Approach to the estimation of print layers offset in the printing system

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Abstract. A significant number of scientific works and inventions is devoted to the problem of quantitative and qualitative accuracy evaluation of color reproduction, including its automation. Various approaches and methods of managing parameters estimating the quality of color image transmission on various information carriers, including printed media, are used in our country and abroad. However, in estimation the offset of printed layers, along with the control of color-to-color registration, it is important to determine the distance between raster point size and the initial one. The paper considers the approach to solving this problem. It is shown that the method provide not only the area of the nana-pattern estimation, but also the amount of nana-pattern offset relative to the ideal nana-dot.

Key words: control automation, printing system, offset of printed layers, accuracy of color reproduction

1. Introduction
A significant factor in obtaining high-quality color reproduction is the high accuracy of superimposing for color-separation images on cyan, magenta, yellow and black inks (Fig. 1). Accuracy of color-to-color ink registration should be within a few hundredths of a millimeter.

![Figure 1. Print layers offset](image-url)

The possibility of ensuring the color-to-color ink registration on the press along the element of cylinder and the direction of paper sheet movement is achieved by ink registration control relative to
them with a step of 1/100 mm. Low distance in color-to-color registration can be corrected from the control panel. By rotating and moving a single plate cylinder, correction of color-to-color registration can be performed along the cylinder circuit and in the axial direction. Diagonal control of color-to-color registration (image rotation) is possible in some models of presses. It is achieved by moving the plate cylinder (the ideal option would be to turn the plate itself on the plate cylinder). Systems of the registration estimation and control in press are developed for speeding up and simplifying the registration process in the printing machine. Most of them are based on the analysis of special marks printed on the matter.

The easiest way to check the ink registration is to examine a certain part of an image in a magnifying glass (Fig. 2, a). If the magnifier is equipped with a measuring scale, the printer can estimate the value of color misregistration and, as required, control the non-registration by the cylinder circuit and in axial direction.

![Image](https://via.placeholder.com/150)

**Figure 2.** Distances in color registration: a) halftone, b) registration mark

In order to simplify the control process, special registration marks are printed. Registration marks are copied onto plates thus that during the exact line-to-line / mark-to-mark registration of each printing inks / color separation images, these mini-marks fall on one another or form certain structures - registration marks, crosses (Fig. 2, b). Distances are visually determined by means of a magnifier and then are taken into account in press setup.

Automated ink registration-probing systems can define the distance, quantify it and display it the printer on the monitor.

2. Problem statement

According to ISO 12647-2 to ensure the quality of offset printing, P. Korytkowski and others have developed a structure that allows to reduce the setup time of printing presses [1]. The structure is an integrated approach to control the perfection factors of printing on an offset press. It allows storing the data for checking the printouts quality in accordance with the ISO, identifying quality defects that will help machine operators to solve most quality problems, and developing corrections for typical settings to shorten up time.

In [2], a description of an automated visual control system for a press in real time is given. The used methods enable a compromise between the resolution and processing speed. The system consists of two parts. The first is a mechanical module, designed to arrange sheets that need to be checked by scanning images. The second is a module of machine vision (Vision) supported by various hardware and software elements. The Vision system consists of the following hardware elements: a control module, an image-processing module and a detection module. It is noted that the most important criterion in determining the priorities of machine vision systems is time that is needed for a system to complete its tasks.

According to [3], the use of sub-pixel methods is especially important for automated verification in order to recover lost information in sampling and quantifying processes. The heart of the method of
identifying imperfections by means of comparison is based on the subtraction of two patterns of the same type. In practice, the ideal coincidence between the two patterns is impossible to achieve. The use of sub-pixel methods for determining the position of the characteristic points, which are then used for reconstruction, can improve the coincidence between the patterns, which will be compared in real time, and eliminates the possibility of data loss.

J. Lundström and A. Verikas [4] presented an estimation of print quality based on Random Forest – machine-learning algorithm – based on objective values of several print quality parameters. Parameter values were obtained using sensors through data mining and analysis of color images. The study shows that the RF model using print quality attributes can provide a print quality estimate that is well correlated with expert’s estimations. The print quality attributes used in this work are automatically measured on simple test charts, the so-called double gray bars, and can be used in expert decision support systems designed for printing and paper production industries.

In view of quite large discrepancy between the subjective estimation of print quality provided by various subjects, the accuracy of the assessment of print quality estimation obtained from the designed model is very encouraging. However, to achieve the best model efficiency, the number of quality attributes should not exceed 3-4.

Among all the criteria, we can distinguish two of the most significant printing quality indexes – color displacement in printing and the distance of a or b components in CIE Lab (Fig. 1).

Morflyuk V.F. and others in order to obtain quality maintenance of printed matter [5] proposed a method for the digital characterization of modeling the ink registration, which ensures the consistency of ink registration control and evaluation precision of its stabilization parameters (0.05-0.01 mm). It also allows objective process control of ink registration. This method is considered for its use in sheetfed printing presses, based on objective processing of amplitude-time parameters of pulse signals from optical sensors, which are installed in sheet transfer system of a press on both sides of the sheet and information transfer about the sheet orientation of the base of special marks in the form of right-angled triangles.

In the works under consideration the value of nana-pattern difference relative to the ideal nana-dot is not estimated and is the aim of the work.

3. Problem solving

This paper discusses a rectangular pattern of the printed matter, containing a system of m x n colored nano-dots that in ideal are circles. In practice, print defects usually occur, in particular, the ink does not completely fill the circle; the paint goes beyond the border of the circle (dot gain), which leads to an image offset.

The copy quality is characterized by a two-dimensional random vector $X(X_1; X_2)$, where the random variable $X_1$ is the area of a real dot print (in $μ^2$ or in coded units), the random value $X_2$ is the area of printed part of the ideal nana-dot with dimensional tolerances. In coded units the area of an ideal nana dot is taken as a unit. The ideal values of a random vector $X$ are $X(1;1)$.

Problem define is to find the distribution of the random vector $X(X_1; X_2)$.

The test specimen of a printed matter with m x n colored nana-dots a rectangular coordinate system and a scale unit are entered. It gives analytical specifying of defined areas ($X_i$ and $X_j$ values for each printed nana-dots) using mathematical and harmonic analysis techniques (Fig. 3).
Figure 3. The offset of printed nano-dot relative to an ideal one

Assume that these areas are areas of elementary region, otherwise the prints are divided into a finite number of elementary regions. The upper ($y = y_i^+$) and lower ($y = y_i^-$) boundaries of each elementary region are specified as Fourier polynomials, after preliminarily measuring the coordinates of points lying on these boundaries. Random variables $X_1$ and $X_2$, as will be shown below, have a distribution close to normal. The test of the hypothesis on the normal partition law was carried out using the Pearson $\chi^2$ fitting criterion.

Estimation of areas $X_1$ and $X_2$ for the i-th nano-dot is found with the help of a definite integral using the formula

$$ S_i = \int_{a_i}^{b_i} (y_i^+ - y_i^-) \, dx, \quad i = \overline{1,m} $$

where $y_i^+$ - Fourier polynomial for the upper boundary of the elementary region, $y_i^-$ - Fourier polynomial for the lower boundary of an elementary region.

To simplify formula (1), the coordinate origin is moved at point $a_i$ of the segment $[a_i,b_i]$ and the difference $b_i - a_i$ is denoted by $a$. Then

$$ y_i^+ = \sum_{k=1}^{n} b_k \sin \frac{\pi k x}{a}, \quad \text{где} \quad b_k = \frac{2}{a} \int_{a_i}^{b} y_i^+ \sin \frac{\pi k x}{a} \, dx, $$

$$ y_i^- = \sum_{k=1}^{n} c_k \sin \frac{\pi k x}{a}, \quad \text{где} \quad c_k = \frac{2}{a} \int_{0}^{a_i} y_i^- \sin \frac{\pi k x}{a} \, dx, $$

$$ S_i = \int_{0}^{a} \sum_{k=1}^{n} (b_k - c_k) \sin \frac{\pi k x}{a} \, dx $$

Random variables $X_1$ and $X_2$ have a distribution close to normal.

A non-contact measurement method with a microscope measuring machine VMM 150 produced by "Walter Uhl technische Mikroskopie GmbH& Co", Germany was used for the development of the algorithm to determine the geometric characteristics of the point (Fig. 4).
Figure 4. Algorithm for measuring the geometric characteristics of the point

The practical implementation of the proposed approach has shown that the accuracy of color reproduction assessment depends on the components of the printing system, print layers offset and affects the amount of color volume (Fig. 5–7). For the description of color, color gamut and bodies of color gamut of printed systems it seems most appropriate to use the colourimetric system CIE L * A * b * due to its UCS and the ability to evaluate color difference [6].
4. Conclusion

Note that this approach allows us to estimate not only the area of the nano-pattern, but also the offset distance of the nano-pattern relatively to an ideal nano-dot. The offset of screen dot contour follows relatively to its center non-uniformly. It also causes total or partial loss of some image elements. The proposed approach to measuring the offset of print layers presents an opportunity to improve the estimating method and the hardware and software of a color image, as well as to automate the control process.

References

[1] Korytkowski P, Olejnik-Krugly A, Zaikin O 2009 IFAC Proceedings 42 (4) 1875–1880
[2] Torres F, Sebastian J M, Aracil R, Jimenez L M, Reinoso O 1998 Image and Vision Computing 1998 Vol. 16 Issues 12–13 947–958. https://doi.org/10.1016/S0262-8856(98)00059-6
[3] Soukup D, Bodenhofer U, Mittendorfer-Holzer M, Mayer K 2009 Image and Vision Computing Vol. 27 Issue 8 989–998
[4] Lundstrom J, Verikas A (2012) Assessing print quality by machine in offset colour printing, Knowledge-Based Systems, Elsevier, 0950–7051.
[5] Morflyuk V F, Karpenko I S, Churkin V V 2016 Method of digital characterization modeling of ink registration in sheet transfer system of a press. Proceedings of BSTU 9 22–28.
[6] Varepo L, Golunov A, Golunova A, Trapeznickova O, Nagornova I 2015 Testing and Measurement: Techniques and Applications: Proceedings of the 2015 International Conference on Testing and Measurement Techniques Testing (January 16-17, 2015). London: Taylor & Francis Group 69–71 DOI: 10.1201/b18470-18.