on Colored CT Images of the Spine // Radiology and Medical Diagnostic Imaging. 2019. Vol. № 2, pp. 1-3.
10. *Potashnikov A.M., Vlasuyk I.V., Ivanchev V.V., Balobanov A.V.* The Method of Representing Grayscale Images in Pseudo Color Using Equal-Contrast Color Space // 2020 Systems of Signals Generating and Processing in the Field of on Board Communications, 2020, pp. 1-6, doi: 10.1109/IEEECONF48371.2020.9078584.
11. *Балобанов А.В.* Цифровые методы формирования и преобразования сигналов цветовых составляющих из черно-белых изображений // Инфокоммуникационные технологии. 2011. Т. 9. № 4. С. 81-86.
12. Свидетельство о государственной регистрации программы для ЭВМ № 2021661887 Российская Федерация. СПО для исследования пространственно-временных и цветовых характеристик ЗСЧ "ПВиЦХЗ". Версия 1.0 : № 2021661046 : заявл. 12.07.2021 : опубл. 19.07.2021 / И. В. Власюк, А. В. Балобанов, А. М. Поташников, С.Г. Романов, А.А. Узеев; заявитель Ордена Трудового Красного Знамени федеральное государственное бюджетное образовательное учреждение высшего образования "Московский технический университет связи и информатики".
13. *Mozhaeva A., Streeter L., Vlasuyk I., Potashnikov A.* Full Reference Video Quality Assessment Metric on Base Human Visual System Consistent with PSNR // 2021 28th Conference of Open Innovations Association (FRUCT), Moscow, Russia, 2021, pp. 309-315, doi: 10.23919/FRUCT50888.2021.9347604.
14. *Liangliang Li, Jia Ren, Peng Wang, Zhigang Lu, Mengyu Sun, Xiaoyan Li, Hui Gao.* An adaptive enhancement method for generic multi-modal high-bit RAW grayscale image displaying on low-bit monitors // Displays. P. 102491, 2023.
15. *Xin Cheng, Jingmei Zhou, Jiachun Song, Xiangmo Zhao*, "A Highway Traffic Image Enhancement Algorithm Based on Improved GAN in Complex Weather Conditions // IEEE Transactions on Intelligent Transportation Systems, vol. 24, no. 8, pp. 8716-8726, 2023.
16. *Wenjing Han, Chang Zhang, Cheng Wang, Luqin Yin.* Constructing a Forest Color Palette and the Effects of the Color Patch Index on Human Eye Recognition Accuracy // Forests, vol.14, no.3. P. 627, 2023.

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