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Improvement of line image reproduction in the system of prepress engineer work

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Abstract. In order to optimise the process of prepress engineer work, it is necessary to provide a high-quality display of the line image, which ensures the most accurate transfer of the geometric dimensions of individual elements. The purpose of the article was to determine the degree of influence of the binarization threshold on the resolution value of raster line images. The experiments were based on the use of general scientific methods of analysis, generalisation, classification, deduction. To assess the quality of line image reproduction in this paper, photoforms were employed using a line test object which was designed as an accurate photograph with the use of an optical density distribution profile. The paper examines the influence of various parameters of raster structures on the playback quality of reproductions. The specifics of using a photo output device as the main link, which ensures the reproduction quality of image details, have been determined. The geometry of the raster structure when using rotation angles with rational tangents has been analysed. Features of the Accurate Screening technology have been systematised. The difference between "rational" and "irrational" rasterization methods has been considered. The main aspects of the use of line details in the reproduction process have been considered. The proposed method for assessing the quality of a line image reproduction with an uneven edge has been called the "signal-to-noise ratio" method, and it has been concluded that the scanning stage affects the quality of image reproduction to a greater extent than the photo output. The practical result of the work is the development of recommendations that can find practical application in reproduction processes. The developed binarization algorithms allow processing of images with significant zonal brightness unevenness, with monotonous brightness areas, and highly noisy images

Keywords: resolution; binarization; scanning resolution; line originals; raster line frequency

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INTRODUCTION

The need to obtain a clear, high-quality reproduction and high-quality line details reproduction of the image, which can be either single or a part of group lines of periodic grids, determines the relevance of the topic of this paper. In the process of reproducing line originals, the main task is usually to accurately convey the geometric dimensions of the line elements. With poor geometric accuracy, lines may be distorted in the reproduction process, this is especially noticeable for small details.

The interval of optical densities between the reproduced transparent and opaque areas of the photoforms should be sufficient to ensure the protection of the mould material from the effects of radiation in the subsequent copying process. As the size of the part decreases, the optical density of the part also decreases. Combined with distortions of geometric accuracy, this can lead to the complete disappearance of small lines in the reproduction process. The sharpness of boundaries may be lost when playing back an analogue image, especially if the contrast ratio is insufficient. When reproducing line details in the system of element-by-element image processing (SEIP) on photoforms and further on printed prints, the well-known effect of reproducing line originals in SEIP is revealed, manifested in the formation of a stepped boundary structure during discrete line formation. In each row, the details of the image may have a sharp U-shaped transition at the boundary, but depending on the mutual orientation of the scanning direction and the location of the line element, when being visually assessed, a rectilinear continuous boundary of contours and lines can be distorted to a greater or lesser extent, affecting the quality of the perceived image.

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Together, all these parameters – geometric accuracy, optical density interval, structure of the edges of object boundaries and line details, image contrast – can determine the image clarity. Currently, there is no systematic data on this problem, so this topic is relevant.

Scientific works [1-3] develop the problem of analysing print quality depending on the specifics of technological aspects of image reproduction mechanisms. But, these works do not consider the concept and possibilities of entering information that affects the image clarity.

Studies [4-6] develop the principles of image discretisation into different raster dots of the same distance. But these studies lack the list and analysis of the principles of how to build adaptive colour separation.

The issues of obtaining images in various registration systems, when transmitting visual information through communication channels, are raised in works [7-9]. However, these works lack recommendations regarding the assessment of methods of image discretisation and quantisation.

Scientific works [10-12] consider the features of reproducing a line image for digital printing. But these works do not provide the results of the study of the sharp properties of a raster line image when using various raster structures.

Aspects of automation and information support of reproductive processes are given in studies [13-15]. However, these works lack the study of the mechanism of digital data processing in order to obtain reproduction.

Problems of colour transformation are analysed in studies [16-18]. However, these works do not take into account the influence of the binarization threshold on the image resolution.

The main aspects of colour representation modelling in different colour systems are given in work [20]. But these studies do not contain consideration of key aspects for adjusting equipment to achieve the required quality of colour image reproduction. Thus, this article was to study the degree of influence of the binarization threshold on the resolution value of raster line images.

The novelty of the work consists in building a model of data flows in the reproduction system, which allows analysing information about the parameters of the printing process and adjusting the equipment settings to achieve the required quality of colour image reproduction.

MATERIALS AND METHODS

To achieve this goal, the article uses the following research methods:

1. Generalisation. Using this method, an experiment has been conducted in which the influence of the raster structure on binarization algorithms has been studied.

2. Classification. Using this method, noise sources in the binary channel acting on the periphery of the binary image, have been investigated;

3. Deduction. Using this method, noise research has been carried out. In real physical systems and complex production processes, noise plays an important role, usually a negative one, because it leads to errors, resulting in undesirable properties;

4. Analysis. This method made it possible to describe the process of printing a pictorial original, for which a photoform was applied using a line test object. This scheme allows identifying characteristic components such as, for example, a binary channel, which is the basis for studying the noise immunity of binarization algorithms.

To study the robustness of binarization algorithms in relation to the printing process, a binary channel model with erasing noise has been introduced. This model, where two input signals 0 and 1 with some probability are converted into one, is well-known in information theory.

Such a noise model has not been considered for digital image conversion. In this model, the channel is a printing device whose input is a binary image obtained from a halftone, and whose output is "paper", where the "paint" reproduces the binary image. The elements "paint" and "paper" can have different implementations, for example, it is possible to talk about electronic paper or ink based on modern technologies. However, the methods of reproducing a halftone or colour image do not change.

In this work, to assess the quality of a line image reproduction, photoforms have been made with the use of a line test object (TO) made by the method of accurate photography. These photo- forms have a profile of optical density distribution. TO consists of 25 groups of lines. Each of these line groups contains a set of lines located at the angles of 0°, 45°, 90°, 135° to the direction of line scanning, which allows analysis for the lines with different spatial orientation. Three groups of lines – 1st, 11th and 21st – were chosen for the research, the sizes of the lines in these groups were measured with a microscope.

RESULTS AND DISCUSSION

Analysis of image detail reproduction using a photo output device

The main link that affects the quality of image detail reproduction is the photo output device, which consists of a raster image processing processor (RIP – Raster Image Processor) and a recording device (RD). Possible options for RIP implementation are a separate electronic device or a program or interface card of a personal computer [10]. It perceives a stripe image recorded in TIFF, PostScript, EPS or PDF format, which contains vector and raster information, and converts the information expressed in this form into bitmaps. In printing, the main data encoding standard is the PostScript graphic language developed by Adobe. As a result of processing in RIP, bitmaps contain information about the size and shape of a line or raster dot, about the angle of rotation of a raster structure. The raster structure is formed according to the matrix-specified transformation entered into the RIP memory.

The task of RIP is the formation of a pixel grid, on the background of which a grid of a raster structure is being formed, the size of its elements will depend on the size and shape of the recording spot (corresponds to the size of the spot of the laser beam), and recording resolution. The value of the dimensions of the image details generated in the photo output device (POD) should match the values actually obtained on the photo material. Theoretically, such a match is relatively easily achieved if the diameter of the laser beam is clearly correlated with the established resolution of the POD when the following condition is met:

$$d_l = 2.54/R, \tag{1}$$

where R is resolution (dpi); 2.54 is the conversion factor from inches to centimetres.

If this condition is not met, the photo output becomes non-linear, i.e., in order to obtain the required value of the line dimensions of the parts and raster dots, it is necessary to take into account the obtained distortions. The greater the discrepancy between the diameter of the laser beam and the output resolution, the greater the nonlinearity. Non-linearity leads to an increase in the size of the raster dot, distortion of the characteristic curve, changes in the size of line details, loss of time for linearization (calibration) of the POD and, ultimately, to a high probability of the defect.

So, in the process of research, the elementary raster structure has been considered as a simple square that can be rotated to a random angle. In the process of digital rasterization, a single raster structure must actually be examined from the standpoint that it is a two-dimensional grid of individual pixels. The reason for this consideration of the raster structure is the fact that pixel structures with truncated elements cannot be obtained. In the case of a single raster structure form with the correct square parameters, the desired result can be obtained when using a rotation angle of 0° (Fig. 1).

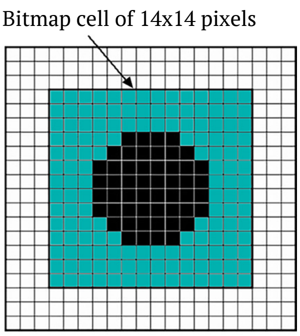

Figure 1. Raster structure of 14x1=196 pixels
Source: [8]

In the case of raster structure rotations, all corners become "occupied" with neighbouring pixels. Angles that have an integer pixel distance both vertically and horizontally are considered acceptable (Fig. 2).

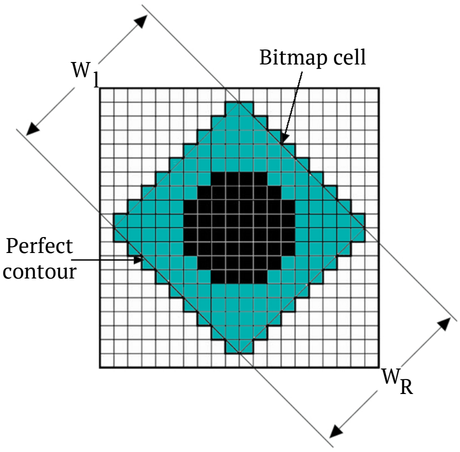

Figure 2. Raster structure at an angle of 45°. Its contour differs from the ideal raster structure
Source: [8]

The process of rasterization is called Rational-Tangent rasterization (RT). A graphical representation of the RT-rasterization process is shown in Figure 3.

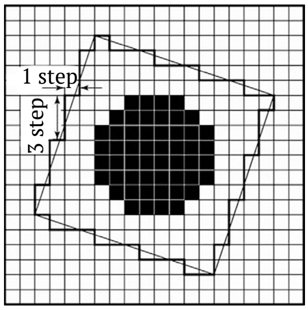

Figure 3. The geometry of the raster structure, changed in the process of RT-rasterization
Source: [8]

The results of the displacement in the process of RT-rasterization are given in the Table 1.

Table 1. Specificity of raster line frequency resulting from RT-rasterization

Paint	Angle of rotation	Raster line frequency
Yellow	0.0°	50.0 line/cm
Blue	18.4°	52.7 line/cm
Black	45.0°	47.1 line/cm
Purple	71.6°	52.7 line/cm

Source: [2]

Adobe developed Accurate Screens as part of PostScript (Level 1) and PostScript (Level 2). Adobe's competitors offered the following technological solutions to support RT-rasterization: Heidelberg developed the HQS (Higher Quality Screening) system, Agfa Corporation created the Balanced Screening technology.

Rasterization analysis by irrational tangents

The difference between the methods of "rational" and "irrational" rasterization is determined by the specific features of rational and irrational numbers.

In the case of "irrational" rasterization, a matrix with precisely defined distances between the centres of raster dots is used. In the case of "irrational" rasterization, the raster dot changes according to the mechanism of pixel changes.

While with amplitude-modulated rasterization (AM-rasterization) individual raster dots are located at equal distances from each other and only their sizes (amplitude) change, when using the method of frequency-modulated rasterization (FM-rasterization) the raster dots have the same dimensions, but they are randomly distributed on the printed surface.

The processing of digital data in order to obtain reproduction in many cases leads to completely new forms of organisation of production (as mentioned at the beginning of this section). These changes made to various digital data flow control systems (Workflow) gave a new sound to the sample and digital colour sample.

One of the traditional phenomena for polygraph reproduction is the appearance of moiré. The moiré phenomenon is based on the fact that when summing signals (electrical, optical, etc.), the resulting signal contains a low-frequency difference component.

To reproduce monochrome products, the recommended regular structure angle should be close to 45 degrees from the horizontal image. This complicates the visual perception of the raster image structure on the print and thereby positively affects the perception of the image as a whole.

To minimise moiré in the conditions of autotype synthesis, a change in the rotation angles of raster structures is used. At the same time, the rasters for contrasting colours (black, blue and purple) form a moiré of a shorter period, because they are separated from each other by 30 degrees. The raster for the yellow paint form, which is at an angle of 15 degrees to the other two, gives a lower frequency, but barely noticeable moiré due to the low visual contrast of the yellow paint (although it is the cause of the visually visible moiré, under standard rasterization conditions).

So, the following are used as standard raster rotation angles in printing:

0° – for yellow paint;
45° – for black paint;
15° – for blue paint;
75° – for purple paint.

In some cases, the interaction of the drawing structure and the periodic raster structure can be observed, which depends on the width of the detail, the relative location of the image details and the direction of the raster structure. In printing, this phenomenon is called object moiré, and it must be taken into account when developing the technique and evaluating the obtained results. The angles that determine the mutual orientation of the detail and the raster structure can be different, therefore the object moiré can be different.

When assessing the reproduction of line details with the help of periodic boundaries, it is necessary to take into account the possible occurrence of object moiré between these boundaries and the raster structure located at these angles. This is a question that also needs research.

When displaying visual information, the problem of accurate transmission of small details arises. Real information display systems always have some blurring, which manifests itself in the fact that an infinitely larger impulse, applied to an infinitely small space and called a b-function, is reproduced by the system no longer in the form of a b-function, but by a blur spot which is characteristic of this system (or its separate link). Among the practically important tasks there is the calculation of the intensity distribution in the image of a single line detail reproduced in the system or in its separate links with blurring. For example, for POD, among other factors affecting the quality of the microstripe image, there is a characteristic due to the transmission properties of the "exposure beam-recording medium" system. Experimental studies to assess the transmission characteristics of such a system have proven the suitability of this method.

The definition of the FPM by the edge function (EF) is of interest, firstly, because the edge of the detail is an object that is easy to manufacture, and secondly, because it becomes possible to define the FPM from ready-made images in which there is no test-object, since the edge is on many objects (corners of buildings, pipes, etc.).

Assessment of the reproduction quality of a line image

The work [4] proposes methods for assessing the FPM of photographic materials using the raster method, which provide the possibility of assessing the FPM for high-contrast images. When measuring the FPM of materials by this method, light is printed on them by the contact method, it is a linear raster with a ratio of transparent and opaque lines of 1:1, which has a constant frequency. The conditions of the experiment are close to those investigated in this work. Prints of a linear raster and a stepped wedge are obtained on contrast photographic film and, after measuring the optical densities of the original wedge, as well as halftone and raster wedges, characteristic curves are being constructed.

The need to move from one function to another is due to the fact that, with the essentially identical information content of different functions, they have different practical properties. For example, the important properties of TNF include, first, the relative convenience of its assessment, and second, with the use of TNF, the transfer characteristic of the system can be easily calculated from the known TNF of individual links. With the use of TNF, it is possible to separate the influence of different links of the TNF system and it can be determined using relevant experimental data, or by calculation according to the known line blur function (LBF) or CF, TNF determines the value of the contrast transmission coefficient of a one-dimensional grid with a sinusoidal distribution of intensity that depends on the spatial frequency of the grid.

Sizes of lines in groups of lines were measured using a microscope and are presented in Table. 2.

Table 2. Sizes of lines and gaps of the studied groups on the original, μm

	Angle 135°		Angle 0°		Angle 90°		Angle 45°	
	Line	Gap	Line	Gap	Line	Gap	Line	Gap
1 group	173.4	184	174.6	183.5	175.5	181.8	171	187
11 group	98.7	101.7	98.7	102.6	96.3	102.9	97.8	102.9
21 group	52.8	56.4	53.7	57.3	54	58.2	54.3	56.7

Source: made by the authors based on [4]

With the use of the obtained photoforms, an assessment of the impact of scanning parameters and line image output on the final quality of its reproduction has been carried out. Scanning was made on a flatbed scanner with the change of:

– scanning resolution R_B -800 ppi, 1520 ppi, 2500 ppi;

– binarization threshold T: 50%, 60%, 70%, 80%;

– scanning functions: Good, High, Excellent, 4 times Excellent.

The physical meaning of the "scanning function" parameter is not clearly defined, probably these functions differ in the organisation of the sharpening processes during scanning, in the accuracy of reading and in the speed of the signal processing. According to the results of line size measurements with a measuring microscope, curves were constructed for three size groups, characterising the dependence of the obtained line width on its spatial orientation and binarization threshold. As a sample, Figures 4-6 present dependences for three size groups at RB=800 ppi and RB=2540 dpi.

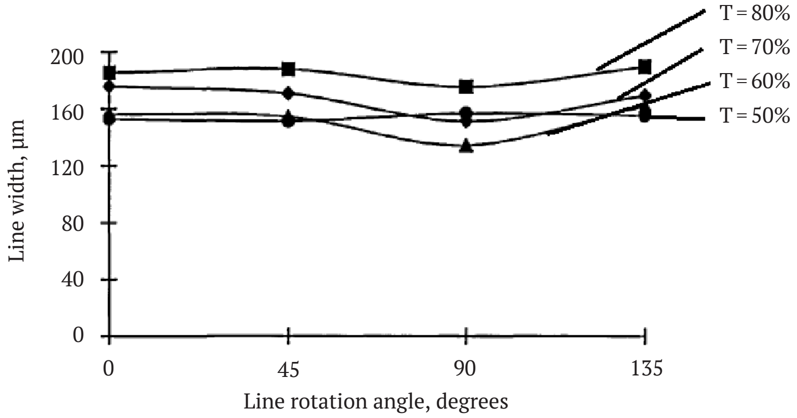

Figure 4. Dependence of the T line width on the photoform for the 1st group on the spatial position of the line at the values of binarization threshold Rв=800 ppi

Source: made by the authors

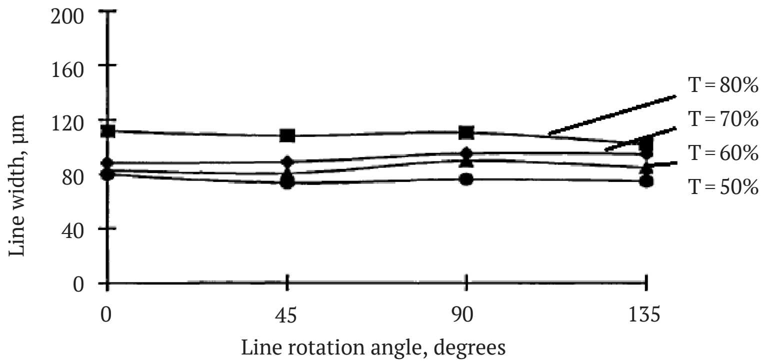

Figure 5. Dependence of the T line width on the photoform for the 11th group on the spatial position of the line at the values of binarization threshold Rв=1520 ppi

Source: made by the authors

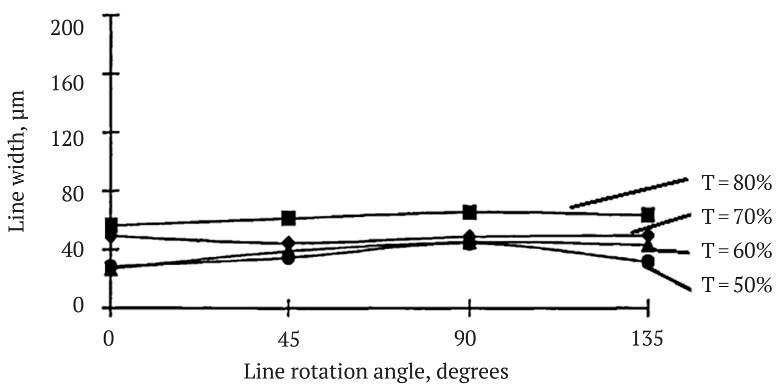

Figure 6. Dependence of the T line width on the photoform for the 21st group on the spatial position of the line at the values of binarization threshold Rв=2500 ppi

Source: made by the authors

The analysis of the experimental data showed that the "binarization threshold" parameter has the greatest influence on the dimensional resolution. In modern photo-printing systems, a rather sharp border of micro-line elements along and across the recording terms is ensured due to the high contrast ratio (y>-8) and the relatively high resolution of the photo material, resulting in the maximum optical density. However, with other line orientations, there is a loss of reproduction quality, caused mainly by a violation of the homogeneity of the line, its breakdown into fragments that form the stepped structure of the image.

Therefore, data on the line width with the part width measured by visual averaging can be considered as approximate, in particular, for lines at 45° and 135° angles. The use of such a criterion as "width of the detail" for a direct assessment of the reproduction accuracy seems time-consuming and quite ambiguous in the presence of a stepped boundary structure of the line detail, loss of line continuity.

The proposed methodical recommendations regarding the improvement of line image reproduction in the system of prepress engineer work continue the author's research [13; 15] on issues of information support of printing production processes. The developed technique can be used to analyse the resolution of raster line images, research possible deviations in the process of raster optimisation, and perform an assessment of reproduction quality.

The developed technique solves the problematic part of managing the processes of prepress preparation of printed products in terms of assessing the accuracy of line image reproduction. This is achieved due to the methodology developed by the authors for optimising the "signal-to-noise" ratio when assessing the reproduction quality of the line image with an uneven edge. At the same time, the authors found that the scanning stage affects the quality of image reproduction to a greater extent than the process of photo output.

This work, as well as studies [2; 9; 12], analysed the reproduction of image details using a photo output device. It considers an elementary raster structure in the form of a simple square with the possibility of subsequent return to an arbitrary angle. However, the mentioned studies [2; 9; 12] do not take into account the aspect of digital rasterization, in which the elementary raster structure must be implemented in the form of a two-dimensional pixel grid. At the same time, it is impossible to obtain partially truncated pixel structures.

This research analyses the specifics of digital data processing in order to obtain reproduction. Studies [1; 5; 8] offer various ready-made information systems to implement the task of processing large arrays of digital data. However, this work, unlike studies [1; 5; 8] analyses the Accurate Screening technology, investigates electronic rasterization according to the Accurate Screening method, considers the features of the PixelBurst coprocessor, which performs offloading functions of the main RIP processor.

The results of this research make it possible to overcome the phenomenon of moiré, which occurs as noise when summing up electrical, optical and other types of signals. At the same time, the resulting signal is a low-frequency difference component. Scientific articles [14; 20], in contrast to this research, give an overview of the processes of line image optimisation without taking into account the moiré effect.

This work, as well as studies [3; 19] used photoforms to assess the quality of rasterization. However, a distinctive feature of this work is the fact that in order to carry out an experiment, it used manufactured photoforms based on a line test object, which was created by the method of accurate photography.

The obtained results of the research on the development of a methodology for assessing the quality of line image reproduction are adequate within the limits of prepress printing production.

The limitations of the created methodology to conduct a study of the degree of how binarization threshold influences the resolution of raster line images were that it does not take into account the possible situations of uncertainty that may arise in the process of measuring line sizes with a measuring microscope for different size groups.

In addition, errors are possible when using a flatbed scanner to assess the impact of scanning parameters and line image output on the final quality of its reproduction. It is possible to overcome these errors due to the involvement of experts, but this, in turn, can lead to the subjectivity of the obtained results of analysing the resolution of raster line images.

CONCLUSION

This research was based on the fact that studying the instability of the printing process is of great practical interest, for example, in order to predict the result at the stage of prepress. To solve these problems, the market offers a huge number of products that lead to increasing stability. However, the question remains open, there are defective copies with certain defects in circulations. It is not possible to completely eliminate defects, but by choosing the correct components of the printing process, in particular by choosing a noise-resistant binarization algorithm, the likelihood of defects can be reduced.

The study of technological aspects of image formation as a result of binarization and raster process implementation made it possible to conclude that image clarity can be achieved by increasing such indicators as the regularity of raster structures, the spatial location of image details in relation to the direction of scanning and the angle of the raster structure rotation, shape and size of a raster dot, input-output resolution ratio, quality factor value combined with castration frequency.

In computer publishing, the "binarization threshold" has the greatest effect on the dimensional accuracy of a binary line image. Special attention should be paid to the correct choice of the binarization threshold as the main condition for ensuring the accuracy of binary line image reproduction.

A modification of the investigated algorithm has been proposed, which uses the randomisation process to improve the visual quality of the binary image.

As a result, there is a binary channel with a binary image in digital form, where zeros and ones at the input are converted into zeros and ones at the output, with the presence or absence of a printed element on paper. In a binary channel, both input symbols are converted into one.

The scientific result of the article is the research systematisation of the influence of binarization parameters on the result of line and raster image reproduction. The obtained binarization values make it possible to increase the contrast, highlight low-contrast details in line images, and improve their visual quality.

The direction of further research may be the development of a comprehensive assessment of reproduction processes.

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Покращення відтворення штрихового зображення в системі роботи препрес-інженера

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Анотація. Для оптимізації процесу роботи препрес-інженера слід забезпечувати якісне відображення штрихового зображення, що забезпечує максимально точне передання геометричних розмірів окремих елементів. Метою статті було визначення ступеня впливу порога бінаризації на величину роздільної здатності растрових штрихових зображень. Проведення експериментів ґрунтувалося на використанні загальнонаукових методів аналізу, узагальнення, класифікації, дедукції. Для оцінки якості відтворення штрихового зображення у даній роботі було використано фотоформи з використанням штрихового тест-об'єкта, який був розроблений як точна фотографія з використанням профілю розподілу оптичної щільності. В роботі досліджено вплив різних параметрів растрових структур на якість відтворення репродукцій. Визначено специфіку використання фотовивідного пристрою як головної ланки, яка забезпечує якість відтворення деталей зображення. Проаналізовано геометрію растрової структури при використанні кутів повороту з раціональними тангенсами. Систематизовано особливості технології Accurate Screening. Розглянуто відмінність методів «раціонального» і «ірраціонального» растрування. Розглянуто основні аспекти використанні штрихових деталей у репродукційному процесі. Запропонована методика для оцінки якості відтворення штрихового зображення з нерівним краєм, названа методикою «відношення сигнал-шум» та зроблено висновок, що на якість відтворення зображення в більшій мірі, ніж фотовивід, впливає стадія сканування. Практичним результатом роботи є розроблення рекомендацій які можуть знайти застосування у практичній діяльності при проведенні репродукційного процесів. Розроблені алгоритми бінаризації дозволяють проводити обробку зображень із значною зональною нерівномірністю яскравості, з монотонними областями яскравості, з сильно зашумленими зображеннями

Ключові слова: роздільна здатність; бінаризація; дозвіл сканування; штрихові оригінали; лініатура растрів