Digital method of analyzing color parameters during PDF document verification⋆

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Abstract

The article highlights the process of checking PDF files before printing. The peculiarity of the selected method, which significantly affects the quality of the final printed publication, is highlighted. The essence of the process is to identify and eliminate all possible shortcomings of the PDF document at the digital processing stage and prepare the file for printing. The main stages and settings of the properties of the PDF verification profile, which are built into the PitStop module, and the possibility of creating new ones as needed are described. The modeling of factors influencing the quality of checking a PDF file is carried out with the preliminary isolation of factors affecting the selected process. A semantic network of factors is constructed, based on which the mathematical modeling of hierarchies is used to establish the ranks of factors. By performing iterative procedures, each of which ensured the formation of the corresponding level, the initial data was obtained, and a multi-level graphic model of the priority influence of factors on the process of checking a PDF file was synthesized. Variants of converting images from the RGB model to CMYK were described.

The correspondence of the color characteristics of images during color separation in Photoshop and Acrobat Enfocus Printstore was also studied. Possible variants of converting images from RGB coordinates to CMYK, which are necessary for printing, were listed. The conditions for converting an image to the CMYK profile of the January 2002 Newspaper in the Enfocus Printstore and Photoshop modules were described. On the original and restored photo images, color coordinates in the La*b* space were determined using Adobe Photoshop and Acrobat software and the Enfocus Ritstop module, demonstrating the work's built-in color coverage. After converting the photo image to the CMYK profile in the selected software packages, a diagram illustrates the color difference value for three control points. The study proves the differences in color reproduction when converting the image from RGB to CMYK and later preparing the publication for printing reproduction in the module Enfocus Pitstop Professional.

Keywords

PDF validation, modeling, image color characteristics, conversion profiles, color difference, color gamut, chromaticity coordinates, additive color model, subtractive color model.

1. Introduction

In the field of printing production, many publications can be submitted to the customers themselves, adhering to the requirements presented by the enterprise. However, it is necessary to consider the possible ignorance of the technological features of preparing the publication for printing reproduction by the customer. To do this, the subsequent stages of the publication's passage in production take into account all stages of the order's passage, and, as a result, there is a need to check the prepared file. To check the PDF for compliance with the accepted requirements, it is enough to select the Preflight operation in Acrobat and in the window that appears, specify the necessary profile - a named set of rules that will ensure verification according to the requirements, taking into account the specifics of the color separation, printing method and type of equipment.

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PitStop Pro has become practically indispensable, especially in the advertising sector, since it processes many different PDF files delivered as print-ready PDF files. The most important functions of this type of software are data verification, correction using actions, and fast data throughput [1].

The article aims to analyze the process of checking PDF files using pre-printing information technology. In particular, to identify and determine the factors affecting the quality of the checking process and to carry out modeling with the allocation of the priority influence of factors on the process of checking PDF documents. In the presented study, it is necessary to determine the correspondence of the color coordinates of the scale fields when converting colors between additive and subtractive spaces in two types of software, particularly when checking PDF files. In the case of ensuring sufficient accuracy of color reproduction during conversion at a later stage of preparing the image for printing reproduction, it will be possible to link the image from RGB to CMYK in the module Enfocus Pitstop Professional.

2. Related works

The era of digital format allows you to work with a document remotely, simplifying the execution for the customer, but the final file must meet the production requirements. An important stage of prepress preparation of the final file is its error checking to avoid defects and unnecessary production costs. Since checking the file before printing is the final stage of pre-printing preparation for the publication, it is necessary to identify and eliminate all possible shortcomings. The PitStop module is an indispensable tool for everyone who works with PDF files in printing production. It is used when checking input files (pre-flighting) and offers a wide range of interactive functions that allow you to automatically make changes to several documents or orders simultaneously.

The printing quality directly depends on the correct sequence of all digital file creation stages. Before choosing a publication release technology, it is important to carry out a final check of the file quality. This check can be carried out according to standard or individual parameters [1,2]. Given the competition, this process is specialized and professional, so real experts rarely describe it. However, some domestic and foreign sources contain explanations and examples of checking in the appropriate software [1-3]. It is an important stage in preparing printed products, directly affecting the quality of the final result.

The Enfocus PitStop Professional software product is a comprehensive solution that combines the functions of automatic correction, editing, and checking PDF files before printing [6].

From a technical point of view, Enfocus PitStop Professional is a module that integrates with Adobe Acrobat. It contains about 20 built-in Enfocus PDF Profiles designed to check key parameters of PDF files and automatically correct common errors. The user is provided with interactive tools for editing and checking PDF documents.

The main advantage of this module is full control over text, graphics, color, and other file attributes during work. Depending on the needs, PitStop can perform the following functions [18]:

- Edit objects on PDF pages - a tool similar to page layout programs.
- PDF pre-print validation - automatically detects potential issues.
- PDF re-profiling - convert printable PDFs to PDF formats for iPad, web resources, or compact files for client approval.
- PDF certification - ensure compliance with international standards.
- Integrated into automated PDF workflows in conjunction with other Enfocus products.

PitStop Pro allows prepress workers to edit fonts, manage colors, adjust image resolution, and change other input file parameters. The module will enable you to check almost all the characteristics of PDF documents, guaranteeing their high-quality printing output. One of the important indicators of the quality of preparation of the information content of the publication for production is the conversion between color spaces of all photo images in the document. Fig. 1 presents a list of checked

parameters, particularly several indicators related to color reproduction: color profile type, color management elements, spot color conversion, transparency management, etc.

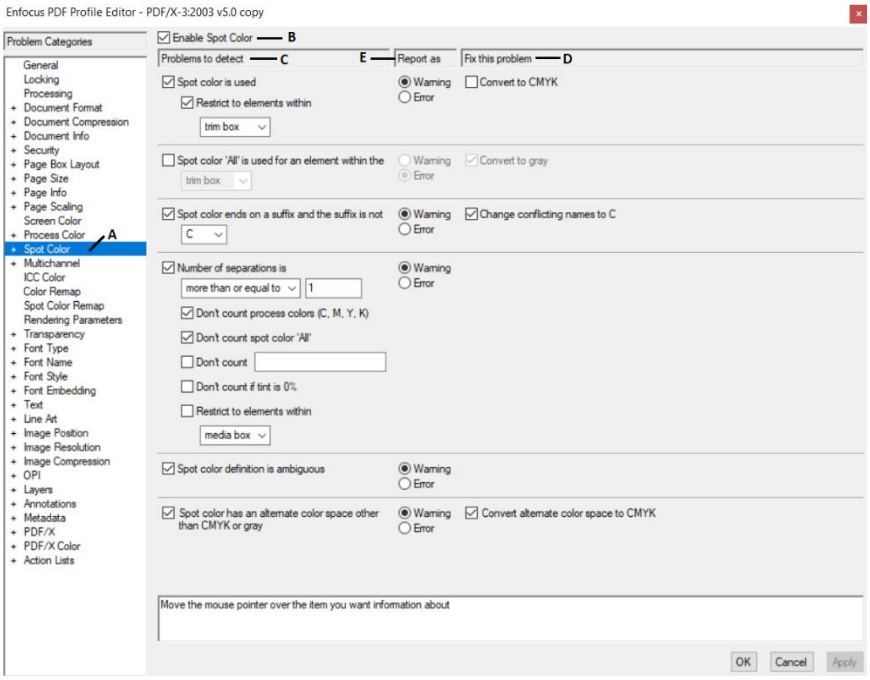

Figure 1: Configuring PDF profile settings.

Click on an image to change its color space or apply or turn off ICC profiles for images. You can also create an archive of frequently used colors, lock objects for the same processing (which significantly speeds up the workflow), and edit OPI processes.

If the color is set incorrectly, you can change the color of images, the fill or stroke of graphic objects, and the color of path lines. You can also define a different color model for them. To do this, use the Enfocus Pitstop Inspector panel.

The Enfocus Pitstop Inspector displays the current color settings for the selected image. Settings related to the use of CMYK transparency (a common problem) can be adjusted, which helps to eliminate color problems to a large extent. The Color Information tab, Fig. 2, contains all color spaces used in the PDF document, with possible additional information [17].

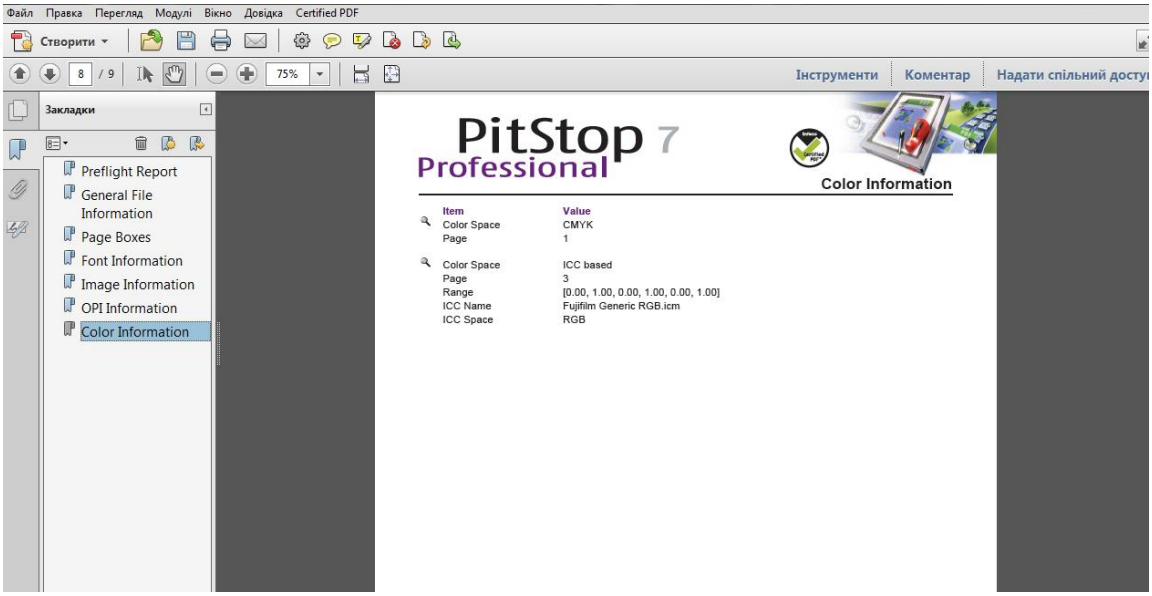

Figure 2: Color information.

The final stage of verification is a conversion, which involves the correction of all errors. After processing the file, it is imperative to check whether new problems have appeared and all old issues have been eliminated. Although the possibilities of testing and correction may have certain limitations, the main advantage of PitStop Pro is the ability to flexibly adjust print parameters and automatically convert spot colors to CMYK [7,8].

In the existing limited list of information sources [18] about the operation of the PitStop Pro software module as a whole and the process of converting color information content, sometimes contradictory data about the resulting image are indicated. Some sources provide data on ensuring the accuracy of color conversion in combination with significantly simplifying the process of preparing printed products, reducing the risk of errors, and increasing the quality of the final result [6]. Other information sources warn about a possible decrease in the quality of digital images and inaccuracies in color reproduction [9]. However, objective experimental data confirming both variants of the technological process of converting colors between spaces at a late stage of the prepress workflow are not provided. Therefore, there is a need to clarify information about the course of the specified technological process, both experimentally and by mathematical modeling, which will be implemented within the framework of this study [21].

3. Modeling the impact factors on PDF file verification quality

3.1. Identifying factors in the verification process

A set of main factors influencing the verification of a PDF file, namely: x_1— pdf file quality check (FGC); x_2 — fonts (FNT); x_3 — image reproduction quality (IRG); x_4— resolution (RZL); x_5— color model (CML); x_6— verification settings profile (ESP); x_7 — pdf version (VRN);

Semantic network of factors. The vertices of the graph (Fig. 3) identify the linguistic factors-arguments of the set $X = \{x_1, x_2, \ldots, x_8\}$, arcs — pairs of vertices (x_i, x_j), or which a relationship is defined $(i, j = 1 \div 8;\ i \neq j)$.

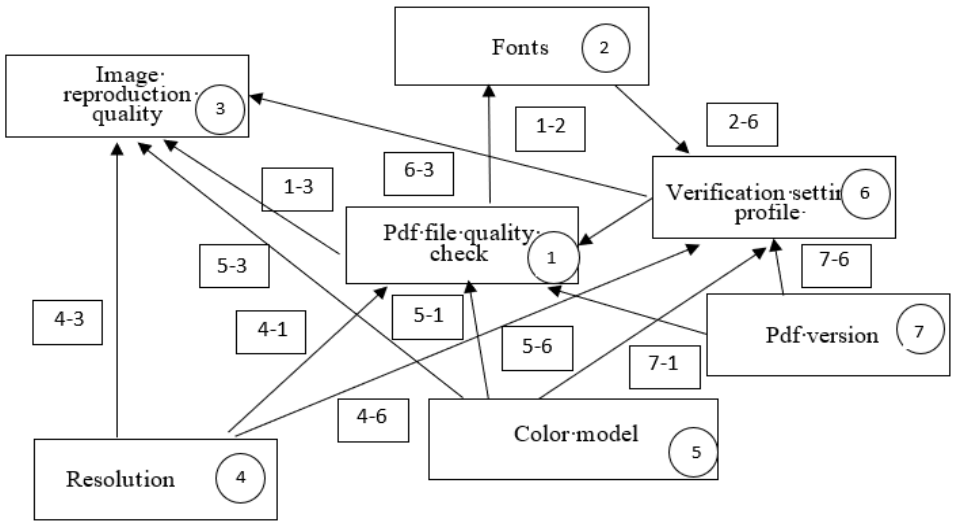

Figure 3: Semantic network of factors influencing pdf file verification.

The semantic network in Fig. 3 reproduces the main factors influencing the verification of a PDF file. In the notations on the arcs, the first digit indicates the factor—the source of influence, and the second digit indicates the factor dependent on it.

Accessibility matrix. The establishment of ranks (levels of importance) of factors can be carried out based on the mathematical modeling of hierarchies or the ranking factors method. According to the first method, a square accessibility matrix is constructed (denoted by B) - a mathematical analog of the dependencies between factors presented in the semantic network. The following logical rule determines the binary elements of the matrix:

$$b_{ij} = \begin{cases} 1, \text{if from the top you can reach the top} j; \\ 0 \ in \ this \ case. \end{cases} \quad (1)$$

Table 1
Accessibility matrix

	X1 FGC	X2 FNT	X3 IRG	X4 RZL	X5 CML	X6 VSP	X7 VRN
X1 FGC	1	1	1	0	0	1	0
X2 FNT	1	1	1	0	0	1	0
X3 IRG	0	0	1	0	0	0	0
X4 RZL	1	1	1	1	0	1	0
X5 CML	1	1	1	0	1	1	0
X6 VSP	1	1	1	0	0	1	0
X7 VRN	1	1	1	0	0	1	1

3.2. Determining the importance levels of factors

In the second column of the table, we record the subset D(wi)— numbers of reachable vertices, or numbers of unit elements of the corresponding rows of the reachability matrix; the third column defines the subset of the predecessor vertices P(wi) — numbers of unit elements of the columns of this matrix. In this case, the dependence will mean the fulfillment of the condition of equality of the numbers of factors specified in the second and third columns of the table, as a result of which a certain level of factors is for

Table 2
Determining the highest level of a factor

i	$D(w_i)$	$P(w_i)$	$D(w_i) \cap P(w_i)$
1	1,2,3,6	1,2,4,5,6,7	1,2,6
2	1,2,3,6	1,2,4,5,6,7	1,2,6
3	3	1,2,3,4,5,6,7	3
4	1,2,3,4,6	4	4
5	1,2,3,5,6	5	5
6	1,2,3,6	1,2,4,5,6,7	1,2,6
7	1,2,3,6,7	7	7

As can be seen from Table 2, the coincidence of numbers is fixed by factor 3 — reproduction quality. This factor will be considered the highest priority and influence the quality of PDF file checking.

Table 3
Determining the next level of factors

i	$D(w_i)$	$P(w_i)$	$D(w_i) \cap P(w_i)$
1	1,2,3,6	1,2,4,5,6,7	1,2,6
2	1,2,3,6	1,2,4,5,6,7	1,2,6
4	1,2,3,4,6	4	4
5	1,2,3,5,6	5	5
6	1,2,3,6	1,2,4,5,6,7	1,2,6
7	1,2,3,6,7	7	7

From Table 3 we remove the factors: 4 - resolution, 5 - color model occupy the second level.

Table 4
Determining the next level of factors

i	$D(w_i)$	$P(w_i)$	$D(w_i) \cap P(w_i)$
1	1,2,3,6	1,2,4,5,6,7	1,2,6
2	1,2,3,6	1,2,4,5,6,7	1,2,6
6	1,2,3,6	1,2,4,5,6,7	1,2,6
7	1,2,3,6,7	7	7

So, factors: 1 - quality of pdf file verification, 2 - fonts and 6 - verification settings profile occupy the third level, and factor 7 - pdf file version occupies the lowest, fourth level.

3.3. Synthesis of the model of the priority influence of factors on the process

As a result of performing iterative procedures, each of which ensured the formation of the corresponding level, we obtained the initial data for synthesizing a multi-level graphical model (Fig. 4.) of the priority influence of factors on checking a PDF file [20].

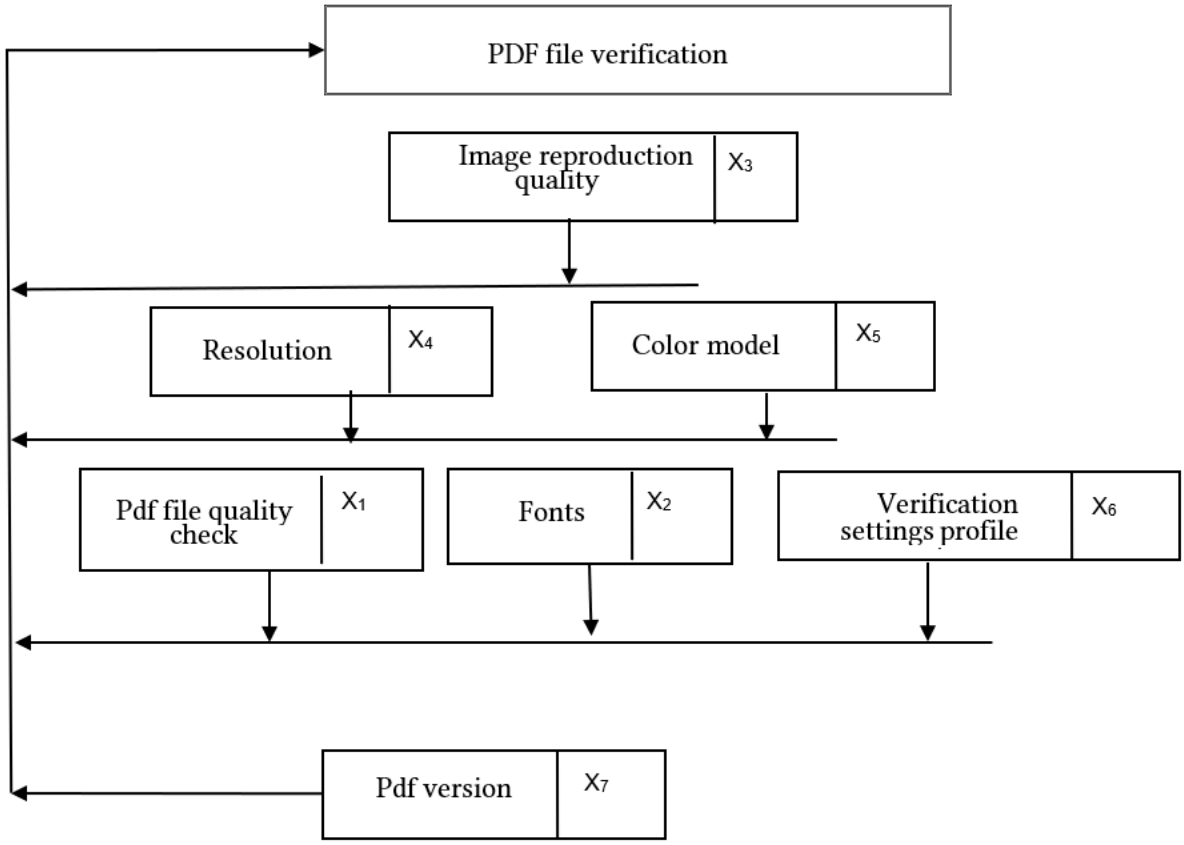

Figure 4: Model of the priority influence of factors on the process of checking an RDF file using the method of mathematical modeling of hierarchies.

4. Research into the correspondence of color characteristics of images during color separation in Photoshop and Acrobat Enfocus Pitstop

The relationship between the additive system with RGB coordinates and the subtractive system with CMY coordinates is described by the following dependencies:

$$\begin{pmatrix} C \\ M \\ Y \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{pmatrix} R \\ G \\ B \end{pmatrix} \tag{2}$$

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{pmatrix} C \\ M \\ Y \end{pmatrix} \tag{3}$$

$$K = \min(1-R, 1-G, 1-B),$$
$$Y = \frac{1-B-K}{1-K},\ M = \frac{1-G-K}{1-K},\ C = \frac{1-R-K}{1-K}, \tag{4}$$

where C, M, Y, and K are the densities of cyan, magenta, yellow, and black dyes normalized to the range [0...1], R, G, B are the numerical coordinates of red, green, and blue colors normalized to the range [0...1] [16].

The transition to CMYK coordinates consists of two parts (Fig. 5). At the pre-printing stage, the R, G, B coordinates are converted into absolute coordinates of the XYZ and LAB color spaces, which allows assigning unambiguous numerical values to colors (formulas (5) – (6)). The second part, which describes the printing link, contains ambiguity and occurs using experimental data, which provides modeling of the color print at the pre-printing stage according to the principle of analog [12, 23].

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} R/255 \\ G/255 \\ B/255 \end{bmatrix} \tag{5}$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.4125 & 0.2576 & 0.1804 \\ 0.2127 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9502 \end{bmatrix} \times \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix}$$
$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} 3{,}2408 & -1{,}5372 & -0{,}4985 \\ -0{,}9693 & 1{,}8760 & 0{,}0416 \\ 0{,}0557 & -0{,}2040 & 1{,}0373 \end{bmatrix} \times \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \tag{6}$$

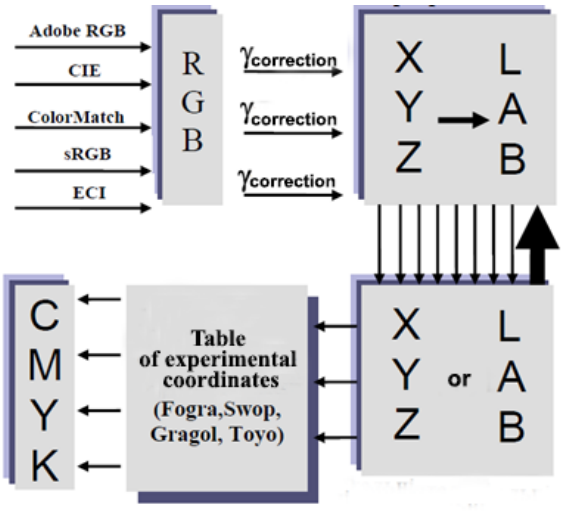

Figure 5: Algorithm for converting additive coordinates to subtractive ones.

Thus, the general task is to convert the values of the photosensitive receiver response obtained with red-, blue-, and green-sensitive separating media into values proportional to the number of printing synthesis inks for colorimetric, i.e., A visually accurate reproduction of the content of the photographic image on a print on a solid medium. In this case, the conversion profile considers the technological features of the print formation process and the printed base and ink (pigments) characteristics. Most specialists convert the image from the RGB model to CMYK in an image processing program (e.g., Photoshop) by assigning it an ICC profile corresponding to a specific printing process. In production, the correctness of the file preparation for printing is checked in Adobe Acrobat Professional or the Enfocus RITstor Acrobat module. In general, these programs are not designed to perform color separation. Still, if an error was made in the technological process and we have an image in the RGB model, it is possible to correct it by selecting the desired profile in this program. During the entire technological process of the order (from photography to the manufacture of forms), the transition from RGB coordinates to CMYK can be made at different stages. Suppose you convert the color to the final output space (CMYK) immediately after processing the image in Adobe Photoshop. In that case, such a process is called early binding, which means that the further technological process proceeds with the attached printing process profile.

The layout process has a variant of intermediate binding (image in the program with the subsequent CMYK profile). The variant of late binding postpones the conversion as much as possible until the final stage, before the exposure of the printing plates. The color separation is performed in the RIP using the same profile. Another example of late communication is the conversion of RGB to CMYK using the Enfocus Rtstor RDF file validation module, Acrobat.

4.1. Study of image conversion conditions according to the CMYK profile January 2002 Newspaper in the Enfocus Ripstop module and Photoshop

The conducted modeling and synthesized multi-level graphical model of the priority influence of factors on checking a PDF file shows that the color model is one of the determining factors that impact the quality of file checking. It is known that converting a photo image from an additive space to a subtractive one can be carried out either in the environment of a raster editor during prepress processing or in the environment of software for checking a PDF file during the final data analysis before output. Since the conversion factor between color spaces is very significant, it is important to check whether the qualitative characteristics of photo images depend on the place of conversion in the prepress workflow and the software for its implementation. For this purpose, an image was selected for which the Adobe RGB 1998 color profile was set. This image contains a plot with objects painted in memorable colors, which are especially critical for color reproduction, as well as graduated scales of the primary colors of the additive and subtractive spaces. This image is converted into a subtractive CMYK Japan 2002 Newspaper profile alternately in the Photoshop graphic editor environment and the Enfocus Pitstop module (Acrobat). On the original and restored photo images, color coordinates in the La*b* space were determined using the Adobe Photoshop software and the Enfocus Pitstop module of Acrobat. The results obtained are displayed on the a*b* chromaticity diagram (Fig. 6). As can be seen from the constructed color gamut figures, a photo image converted from the Adobe RGB 1998 color profile to the CMYK Japan 2002 Newspaper profile by the Enfocus Printstop (Acrobat) software is characterized by a wider color gamut, which even goes beyond the color gamut of the offset printing method according to the ISO 12647 standard. This, in turn, means an inevitable compression of the color space of the photo image during its subsequent reproduction by the offset printing method. The color gamut of photo images in the additive Adobe RGB 1998 space coincides when analyzed in the environment of both software products. From the results, the type of software that performs the conversion between additive and subtractive color spaces has a significant impact.

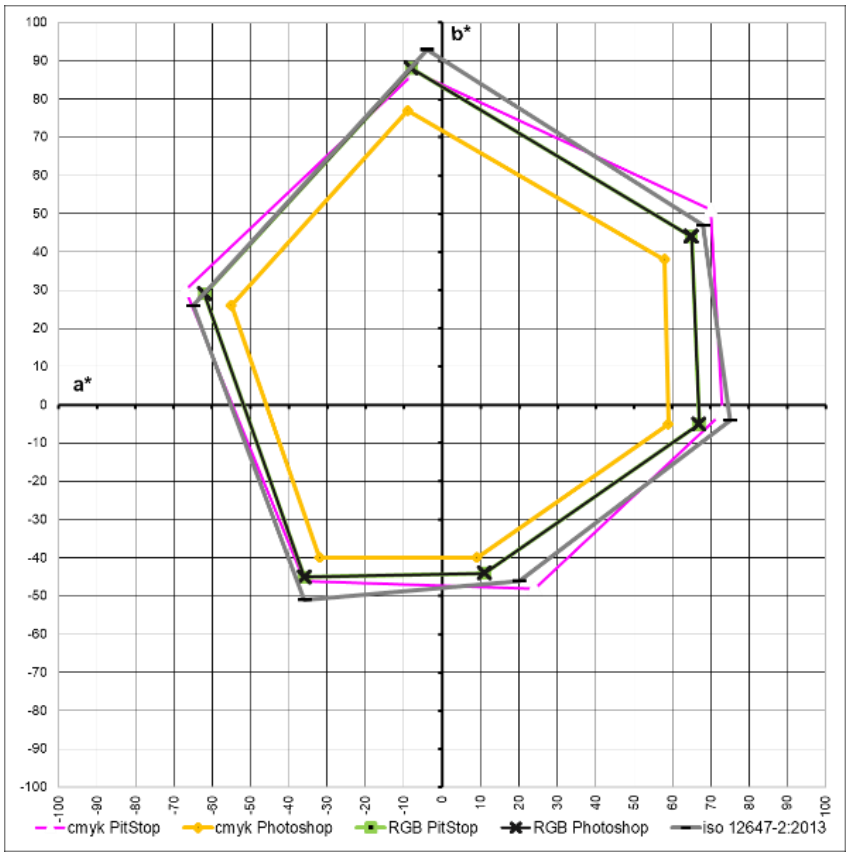

Figure 6: Photographic color gamut chart.

The results already prove that when converting from the additive Adobe RGB 1998 profile to the subtractive CMYK profile, January 2002 Newspare in the Enfocus Ritstor module, the color characteristics of the photo image differ significantly, as can be seen from the constructed diagrams. To better understand how the position of the conversion stage in the workflow affects the outcome, we also measured the color coordinates of three control points in the photo image. According to the obtained data, the degree of identity of their colors was calculated by the magnitude of the color difference between the color of the same area in the Adobe RGB 1998 profile and the CMYK Japan 2002 profile. - a unit of measurement of the difference between two colors, as the distance between two chromaticity points in the three-dimensional CIELAB color space. There are several formulas for calculating color difference, which take into account different numbers of factors. Standard- ΔE (CIE1976), ΔE (CIE1994), ΔE (CIE2000) and others. Following modern standards for assessing the quality of color reproduction, in our study, we will use the formula to calculate the color difference ΔE (CIE2000):

$$\Delta E_{00}^{*} = \sqrt{\left(\frac{\Delta L'}{S_L}\right)^2 + \left(\frac{\Delta C'}{S_C}\right)^2 + \left(\frac{\Delta H'}{S_H}\right)^2 + R_T \frac{\Delta C'}{S_C}\frac{\Delta H'}{S_H}} \quad (7)$$

Where RT is the color angle rotation of the hue, SL is the compensation for lightness, SC is the compensation for color saturation, and SH is the compensation for hue. Fig. 7 shows a diagram that demonstrates the magnitude of the color difference for three control points after converting the photo image to the CMYK profile Japan 2002 Newspaper by Adobe Photoshop and Acrobat Enfocus Pitstop, respectively. For offset printing, this value should be no more than 4-5 units, and for reproducing branded colors, even less [14].

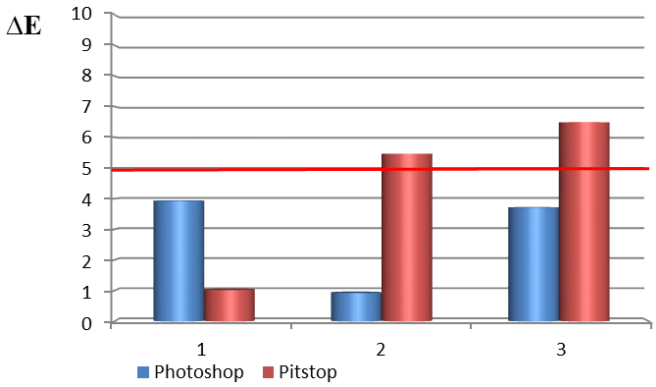

Figure 7: Diagram of the color difference magnitude for three control points after converting a photo image to a CMYK profile, Japan 2002 Newspaper using Adobe Photoshop software and Acrobat module Enfocus Pitstop.

The diagram in Fig. 8 shows that converting a photo image to the CMYK Japan 2002 Newspaper profile using Adobe Photoshop software provided an acceptable color difference of fewer than 5 units. This will ensure the identity of the observer's visual perception of colors. In contrast, converting between profiles using the Enfocus Pitstop module provided acceptable color reproduction accuracy for only one of the samples, while for the other two, the color difference would be visually noticeable.

5. Conclusion

Describes the process of proofreading PDF files before printing, which is error-free, since a printing professional performs it. According to the results of the research, the following was done: factors affecting the quality of the research process were identified and specified, a semantic model was built based on the identified factors, depending on which a model of the priority influence of factors on the PDF file verification process was compiled using the method of hierarchies and iteration tables, the correspondence of CMYK coordinates during early and late binding of image preparation for printing in the Enfocus Pitstop Professional module was proven, a synthesized multi-level graphic model of the priority influence of factors on the PDF file verification process was built, which indicates the importance of positioning the process of converting between color spaces in the prepress workflow. Thus, the results confirm the need to consider the technological process of preparing publications and prioritizing conversion between color spaces when processing visual information in a graphic editor.

Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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