Information Technology of Digital Images Processing with Saving of Material Resources

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Abstract. The authors proposed new information technology that is built on representing original image in a new color space ICaS. We found the exact solutions of equations for synthesis of color image, which allowed to optimize the using of inks. The specialized software for processing digital originals by traditional and new technologies in the common information environment was developed. The software is based on a new color separation information model developed by the authors. It is shown that the new technology works on analytical methods.

Keywords: information technology, color separation, autotype equation, specialized software, digital original, methods, models.

1 Introduction

A color space of digital originals is represented as RGB. Color gamut of RGB is determined by its primaries: a set of the emitters. Whereas the primaries of printing devices are the pigments: Cyan, Magenta, Yellow and Black. Performing a color separation process is needed for convertation of color information from RGB to CMYK.

The autotypical synthesis is a basis of reproduction a color image in printing process. However, the autotypical equations for four-color printing are written as a system of three non-linear equations with four variables. Therefore, a solving approach is mathematically incorrect. Nowadays, the traditional color separation technology is based on the use of ICC profiles of printing system. The RGB → CMYK transformation is proceeded according to the table values of characterization data of LUT (Look-Up Table). It is a principle of searching a value by a comparison, not via calculation method.

Problem. Classical technology does not solve the problem of uniquel convertation of the digital original image into the color imprint. The aim of the work is to develop new methods of the digital processing of images in preprint processes for the reproduction of tone and color range of digital original image in printing processes. In spite of this, these methods are needed for providing the optimal value of printing inks in color separation for gaining the stable and saving printing process.

2 New Image Separation Information Technology

A new oppositional color space ICaS was developed as a result of the study of non-orthogonal color spaces [1]. It serves as a connecting link during color changes from RGB to CMYK. The conversion from RGB to ICaS is described by a matrix based on the discrete Hartley transform. Also, the authors developed a method for determining the nonlinearity index γ of colored inks reproduction on the imprints. This nonlinearity index has become the only parameter that takes into account the color reproduction features in the given printing conditions [2] in the new color separation technology [3]. The projection of the color gamut of the printing process on a chromatic CaS-plane was modeled. As a result of the analysis of these projections, a new principle of color separation of the image with two color inks and black one was formulated.

The general vector equation of autotypical synthesis is reduced to a system of non-linear equations with three unknowns in accordance with the formulated principle:

$$\begin{cases} I_{AU} = S_K^0 \left[I_{ij} + S_i^0 \left(I_j - I_{ij} \right) + S_j^0 \left(I_i - I_{ij} \right) + S_i^0 S_j^0 \left(I_W - I_i - I_j + I_{ij} \right) \right] \\ C_{AU} = S_K^0 \left[C_{ij} + S_i^0 \left(C_j - C_{ij} \right) + S_j^0 \left(C_i - C_{ij} \right) + S_i^0 S_j^0 \left(C_W - C_i - C_j + C_{ij} \right) \right], \\ S_{AU} = S_K^0 \left[S_{ij} + S_i^0 \left(S_j - S_{ij} \right) + S_j^0 \left(S_i - S_{ij} \right) + S_i^0 S_j^0 \left(S_W - S_i - S_j + S_{ij} \right) \right] \end{cases} \tag{1}$$

where (I, C, S) – coordinates in space ICaS; subscript AU – denotes the color in autotypical synthesis; subscripts i, j, ij – indicate color of i-th, j-th inks and color that is formed by mixing the i-th and j-th inks; subscript W – indicates the paper color; S_i, S_j, S_K – relative dot areas of i-th and j-th inks and black (K) one.

The expression for the black ink is obtained from the achromatic coordinate I_{AU}:

$$S_K^0 = \frac{I_{AU}}{I_{ij} + \left(I_j - I_{ij} \right) S_i^0 + \left(I_i - I_{ij} \right) S_j^0 + \left(I_W - I_i - I_j + I_{ij} \right) S_i^0 S_j^0} \tag{2}$$

A system of nonlinear equations for two color inks is derived:

$$\left. \begin{aligned} \alpha_{00} + \alpha_{10} S_i^0 + \alpha_{01} S_j^0 + \alpha_{11} S_M^0 S_Y^0 = 0 \\ \beta_{00} + \beta_{10} S_i^0 + \beta_{01} S_j^0 + \beta_{11} S_M^0 S_Y^0 = 0 \end{aligned} \right\} \tag{3}$$

The coefficients define determinants of the matrices 2×2 in this system of equations. Expression for j-th ink has obtained from the first equation of system (3):

$$S_j^0 = -\frac{\alpha_{00} + \alpha_{10} \cdot S_i^0}{\alpha_{01} + \alpha_{11} \cdot S_i^0} \tag{4}$$

The quadratic equation (5), which has two solutions, one of which is valid, is obtained as a result of substitution of expression (4) into the second equation of system (3):

$$a + bS_i^0 + c(S_i^0)^2 = 0 \tag{5}$$

where *a, b, c* are specified by the values of the matrices determinants 3×3:

$$\begin{gathered}
a = \begin{vmatrix} I_{AU} & I_j - I_{ij} & I_i - I_W \\ C_{AU} & C_j - C_{ij} & C_i - C_W \\ S_{AU} & S_j - S_{ij} & S_i - S_W \end{vmatrix}; \quad c = \begin{vmatrix} I_{AU} & I_i & I_{ij} \\ C_{AU} & C_i & C_{ij} \\ S_{AU} & S_i & S_{ij} \end{vmatrix}; \\
b = \begin{vmatrix} I_{AU} & I_{ij} & I_i + I_j - I_W \\ C_{AU} & C_{ij} & C_i + C_j - C_W \\ S_{AU} & S_{ij} & S_i + S_j - S_W \end{vmatrix} + \begin{vmatrix} I_{AU} & I_i - I_{ij} & I_j - I_{ij} \\ C_{AU} & C_i - C_{ij} & C_j - C_{ij} \\ S_{AU} & S_i - S_{ij} & S_j - S_{ij} \end{vmatrix};
\end{gathered} \tag{6}$$

The described analytical model of autotypical synthesis of colors on the imprint became the basis for the new ICaS-ColorPrint information technology of image color separation [3]. The authors developed a computer program ICaS-ColorSynthesis [4], in which it is possible to prepare the image for printing using the new technology, carry out a quantitative analysis of the consumption of inks.

3 Creating a Database of Non-Reproducible Colors

In the process of color separation, colors that can not be reproduced in the target color space must be converted (gamut mapping). Traditional technology uses four basic color rendering intents, which are recommended by the ICC specification.

For a certain set of colors of the original image we have obtained non-permissible solutions of the autotypical synthesis equations: the negative values of relative dot areas of printing inks, numbering more than 1, and complex numbers. This means that such colors are beyond the color gamut of the printing process. We have been provided a color replacement for the first two cases taking into account two components of color: the color tone and chromaticity, using the CaS-diagram.

If the solutions of the equations of autotypical synthesis are complex numbers (7) the replacement of colors is not done correctly. Therefore, there was a task of technology improvement by creating a non-reproducible color database for this case.

Consider a more detailed analytical solution of the autotypical synthesis equation, namely, its subroutine expression:

$$S_i^0 = -\frac{1}{2a}\left(b \pm \sqrt{b^2 - 4ac}\right), \quad \sqrt{b^2 - 4ac} < 0, \quad \text{if } b^2 < 4ac \tag{7}$$

If the condition of formula (7) holds, the solutions of the equation are complex numbers. It was developed an algorithm for locating non-reproducible colors. It includes: determining the coefficients *b*, *a*, *c* of equation (7), checking the condition and sorting them by the achromatic coordinate (*I*) in the space ICaS. This method allows the color replacement of the original and keeps in the maximum as possible degree of correct and reliable transmission of tones and colors of the original.

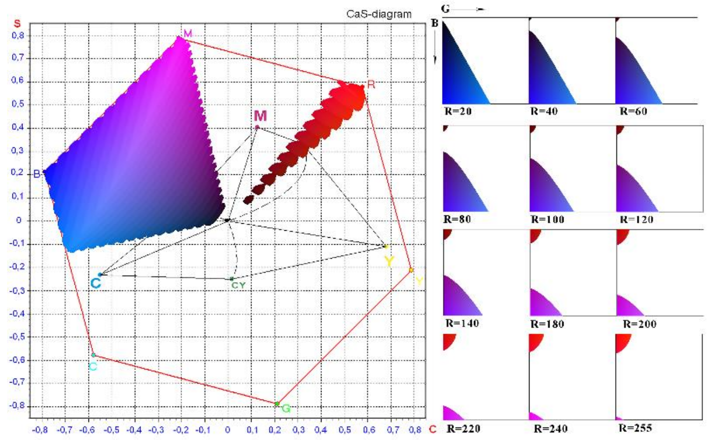

Fig. 1. Presenting colors on CaS-diagram that cannot be reproduced within the CMYK

The Figure 1 shows the visualization the colors that cannot be reproduced by the CMYK printing inks. These colors belong to two color gammas, formed by mixing cyan and magenta inks, and magenta and yellow inks. These colors form planes which were sorted by the level of achromatic.

The color database and the corresponding replacement is designed for two standardized print conditions: (Fogra51) and (Fogra52). The Relative Colorimetric color replacement method has been used. In this method, the image colors are recalculated relative to the white point of the output device. For the vast majority of cases, this method shows its high efficiency. According to the described method, a database of non-reproducible colors can be created for any printing conditions.

4 Comparison of Color Separation Technologies

ICaS-ColorPrint information technology for image separation is based on the principle which implies that every color of original image is created by only two color and third one is black ink. The color position on the chromatic CaS-diagram determines which two color inks are used in the synthesis. Consequently, this fact suggests that the use of developed technology in the process of preparing images for printing will provide savings of color inks. It is important that, in this approach, the visual identity of the imprints obtained from a separation that uses a smaller amount of color inks and with separation using the ICC-profiles is preserved. It is advisable to perform a comparative analysis of the results of color separation using two technologies according to the following indicators: the percentage of saving color inks and the value of color differences between imprints.

There were held tests of printing a great set of color digital images. We used inkjet printer for color proof to perform test printing, Spectrolino spectrophotometer for colorimetric measurements, SpectroScan robot for precise positioning and automated measurement and the ProfileMakerPro software package.

Here, to compare the results of color separation using two technologies, the testchart was used as a test image, which consists of 192 control patches. The color data of each patch of the testchart is converted from the RGB model to CMYK mode by classical technology and by ICaS-ColorPrint technology. ICC-profile based on characterization data Fogra51 was used for color separation in Adobe PhotoShop software. With the new ICaS-ColorPrint technology for the same print conditions (Fogra51) the calculation of autotypical equations has been applied using ICaS-ColorSynthesis application.

It is possible to compare two technologies of color separation by quantitative indicators in one software environment ICaS-ColorSynthesis 2.0 [4]. The program provides complete information on the average relative dot area of each ink for the whole image, the value of the total relative dot area and TAC (total area of coverage) of color and black inks. A quantitative analysis of color separation was implemented. Saving color inks for the given test chart is 37%, and saving of all inks is 18%.

The international standard ISO 12647: 2013 estimates the accuracy of the reproduction by the color differences (ΔE) between the original and the imprint, or between two imprints. Color difference is determined by the formula ΔE 1976. As part of our study, the color differences between the corresponding patches of test image on two compared imprints were determined. As an example, the relative dot areas of CMYK inks are shown only for some of the patches in Table 1. The inks savings for each patch of test chart were calculated, as well as the color differences between the corresponding color patches of the two compared printed images. Average value of ΔE is 1,58 units, maximum 2,51 units. Such values are permissible and the difference between the color patches visually is not noticeable.

Table 1. The percentage of saving color inks and the value of color differences between two imprints with using classical and ICaS-ColorPrint color separations

Name of patch	Color separation with ICC-profile	Color separation with ICaS-ColorPrint	Save inks using ICaS-ColorPrint	Color differences between two printed images
	$C_1M_1Y_1K_1$, %	$C_2M_2Y_2K_2$, %	Σ CMYK, %	ΔE, unit
A1	37;65;57;60	0;47;43;77	24	2,16
A2	27;30;30;11	0;11;12;42	34	1,48
A3	50;31;69;46	25;0;57;69	23	1,24
A4	9;93;70;32	0;89;69;42	2	1,89
A5	87;25;55;50	84;0;52;64	8	2,46
A6	67;46;23;29	51;24;0;56	21	0,94
A7	35;35;63;39	0;7;46;65	31	1,99
A8	33;46;31;20	0;27;7;53	33	1,65

For the theoretical forecast of the saving inks, it has been numerically calculated the autotypical synthesis equations for an arbitrary color. A number of possible correlations of CMYK inks have been obtained. The resulting series of correlations has two boundaries: the reproduction of the given color by the three CMY colored inks and the two color and black one. The reliability of the calculations with great accuracy is confirmed by experimental data. As a result of the experimental research, it can be argued that the color separation of digital originals using autotype equations, basic color vectors of inks and the index of non-linearity of the printing process enables to save color inks and thus provide colorimetric accuracy of color reproduction.

5 Conclusion

In this paper new methods of the digital processing of images are presented. They demonstrate a fundamentally new approach to the implementation of the process of color separation and save inks with a significant extent.

Analytical solutions of the autotypical equations of the image synthesis on the imprint with colored inks which have been obtained due to the using of a new color space ICaS. This result allowed us to create a new analytical model of the color synthesis on the imprint. Therefore, the computer program ICaS-Color Synthesis-2 was developed. In this program was implemented the method of definition and replacement of colors of original, which physically cannot be reproduced in printing, developed by the authors. A database of these colors was created for standardized print conditions that can be expanded for particular production conditions.

New methods of the digital processing of images and their software implementation are the basis of the new information technology of color separation ICaS-ColorPrint. New technology testing was completed and was compired with classic one by quality and quantitative indicators. The obtained results confirm the economic effect and quality of color reproduction.

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