Computer visualization of quality estimation the color reproduction in digital printing systems measuring colour gamut of the color-reproducing system: interpretation aspects

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Computer visualization of quality estimation the color reproduction in digital printing systems measuring colour gamut of the color-reproducing system: interpretation aspects

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Abstract. Forecasting of the quality estimation the color reproduction for selection of the optimum printing system from the available range and the achievement of the required quality of multicolor products justifies the urgent problem. To solve the problem, a procedure of quality estimation of color reproduction using tools of the CIE L * a * b * – 1976 colorimetric model was used, i. e. the volume of color gamut body and the set of its cross sections. Practical implementation of the approach for complex estimation of the color reproduction quality in digital printing systems and its computer visualization is shown on the example of the "laser (LED) printer-paper" printing system. It is noted that the estimation of color reproduction using the volume index of the gamut body and the set of its sections, as an element of computer graphics for visualizing the result, interprets the accuracy of reproduction of the multicolor image as for the original.

Keywords: color reproduction, computer visualization, geometry of color gamut body section, volume of color gamut body, printing system

1. Introduction

The problem of estimating the color gamut for color reproduction systems, in particular by the use of printing technologies, has been studied in detail since the mid-1970s of the twentieth century. First the investigation was started by Padham and Saunders [1], and then Judd and Vyshetsky [2], whose works have now became classical.

Color gamut of color reproduction systems was carried out with the help of **xy** chromaticity figures (color system CIE (Commission internationale de l'éclairage) XYZ-1931) and **uv** equal-contrast color diagram (CIE uv-1960). In 1976 CIE enacted the color system L*a*b* –1976 and color gamut was evaluated using its parameters, in particular, applying a chromaticity diagram a*b* [3, 4].

With the development of computer technologies, since the 2000s, the estimation of color gamut was carried out in three-dimensional color space, particularly by the body of color gamut in the color system XYZ and in the uniform color space of L * a * b [5–13] color system. However, the evaluation in three-dimensional space is an intricated problem and time-consuming.

Authors [9-12] have developed and proposed an integral performance index of color gamut estimation (IPICGE), further improved by [14–17]. It helped to simplify the technology of estimation and operate with numerical indexes.

Today, the digital printing market is actively developing; the range of printers is increasing every year. Thus, assessing the quality of color reproduction is one of the most important and urgent problems.

2. Statement of the problem

Electrophotographic printing technology, supported in laser and LED printers, is one of the most perspective. To estimate the quality of prints a significant number of indexes are used, including the optical density of background, uniformity of printing, half-toning, resolution of printing, etc.

One of the main tasks is the estimation of color reproduction, i. e. accuracy of reproduction the memorable colors, color scale (gamut), comparison of color reproducing characteristics of printers in different areas of color space.

As noted in [18, 19] printers usually generate a limited number of colors and can't create continuoustone color images. It is noted by the authors that in reproduction of halftone images the blurred edges and textures may appear. To correct the expected errors various solutions are proposed. I. e. the method of using different filters for halftones of different color components [18] and the determination of conditions under which colors reproduce without mistakes [19, 20]. Components of conditions are, for example, resolution of input or output, paper. Herewith, the selected conditions should ensure the adequacy of color images reproduction accuracy.

To evaluate the printing characteristics, a separate model of color areas in halftone printing is proposed by the authors [21]. The result of color separation process is a monochromatic image, which is further processed by segmentation methods for obtaining the exact regions of a certain color or the regions with halftone dots. It should be noted that the accuracy of evaluating the printing characteristics highly depends on the level of segmentation of the color areas involved in printing.

The authors of [22, 23] suppose that modification of paper surface by the use of various chemicals courses the enhancement of pigments fixation on its surface. This result is obtained for inkjet printing.

The aim of this research is a complex estimation of color reproduction and a computer visualization of the result in printing system "laser (LED) printer - paper" as the example.

3. Problem solution

By a printing system it is understood "a combination of technical and technological means of printing setup and directly printing – from the original. This term is equally applicable both to the characteristic of a printing method in general, for example, an inkjet printing system as a mean of obtaining an image, and regarding to a really operated, for example, digital printing system in the configuration of computer – software – settings – coloring materials – printer – printed material "[9].

The system of digital printing simplify if it uses one computer, the same application settings, and in printers – the original consumables (cartridges for electrophotography technology) as "printer - printed material".

Color gamut of any color reproduction system, for example, a printing system, is that the maximum number of colors that this system is capable to reproduce. The method for estimating the color reproduction, considered as standard, consists in estimating the areas of the hexagons of color coverage (Fig. 1), which is represented on the color chart (color diagram) of the color system CIE L * a * b *.

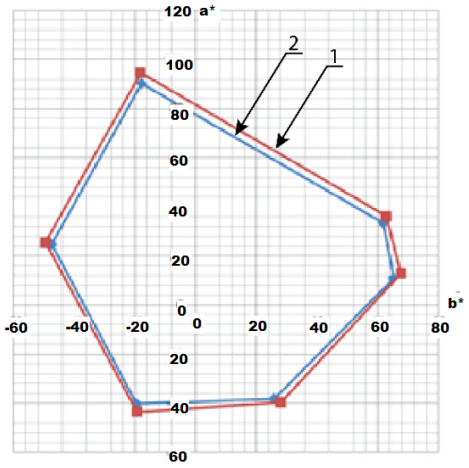

Figure 1. Color chart a* b* of printing systems № 3: 1 – mat paper № 2; 2 – gloss paper № 1

In [10, 12], a method, an algorithm and a program for calculating the volume of a color gamut body are developed and tested, and then improved [14–17]. The program (Project 1) is developed to calculate both the volume of the color gamut body and the data for constructing a set of its (body) cross-sections for different values along the L * axis. At that, the more different values along the L * axis are used, the more accurate the configuration will be described. The source data for calculations are the spectral characteristics of reflection (i. e. the dependence of the reflection factor on the wavelength) of the main stimuli (in the case of electrophotography - toners) of subtractive synthesis (Fig. 2).

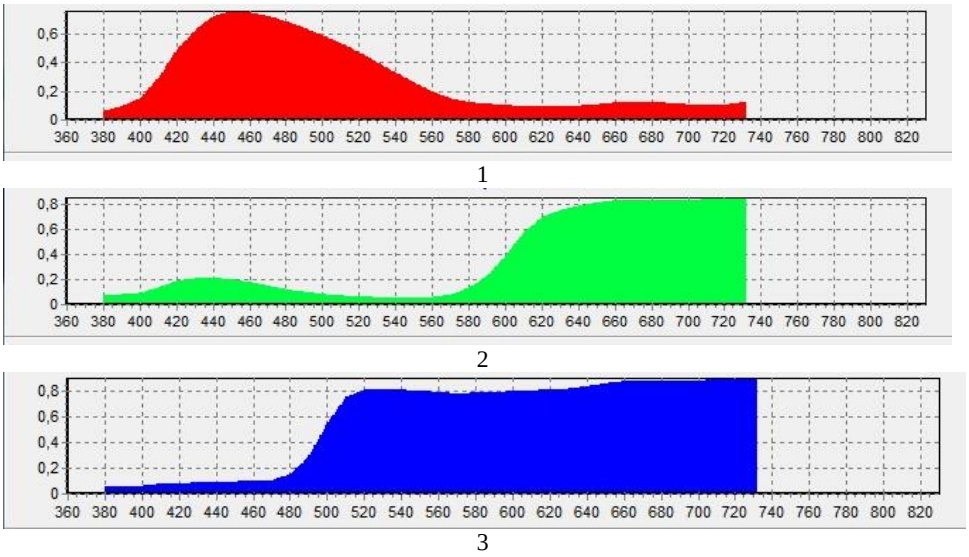

Figure 2. Spectral characteristics of reflection of the main stimuli
(1 – cyan, 2 – magenta, 3 – yellow) for the printing system № 3 (matt paper № 2)

4. Experimental Rerults

The researches of six electrophotographic printing systems of "laser (LED) printer – paper" were carried out for estimating color reproduction in complex.

The components of investigated systems are the modern models of laser (LED) printers by companies that are the world's leading manufacturers (HP Laser Jet Pro 300 Color M351a, Konica Minolta with 364 series PS, OKI C96 55) and paper with different characteristics. The object of the study is the IT-8 test scale.

Measurements of reflection spectra of pure color fields were made and the volumes of color gamut bodies in units of ΔE00 were calculated (Table 1).

Table 1. Characteristics of system colors

Number	**Printing system**				**Volume of color gamut body, units. ΔE_{00}**
	Printer model	Paper characteristics			
		Number	Coating	Whiteness, % CIE	
1	HP Laser Jet Pro 300 Color M351a	1	Gloss	165 ± 2.0	108406
		2	Matt	170 ± 3.0	107399
2	Konica Minolta c 364 series PS	1	Gloss	165 ± 2.0	99592
		2	Matt	170 ± 3.0	93789
3	OKI C96 55	1	Gloss	165 ± 2.0	92582
		2	Matt	170 ± 3.0	84698

According to the received data, in the coordinate system of the color space L * a * b * CIE a color gamut body was visualized on the figure. Particular interest in the solution of the problem assigned in this work was presented in finding the geometric characteristics of color gamut body, primarily its volume. For this purpose, the method of spatial triangulation was used.

To represent the actual color gamma it should be noted that the maximum possible volume of color gamut body is 250,000 units ΔE00. This volume of color gamut body is the maximum possible, i. e. it is the volume of color gamut body for the ideal subtractive synthesis.

Fig. 3 and 4 the examples of computer visualization of a set of cross-sections for color gamut bodies are shown, They were constructed from the data of calculations with a step along the L * axis, equal to 20.

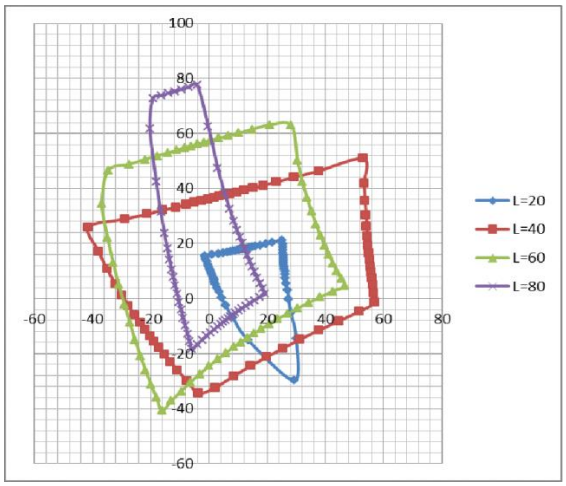

Figure 3. Cross-sections of color gamut body on color diagram a^*b^* for the printing system № 3 (gloss paper 1)

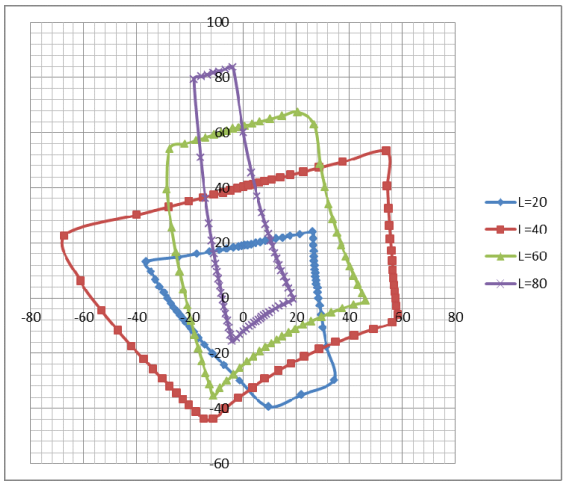

Figure 4. Cross-sections of color gamut body on color diagram a^*b^* for the printing system № 1 (gloss paper 1)

5. Results and Discussion

The results of calculating the volume of color gamut body in the systems "laser (light-emitting) printer - paper" show that the systems reproduce different amounts of colors, which is confirmed by the volume of color gamut body. Differences in the volume of color gamut body of studied printing systems are about 20% (Table 1).

A significant effect of the paper characteristics on the quality of a print in the analyzed printing system was noted. Depending on the paper characteristics changes in the volume of color gamut body ares up to 10%.

Computer visualization of a set of cross-sections of a body for different values along the L * axis clearly shows the reproduction of colors in different areas of color space (Fig. 3, 4). For example, for the HP LaserJet Pro 300 Color M351a printer, the gamma of reproduced shadow and midtone by the luminosity colors (L * = 20 and L * = 40) is about 2 times greater than for the OKI C96 55 printer.

It is estimated that highlight colors (L * = 60 and L * = 80) are better reproduced by the printing system No. 3. On the contrary, the printing system No. 1 better reproduces saturated colors in the yellow, green, cyan, blue, and magenta areas of the color space, only in the red saturation is approximately the same.

6. Conclusions and Summary

On the basis of the analysis the experimental data, it is shown that the improved estimation of the color gamut with the use of the integrated index of color gamut estimation and the set of cross-sections of color gamut body o is more objective, it allows to efficiently estimate the number of reproduced colors and their distribution in the areas of color space.

A computer visual representation of color gamut for the multicolor image reproduction systems interprets the reproduction accuracy of multicolor image according to the original. It allows to compare the potential possibilities of color reproduction for the studying systems and forecast the quality of a multicolor image.

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