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ASSESSMENT METHODS OF HALF-TONE ORIGINALS DETAIL DISTORTIONS DURING RASTERIZATION

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One of the most important problems of printing industry is rasterization. It is the rasterization technology that determines the gradational content of the imprint and is responsible for the transfer of small image details and its clarity. In addition, the raster structure itself, becomes a source of noise in the reproduced image when it is visible. Manufacturers of raster structures strive to ensure accurate transfer of gradations of the original, image clarity, i.e., convey its structure while eliminating the visibility of the raster to such an extent that the image can be visually perceived as the original analog. That is why the market is saturated with various raster structures. Developers for advertising purposes describe their advantages, but in practice, the difficulties of working with raster structures and their shortcomings are revealed. Different raster structures differ in their properties, and no such raster structures can equally well solve all image reproduction tasks since images are different in their structure. Researching the possibilities of raster structures and structural properties of images intended for reproduction will allow the best combination of them to obtain the necessary reproduction quality.

Nowadays, in printing industry, there are no effective methods and tools for assessing distortions, which depend on the parameters of the printed elements, which are set by the raster transformation at the pre-printing stage, and are enhanced by various physical and chemical processes (exposure, development, etching, pressing, slippage, etc.), occurring at the form and print stages. This causes significant problems when choosing a raster transformation for better reproduction of originals with significant high-frequency content under the conditions of a specific reproduction process.

***Keywords**: density, raster, halftone original, frequency-contrast characteristic.*

Problem statement. The invention of screening was a powerful catalyst for the society development, as books and other illustrated printed materials became affordable and widely available. However, as various fields of knowledge progressed, the requirements for the reproduction process changed, and the drawbacks of this type of halftone became increasingly apparent. These drawbacks include:

– Nonlinear dependence of the halftone dot size on the nominal relative size (% of halftone).
– Visual unevenness of gradients.
– High likelihood of moiré.
– Technological limitations on lines frequency.

The task is to analyze methods of objective evaluation of halftone structures to choose the best combination with reproducible originals and achieve the desired quality of reproduction.

The state of theme research. The negative phenomenon of dot gain is well-known to printers. It can be said that this is a familiar enemy with which they have learned to fight, but probably will never be able to completely overcome. The non-linear behavior of this parameter (different degrees of dot gain in highlights, shadows, and mid-tones) and its dependence on various conditions do not allow for the development of a universal and reliable antidote.

This phenomenon is the basis of the second drawback of traditional halftones. Experts are familiar with the so-called 50% jump effect, which is a result of the visual unevenness of halftone gradient fills [1].

In expensive photocomposing machine models for forming such fills, special hardware procedures were even used to obtain smoother transitions.

The aim of the article. The purpose of the article is to describe the existing screening technologies, taking into account the study of spatial-frequency indicators created by the raster structure; assess the degree of geometry destruction of small details and contours formed when using different screening technologies; assess the possibility of reproducing details during screening with different halftone structures.

The main material. At a certain stage of prepress preparation, the source images (digital originals) are discrete in their structure. By the number of values that the signal amplitude can take, they can be divided into binary (two-level) and a semitone (multi-level) [2, 3].

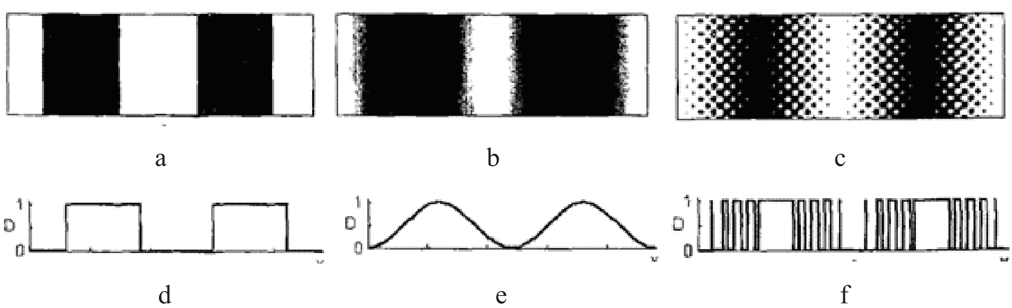
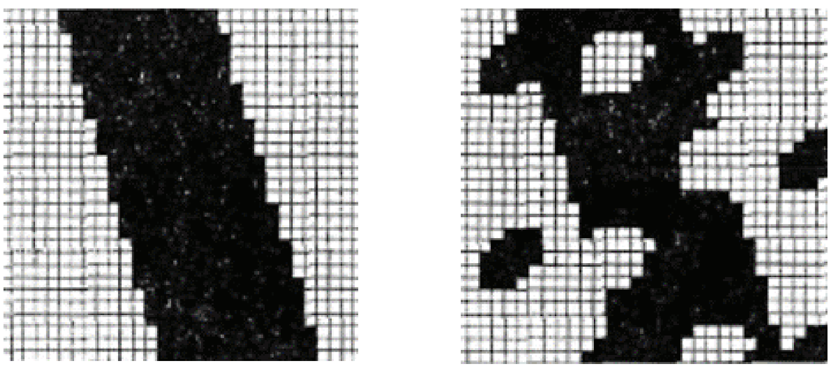


Fig. 1. Hatched fragment of a halftone original (a), its photographic (b) and raster (c) copies: d, e, f - corresponding tone distributions along the horizontal axis for these images

At the same time, all physical originals and, correspondingly, their digital equivalents in the reproduction system are halftones, which creates certain problems with their replication. In the printing process, an imprint is formed by transferring ink from the printing elements of the printing plate to the paper or other material being printed. In most printing methods, the thickness of the transferred ink is constant across the entire surface of the imprint. Accordingly, only two gradations, two shades, can be formed on it, which are determined by the optical densities of the unprinted paper (gaps) and the solid ink layer (printing element) [4, 7]. It should be noted that it is quite difficult to form an imprint so that the optical density of all its printing elements (screen dots and text symbols) is identical. Deviations in densitometric parameter values will be affected by uneven pressure in the printing pair, paint rolling, paper properties across the imprint area, and much more. When using high-quality printing equipment and proper setup, such deviations are minimized but not eliminated.

Thus, most printing methods, except a few rare varieties, cannot physically reproduce a halftone image on the imprint. Therefore, there is a need to convert the image structure in the reproduction process from halftone to binary, microdot, as such a structure can be reproduced on the imprint by the printing method [5, 6].

Evaluation of the effectiveness of reproducing high-frequency content of the original. The method is as follows: a halftone original with a dashed information content, of the world, always has a certain dashed (binary) pattern in which information about the geometry of the dashes dominates over information about their tone. If you imagine such a dashed prototype of the original (Fig. 2, a), as well as its raster copy (Fig. 2, b), in the form of a bitmap, then at the elemental level it will be possible to evaluate the change in the process of raster transformation of the quality of reproducing small details through a direct quantitative assessment of the magnitude of raster distortions.



a b

Fig. 2. Matrices (bitmaps) of the hatched precursor of a halftone original (a) and its raster copy (b)

The norm of raster distortions N_{RD} can be used as a quantitative measure of the geometry's small details and contours destruction in the autotypic process, which is calculated by the formula (1). For the convenience of interpretation and normalization of the obtained values, and even the similarity of the shape of the graph of the raster distortion value depending on the frequency of the original (Fig. 3), the following parameters were proposed by the frequency-contrast characteristic (FCC): the coefficient of geometric accuracy C_{GA} (2) and the normalized contrast of details on a raster reproduction C^{*}(3).

$$N_{RD} = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} \left| a_{ij} - b_{ij} \right|}{2\sum_{i=1}^{M}\sum_{j=1}^{N} a_{ij}}, \quad (1)$$

$$C_{GA} = 1 - N_{PI}, \tag{2}$$

$$C^* = 1 - \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} \left| b_{ij} - a_{ij} b_{ij} \right|}{\sum_{i=1}^{M} \sum_{j=1}^{N} a_{ij} b_{ij}}, \tag{3}$$

where a_{ij} – is an element of the bitmap value matrix of the original image, for example, shown in Figure 2 (a), b_{ij} – is an element of the bitmap value matrix of the halftone image shown in Figure 2 (b); i and j – are the numbers of the row and column of the matrix in which the element is built; M and N – are the numbers of rows and columns in the matrices, accordingly. A method for defining these parameters has been developed.

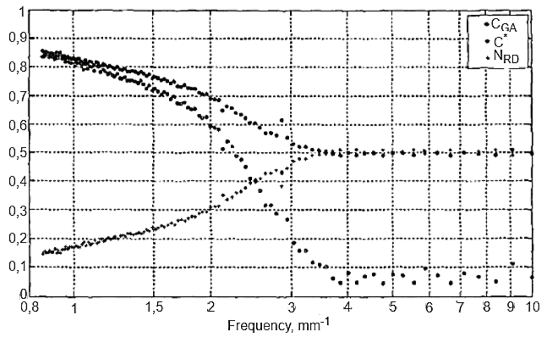


Fig. 3. Frequency distributions of the norm of raster distortion, the coefficient of geometric accuracy and contrast of details on a raster reproduction

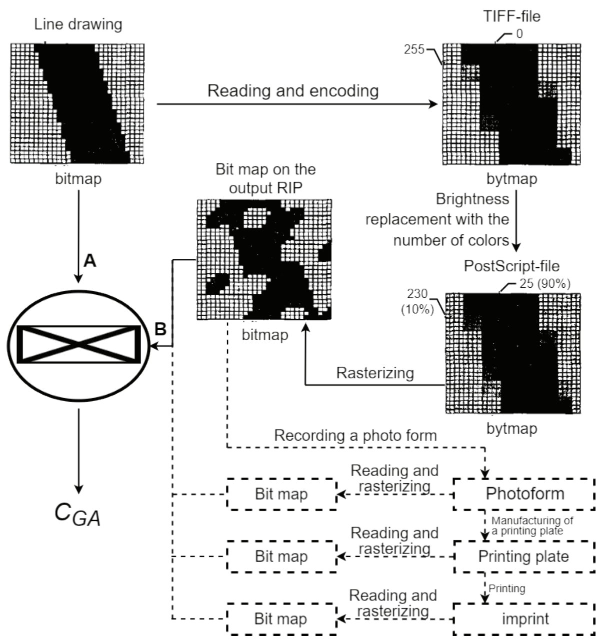


Fig. 4. The sequence of operations on the coefficient of geometric accuracy

On the example of determination of C_{GA} it is shown in Figure 4.

Conclusion. The frequency distributions of the norm of raster distortion, coefficient of geometric accuracy, and contrast of details on the raster reproduction are obtained, the form of which is shown in Figure 4. The technical meaning of the parameters C_{GA} and C^* being equal to 1, 0 is that the drawing is not distorted at all during the raster conversion process, in other words, the raster processor works as a Boolean repeater (Fig. 5, a).

a b c

Fig. 5. The original-imprint pairs: the imprint is identical to the original (a), the average brightness of the original area is transferred on the imprint (b), the original is converted to its negative (c)

The values of C_{GA} = 0.5 and C^* = 0 mean that half of the samples of the bitmap of the original have changed their values, and the raster structure instead of the details of the original reproduces the average brightness of this area (Fig. 5, b). The value of C_{GT} = 0 corresponds to the hypothetical case when absolutely all samples of the bitmap of the rasterized image have changed relative to the original, and as a result of rasterization, the original has been transformed into its negative (Fig. 5, c).

The relationship between the coefficient of geometric accuracy of the reproduction of small details and their contrast in raster reproduction is established:

$$C_{GA} = \frac{0.9259}{1.9334 - C^*}. \quad (4)$$

Judging by the close interrelation between these two parameters, it is assumed that the representation of the obtained values of one of them will automatically indicate the representation of the obtained values of the other.

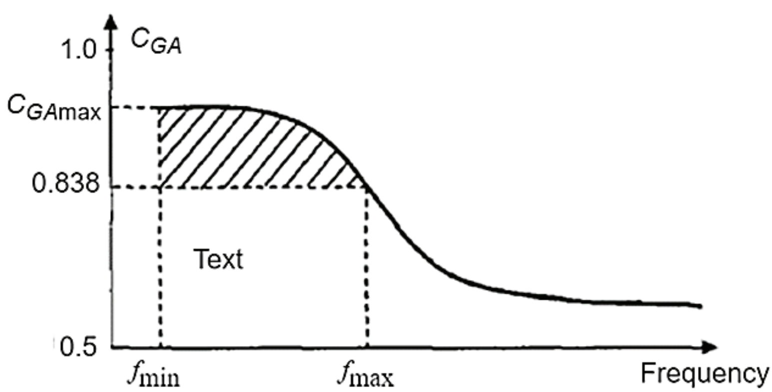


Fig. 6. Determining the efficiency of parts transfer

$$\psi_{f_{\min}} = \int_{f_{\min}}^{f_{\max}} \left(C_{GA}(f) - C_{GA}^{thr} \right) df, \tag{5}$$

where C_{GA} *(f)* is a curve that approximates the experimentally obtained values of C_{GA}; is the threshold value of the coefficient of geometric accuracy, f_{max} is the maximum reproducible frequency of the test object; f_{min} is the minimum frequency of the test object.

The proposed criterion of integral evaluation is the efficiency of parts transmission, which is determined by the formula (6) as part of the area under the frequency distribution curve of the coefficient of geometric accuracy (Fig. 6). The resolution of the system f_{max} is determined at the level of C_{GA} = 0,838 (Fig. 6). This value, at full contrast of the tested original, based on formula (4), corresponds to the modulation transfer coefficient *T*, which is generally accepted in the technique for determining the frequency properties of systems, equal to 0,707.

СПИСОК ВИКОРИСТАНИХ ДЖЕРЕЛ

1. Cheng Z., Dong H., Zhao Y., Zhang X., Fang J. One rasterization approach to high performance internet map server design and implementation, 2010 18th International Conference on Geoinformatics, Beijing, China, 2010. Pp. 1–4. doi: 10.1109/GEOINFORMATICS.2010.5567570.
2. Chang C.-F., Chen K.-W., Chuang C.-C. Performance comparison of rasterization-based graphics pipeline and ray tracing on GPU shaders, 2015 IEEE International Conference on Digital Signal Processing (DSP), Singapore, 2015. Pp. 120–123. doi: 10.1109/ICDSP.2015.7251842.
3. Petrov P., Kostadinov G., Zhivkov P., Velichkova V., Ivanov S., T. Balabanov. Multi-Objective Optimization in Image Approximation, 2020 International Conference Automatics and Informatics (ICAI), Varna, Bulgaria, 2020. Pp. 1–5. doi: 10.1109/ICAI50593.2020.9311351.
4. Wang X., Guo F., Zhu M. A more efficient triangle rasterization algorithm implemented in FPGA, 2012 International Conference on Audio, Language and Image Processing, Shanghai, China, 2012. Pp. 1108–1113. doi: 10.1109/ICALIP.2012.6376782.
5. Lemoine R., Boyer V. Rasterization by Multiresolution Integration, 2010 Sixth International Conference on Signal-Image Technology and Internet Based Systems, Kuala Lumpur, Malaysia, 2010. Pp. 127–133. doi: 10.1109/SITIS.2010.31.
6. Ковальський Б., Писанчин Н., Шовгенюк М. Дослідження градаційних характеристик фотоформ растрового зображення з модульованою частотою. Комп’ютерні технології друкарства. 2005. N.B. С. 241–243.
7. Lim H., Park H. Depth Map Rasterization Using Triangulation and Color Consistency for Various Sampling Structures. *IEEE Transactions on Circuits and Systems for Video Technology*. July 2015. Vol. 25. no. 7. Pp. 1081–1098. doi: 10.1109/TCSVT.2014.2376313.

REFERENCES

1. Cheng, Z., Dong, H., Zhao, Y., Zhang, X., & Fang, J. (2010). One rasterization approach to high performance internet map server design and implementation, 2010 18th International Conference on Geoinformatics, Beijing, China, 1–4. doi: 10.1109/GEOINFORMATICS.2010.5567570 (in English).

2. Chang, C.-F., Chen, K.-W., & Chuang, C.-C. (2015). Performance comparison of rasterization-based graphics pipeline and ray tracing on GPU shaders, 2015 IEEE International Conference on Digital Signal Processing (DSP), Singapore, 120–123. doi: 10.1109/ICDSP.2015.7251842 (in English).
3. Petrov, P., Kostadinov, G., Zhivkov, P., Velichkova, V., Ivanov, S., & T. Balabanov. (2020). Multi-Objective Optimization in Image Approximation, 2020 International Conference Automatics and Informatics (ICAI), Varna, Bulgaria, 1–5. doi: 10.1109/ICAI50593.2020.9311351 (in English).
4. Wang, X., Guo, F., & Zhu, M. (2012). A more efficient triangle rasterization algorithm implemented in FPGA, 2012 International Conference on Audio, Language and Image Processing, Shanghai, China, 1108–1113. doi: 10.1109/ICALIP.2012.6376782 (in English).
5. Lemoine, R., & Boyer, V. (2010). Rasterization by Multiresolution Integration, 2010 Sixth International Conference on Signal-Image Technology and Internet Based Systems, Kuala Lumpur, Malaysia, 127–133. doi: 10.1109/SITIS.2010.31 (in English).
6. Kovalskyi, B., Pysanchyn, N., & Shovgeniuk M. (2005). Study of gradation characteristics of raster image photoforms with modulated frequency: Computer technologies of printing, N.B, 241–243 (in Ukrainian).
7. Lim, H., & Park, H. (July 2015). Depth Map Rasterization Using Triangulation and Color Consistency for Various Sampling Structures: IEEE Transactions on Circuits and Systems for Video Technology, 25, 7, 1081–1098. doi: 10.1109/TCSVT.2014.2376313 (in English).

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МЕТОДИ ОЦІНЮВАННЯ СПОТВОРЕНЬ ДЕТАЛЕЙ ПІВТОНОВИХ ОРИГІНАЛІВ ПІД ЧАС РАСТРУВАННЯ

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Однією з найважливіших проблем поліграфії є растрування. Саме технологія растрування визначає градаційний зміст відбитка, відповідає за передачу дрібних деталей зображення та його чіткість. Крім того, сама растрова структура, коли її видно, стає джерелом шуму у відтвореному зображенні. Виробники растрових структур прагнуть забезпечити точну передачу градацій оригіналу, чіткість зображення, тобто передати його структуру, усунувши при цьому видимість растра настільки, щоб зображення можна було візуально сприймати як оригінал-аналог. Саме тому ринок насичений різноманітними растровими структурами. Розробники в рекламних цілях описують їхні переваги, але на практиці виявляються труднощі роботи з растровими структурами та їхні недоліки.

Різні растрові структури відрізняються за своїми властивостями, і не існує таких растрових структур, які б однаково добре вирішували всі завдання з

відтворення зображень, оскільки зображення різні за своєю структурою. Дослідження можливостей растрових структур і структурних властивостей зображень, призначених для репродукування, дозволить найкращим чином їх комбінувати для отримання необхідної якості репродукції.

На сьогодні у поліграфії не існує ефективних методів та засобів оцінки спотворень, які залежать від параметрів друкарських елементів, що задаються растровим перетворенням на додрукарській стадії, та посилюються різними фізико-хімічними процесами (експонування, проявлення, травлення, розтискування, проковзування), що відбуваються на формній та друкарській стадіях. Це викликає суттєві проблеми при виборі растрового перетворення для кращого відтворення оригіналів зі значним високочастотним змістом за умов конкретного репродукційного процесу.

Винайдення растрування послужило потужним стимулом розвитку суспільства, оскільки книги та інші друковані ілюстровані видання стали доступними за ціною і, як наслідок, набули широкого розповсюдження.

Keywords: *щільність, растр, напівтоновий оригінал, частотно-контрастна характеристика.*

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