Revisiting measuring colour gamut of the color-reproducing system: interpretation aspects

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Abstract. According to the ISO standard, the color gamut body volume is used to evaluate the color reproduction quality. The specified volume describes the number of colors that are in a certain area of the color space. There are ways for evaluating the reproduction quality of a multi-colour image using numerical integration methods, but this approach does not provide high accuracy of the analysis. In this connection, the task of increasing the accuracy of the color reproduction evaluation is still relevant. In order to determine the color mass of a color space area, it is suggested to select the necessary color density values from a map corresponding to a given degree of sampling, excluding its mathematical calculations, which reflects the practical significance and novelty of this solution.

Keywords: color gamut body measuring, integrated index, color accuracy, printing quality, coordinate system \(L^*a^*b^*\).

1. Introduction

It is known that the task of evaluating the quality of color reproduction is rather complicated. Approaches to evaluating the quality of color printing are very diverse. There is a gap between instrumental measurements and visual evaluation. Color management systems ensure the correct color control throughout the entire production cycle, starting with the prepress stage, integrating all the devices into one common color space.

According to some authors [1], the color reproduction of a seal is determined by the properties of the printed material, in this case - of paper, and by the type of printing equipment. A similar opinion is shared by the authors of [2] who also note that variations in the quality of offset printing are connected with numerous parameters of printing equipment and paper. Since in most cases quality evaluation is carried out manually, the investigators [2] propose a new system for evaluating the print quality. This system is based on the use of conventional printed labels. So-called virtual sensors are used to evaluate print attributes using double mesh images. The main feature of this solution is the connection between the estimated print quality and the known process conditions.

In [3], a method for calibrating a printing machine based on regression models is developed. According to this research, the method is advantageous because it allows us to obtain a mathematical model describing the printing machine characteristics, which forms the basis for the current colorimetric correction of the printing.

However, to test complex multi-colour printouts, the resources of many known systems are limited. In addition, many well-known models mainly reflect the relationship of the evaluated optimization parameter (the color reproduction index) to the variables being investigated, for example, the paper characteristics.

An indicator that meets all the requirements of the ISO standard (i.e., describing the number of reproduced colors) is the color gamut body volume of the color-reproducing system, evaluated, including the printing system, in units of the color space \(\Delta E\) \(\text{CIE } L^*a^*b^*\) [4, 5].
The specified volume describes the number of colors that are in a certain area of the color space (for example, belonging to the printing system color gamut body) and differentiated by the typical observer. Obviously, other things being equal, a larger color gamut body means more colors reproduced by the printing system. The color in such a system is represented as one brightness coordinate and two color-difference chromaticity coordinates.

The determination of the volume of the color-reproducing system gamut body consists of two main parts: the description of the gamut body in the L*a*b* space and the determination of its volume. In [6], it is noted that in this case it is appropriate to use numerical integration methods.

The description of the printing system color gamut body and the calculation of the color gamut body volume in units of ΔE and ΔE00 is discussed in detail in [7-10]. A graphic interpretation of the color gamut body is given there.

Nevertheless, the task aimed at improving the accuracy of the color rendering index is not fully solved.

2. Statement of the problem

The more precisely the color differences are calculated, the more the result of calculating the color gamut body volume will be consistent with the color perception. The search for solutions to the problem under consideration remains relevant.

For an objective evaluation of the printing system, in addition to the existing ones, it is necessary to use an integral numerical indicator expressing its color gamut. On the one hand, this indicator is required in order to objectively compare the printing systems color gamut with a minimum error; on the other hand, as a criterion used to solve problems of determining the optimal color characteristics of the triad stimuli used by the system being evaluated. The replacement of the color-difference function ΔE by another, more perfect, is an up-to-date task.

3. Problem solution

As it was noted above, L*a*b* system is not a contrast one, as it is usually named. An ideally equal-contrast system is homogeneous in terms of a person color perception. This means that an equally contrasting color space has a constant color density that is, the location density of the points of the colors differentiated by man in the color space. In a truly color-equal (isotropic in color perception) space, the indicator of its color density is the parameter ΔE = const. In this case, by calculating the volume of the color gamut body in units of ΔE (as the distance between the points of colors in an equally contrasting, uniformly dense, color space where the same distances between the points of the colors being compared correspond to the same visual differences), one can determine its color mass.

In this application, the color mass is an indicator characterizing the amount of colors distinguished by a person in a certain area of the color space, for example, within the body of the color gamut of the color reproducing system and the printing system in particular. In the L*a*b* color space ΔE parameter cannot be an indicator of the color density, since the system is largely unequal and not isotropic from the point of view of the color difference. In other words, the color space in its different areas and in different directions is characterized by a different color density.

As an indicator of the color density, parameter ΔE00, which to the greatest extent (nowadays) corresponds to the coloration of the standard observer can be used. Indicator ΔE00 takes into account the heterogeneity of the L*a*b* color space in different areas and directions (ΔE001 ≠ ΔE00a ≠ ΔE00b).

Integral index Θ of the color gamut evaluation is the indicator characterizing the number of colors, reproduced by a certain color-reproducing system and differentiated by a typical observer.

It was calculated as the volume of the unequally-contrasting (non-isotropic from the point of view of color differentiation) color space area. At the same time, the unevenness of the color space when calculating the area volume was taken into account using the refined color separation function ΔE00 at the stage of the elementary volume determination [6].

Actually, the essence and the algorithm for calculating the index Θ was a natural development of the indicator of the color gamut body volume of the color-reproducing system (or a random color space area) as an integral indicator of their color gamut: evaluation of the number of colors reproduced by the printing system (or contained in a certain area). Namely: if we assume that the color space is equally contrasting, i.e. the volume of a certain closed region of this space serves as an indicator of the amount of colors that are detected by the standard observer in it.
If the color space is equally contrasting, the volume of a closed area is calculated taking into account the description of this inhomogeneity (function $\Delta E_{00}$). The result is the interpretation of the index $\Theta$ as the volume of the color space area calculated using the refined color function $\Delta E_{00}$.

By introducing the color density and color mass concepts index $\Theta$ can be interpreted much more accurately by its nature and in accordance with the physical analogy. If it is assumed that the function $\Delta E_{00}$ is a description of the color space $L^*a^*b^*$ density, then the elementary volume $V_{el}$ ($\Delta E_{00}$) is, in fact, not specified from the point of view of color perception by the volume of the micro-area, but is an indicator of the number of colors distinguished by a typical observer that is the elementary volume color mass. At that, a certain color space area, composed of several volumes, will have a color mass $M_{CSA}$ that is an index, characterizing the number of its colors, distinguished by atypical observer.

Color mass of a certain area of the color space (Fig. 1) can be found by using the numerical integration method:

$$M_{CSA} = \sum_{L^*} \sum_{a^*} \sum_{b^*} M_{el},$$

where $M_{CSA}$ is the colour mass of the colour space area under investigation, $L^*, a^*, b^*$ are the numerical integration limits, describing the area boundaries, $M_{el}$ is the colour mass of the elementary volume $V_{el} = \Delta L^* \times \Delta a^* \times \Delta b^*$, where $\Delta L^* = \Delta a^* = \Delta b^*$.

$$M_{el}(\Delta E_{00}) = \Delta E_{00L^*} \times \Delta E_{00a^*} \times \Delta E_{00b^*},$$

where $\Delta E_{00L^*} = \Delta E_{00}(L^*_1, a^*_1, b^*_1; L^*_2, a^*_1, b^*_1)$,

$\Delta E_{00a^*} = \Delta E_{00}(L^*_1, a^*_1, b^*_1; L^*_1, a^*_2, b^*_1)$,

$\Delta E_{00b^*} = \Delta E_{00}(L^*_1, a^*_1, b^*_1; L^*_1, a^*_1, b^*_2)$,

$L^*_1, a^*_1, b^*_1$ и $L^*_2, a^*_2, b^*_2$, are the colour coordinates of the elementary volume reference points, where $\Delta L^* = L^*_2 - L^*_1$, $\Delta a^* = a^*_2 - a^*_1$, $\Delta b^* = b^*_2 - b^*_1$.

Figure 1. Elementary volume ($\Delta L^* \times \Delta a^* \times \Delta b^*$) in $L^*a^*b^*$ space ($\Delta L^* = \Delta a^* = \Delta b^*$).

In this interpretation of $\Theta$, as the authors suggest, a complete analogy with the physical concepts of "density - volume - mass" will take place.

The specified values of colour density $P(L^*, a^*, b^*)$ are found as the ratio of the color mass of an elementary volume to this volume:

$$P(L^*, a^*, b^*) = \frac{M_{el}}{V_{el}},$$

(3)
where \( V_{cl} = \Delta L^* \times \Delta a^* \times \Delta b^* \), having \( \Delta L^* = \Delta a^* = \Delta b^* \).

Such map of colour density can be calculated for all the colour space \( L^*a^*b^* \) at the specified value of its sampling \( \Delta L^* = \Delta a^* = \Delta b^* \), and will include the values of \( P (L^*, a^*, b^*) \) for every elementary volume of the colour space.

4. Conclusion
Based on the above, we can state the following.

- When calculating the color weight of the color space area, you do not need to calculate the color density each time, you only need to select the desired values from the map corresponding to the specified degree of sampling.
- The determination of the color weight of a certain area of the color space in this case will be reduced only to determining the occurrence of an elementary volume in the color space area and summing the corresponding values of the color masses of elementary volumes.

However, we believe that the presented interpretation of the indicator \( \Theta \) as the color mass, as well as the very introduction of the concepts of color density and color mass, requires further discussion.

References

[1] Maryam Ataeefard 2014 Investigating the effect of paper properties on color reproduction of digital printing J. Progress in Organic Coatings vol 77 Issue 9 p 1376-1381
[2] Undström J, Verikas A, Tullander E, Larsson B 2013 Assessing, exploring, and monitoring quality of offset colour prints J. Measurement vol 46 Issue 4 p 1427-1441
[3] Olejnik-Krugły A, Różewski P, Zaikin O, Sienkiewicz P 2013 Approach for color management in printing process in open manufacturing systems J. IFAC Proceedings vol 46 Issue 9 p 2104-2109
[4] ISO 15076 1(2005) Image technology colour management – Architecture, profile format and data structure, 2005
[5] ISO 12647-2: 2004 Graphic technology – Process control for the production of half-tone colour separations, proof and production prints – Part 2: Offset lithographic processes, 2012
[6] Pozharsky A O, Sysuev I A 2006 Evaluation of the printing system color gamut by color gamut body volume, calculated by using color space heterogeneity J. Educational Institutions. Problems of printing and Publishing No 4 p 3–12 Russian
[7] Pozharsky A O and Sysuev I A 2005 Evaluation of the printing system color gamut by color gamut body volume, calculated by using color differences precise function J. Omsk scientific bulletin No 4 pp 180 Russian
[8] Pozharsky A O 2006 Plotting of color gamut body, reproduced by a printing system as a part of its volume calculation task J. Omsk scientific bulletin No 2 p 136–138 Russian
[9] Varepo L, Golunov A, Golunova O, Trapeznicova O and Nagornova I 2015 Method of calculation volume of the color gamut body Testing and Measurement: Techniques and Applications p 69-71
[10] Varepo L, Trapeznicova O, Golunov A, Panchuk K and Lyashkov A 2017 Computer visual representation of color gamut of the multicolor image reproduction systems J. Geometry and graphics vol 5 Issue 3 p 86-91 Russian