Estimation of Basic Structural Elements of an Imaging of Digital Printing

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Abstract

Electrographic technology of digital printing is used for reproduction of computer documents containing various information. This technology relates to the category of short-run-off printing (Printing-on-Demand) of Computer-to-Print type[1] and possesses capability to personalize and update constantly output data obtained on the paper as hard copies of the monocolor or multicolor image. The image can be both double gradation alphanumeric (Text Information) and half-toning (Image Information).

Quality of such a diverse image is usually evaluated according to several parameters, which could be theoretically referred to several groups:

parameters of power conversion of an intelligence signal,
spatial and frequency parameters,
color parameters.

System of printing quality parameters is also determined by requirements of ISO-13660.[2] They are subdivided into 8 parameters of evaluation of characters and separate lines and 6 parameters of evaluation of large filled areas.

However, practically all the mentioned elements are derivatives of parameters of the basic structural elements of the electrographic image. Quality of reproduction of the latter depends upon technology of digital printing and affects considerably all other parameters having visual nature mainly. The present report is devoted to analysis and evaluation of the basic structural elements.

Introduction

Parameters of the electrographic image of digital printing depend upon quality of reproduction of the mentioned elements. The following are basic structural elements put down in order of importance:
Dot,
Line,
Large Area.

Table 1. General characteristic of structural elements

Structural Element	Components of Structural Element	Construction of Structural Element	Criteria of Structural Element Evaluation
Dot	Particles of toner	Precipitation of charged particles at PR area discharged under laser sweep. Possibility of changing dot diameter in increasing duration of strobing impulse	Diameter of a dot ∅ (for the elliptic dot it is separate along x, y axes).
Line	Dots or dot matrixes	Dot arrangement along the linear element with a definite step (discrete) as a result of the pulsed laser sweep. For half-toning version dots are arranged like a matrix.	Optical density D_{max}, maximum spatial gradient q_{max}, half-width of line $l_{0,5}$
Large Area	Lines	Superposition of lines as a thin spatial grate of the laser sweep raster. For a half-toning version the lines have a matrix structure with amplitude (AM) or frequency modulation (FM) of dots.	Carrying spatial frequency N, raster optical density D_p, the area covered with A toner

By means of these elements the electrographic image of any type is arranged by using technology of reverse imaging of discharged areas. Monocolor halftoning structures are also applied to make a color image. These structures and their overlapping are repeated several times and synthesize the required color.[1,4] Thus analysis of basic elements could be limited by monocolor structures. General characteristic of structural elements is given in Table 1.

Criteria of Evaluation of Basic Structural Elements of Image

Dot

It is a minimum element of the image structure of digital printing which is formed in precipitating charged particles of the toner on the discharged area of the photoreceptor surface.[1] Depending on focusing of the laser radiation spot it can have a round or elliptic shape. In sweeping in the direction of a short axis depending on the impulse duration it changes its sizes in the given direction.

The structural element is evaluated with the dot diameter. For the elliptic shape sizes are determined along x, y axes. Usually the dot is a double gradation element though in some models of digital printing apparatus its sizes and so optical density could be changed by regulated variation of the exposure rate of the photoreceptor surface. In that case a dot is able to receive several levels of grey used in constructing inclined lines.[1] Practically in the apparatus of digital printing the minimum dot diameter is 15 – 20 mkm, and its sizes can reach (20x60) mkm.[3]

The dot is perceived visually as a short line or homogeneous physical dot though it has a thin structure caused by the size of the toner participles and their disposition in developing.

Line

A structural element of a separate line is formed of dots arranged in the linear order with a definite pitch of discretization. The pitch of discretization could exceed radius of a dot insignificantly to exclude pulsation of the line width.[1] In this case the minimum line width is equal to the dot diameter. In reproducing a half-toning line its minimum width increases up to the sizes of a half-toning cell (matrix) with precise arrangement of the dots by principle of amplitude modulation or their stochastic spread by principle of Frequency Modulation.[1]

If there is necessity of reproducing wider lines they are obtained by parallel disposition of corresponding (double gradation or half-toning) lines of the minimum width. To eliminate a “moive effect” in forming the inclined line a program method of regulation of the dot diameter or variation of their addressing at the joint point is used widely to smooth out levels. It also allows to increase electronic resolution of the digital printing apparatus with the program method.

Parameter of maximum spatial gradient q_{max}[1,5] is used for objective evaluating sharpness of the line edge. This parameter is well-known in photography. The maximum gradient is defined in $D=D_{max}/2$ point by drawing a tangent to the line profile up to interception with X axis and $D=D_{max}$:

$$q\max = tg\alpha \frac{D\max - Df}{\Delta x}, \qquad (1)$$

α - angle of the tangent inclination to the profile in $D_{max}/2$ point;
D_{max} – maximum value of optical density;
Df – background value of optical density;
Δx – X-intercept cut off by the tangent to the profile.

A system of two parameters – q_{max} and half-width at the level of $D_{max}/2$ (indicated as $l_{0,5}$) allows to control thickness of the line and its sharpness.

Practically the line width is defined at the visual level in the digital printing apparatus and that provides higher values by comparison with $l_{0,5}$ value. Such a width is within the limits of 20 – 60 mkm. The minimum width of the half-toning lines depends upon varied sizes of the half-toning matrix and quantity of the grey levels. Maximum optical density measured in the center of the double gradation lines is usually within D_{max} = (1,0-1,5)B. Gradient for 12-15 mkm lines is important[1] at the level of (0,10 – 0,15)B/mkm.

Visually the structural elements is perceived as a homogenous line though it has a thin structure caused by the pitch of the dot discretization or fluctuation of their disposition as a result of AM or FM modulation.

Large Area

A Large Area is a big filled area created by overlapping of thin lines, which form a spatial grate in frame scanning. This grate is a peculiar carrying spatial frequency. Therefore analysis of this structural element is analysis of such a spatial grate.

The goal is similar to investigation of so called experimental function of modulation transfer.[1,4] Restriction of modulation transfer is its incapacity to be used for theoretical modeling the image according to input parameters of non-linear electrographic process. In constructing experimental MTF effective contrast of the image is determined by the following way (Fig. 1):

$$Kef(\nu) = \frac{D\max(\nu) - D\min(\nu)}{D\max(\nu) + D\min(\nu)}, \qquad (2)$$

D_{max} – optical density measured on the lines of the spatial grate image;
D_{min} – optical density measured at the space between the lines;
V – spatial frequency of the lines.

Experimental (.) and calculated (x) points of the function[1] are shown at the curve. K_e contrast and $\mathbf{v}_e$ frequency are marked at the level of l/e = 0,368. $\mathbf{V}_k$ spatial frequency is cut off at the axis by the tangent drawn from that point. Its physical sense is frequency under which the lines blend completely.

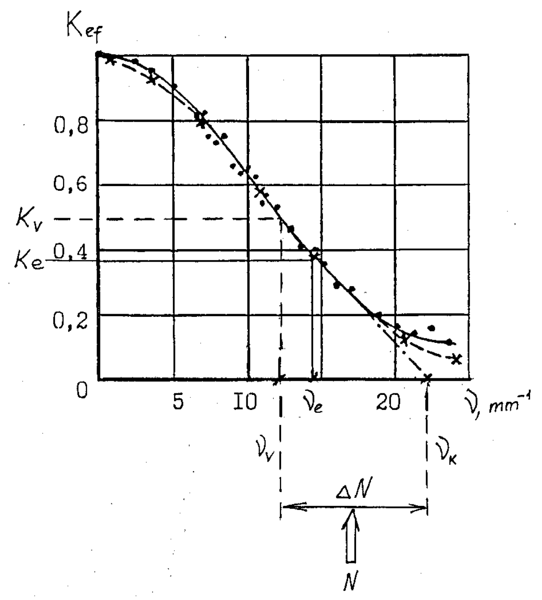

Figure 1. Usage of experimental MTF for evaluating the raster structure of the large area:

K_{ef} – effective contrast of the grate
K_v – contrast perceived visually
K_e – contrast at l/e level
***V** – spatial frequency of the grate*
$\mathbf{V}_v$ – frequency perceived visually
$\mathbf{V}_e$ – frequency at l/e level
$\mathbf{V}_k$ – tangent frequency
N – carrying spatial frequency
ΔN – interval of carrying frequency choice

Besides the mentioned characteristic values of frequency it is possible to determine visual spatial frequency by MTF curve that is frequency at which a thin linear structure of the image becomes imperceptible under conditions of visual observation. It is caused by the fact that a human eye under normal conditions distinguishes objects angular value of which is 1-1,5 angular minutes. It is 80 mkm or 12,5 mm^{-1} (approximately 300 dpi) for distance of resolution used usually. Therefore v_v=12,5mm^{-1} value can be accepted.

According to MTF example it is possible to determine an operating range of carrying spatial frequency N. It is within $v_v \leq N \leq v_k$. Beyond the bounds of this range operation is not advisable: at $v<v_k$ impression of the linear structure of the large area is not eliminated and $v>v_k$ frequency is redundant. Within the mentioned operating range increasing of N allows to improve quality of the image: the raster linear structure continuous to be smoothed out and it affects output qualitative parameters. However, from the other hand, it decreases speed of recording and diminishes capacity of the apparatus. So in each particular case it is necessary to choose compromise settlement. Average optical density of the area or so called raster optical density is determined if there is a thin raster structure on the image of the large area. Its formula is the following:

$$Dr = \lg \frac{S}{S-A} \quad , \qquad (3)$$

S – total measured area,
A – area occupied by the developed elements of raster,

To evaluate the grey area covered by A toner the following formula is provided by ISO[6]:

$$A(\%) = 100 \cdot \frac{1-10^{-\left(D_r^n - D_f\right)}}{1-10^{-\left(D_n - D_f\right)}} \quad , \qquad (4)$$

D_n – reflective optical density of developed areas;
D_f – reflective optical density of background areas;
D^n_r – reflective optical density of raster structure of halftones.

It allows to control the level of grey in reproducing halftones that is obtained by variation of quantity of blackened dots in matrix structures of lines. The level of grey should be also regulated under subtractive synthesis of the color image by means of overlapping of multicolor structures of such a grey area.[4,7] In visual observing all the mentioned variants of the large area are perceived as uniform filled areas because the raster structure assists elimination of edge effect[1] and the thin structure of the lines is imperceptible for an eye. However, if it is made out with enlargement, a thin structure of the area can be seen. It is caused by fluctuation of the raster dot arrangement.

Conclusion

Herein basic structural elements have been described. They are used to create the image of computer documents being output to electrographic apparatus of digital printing of different designation. These structural elements are the following:
Dot,
Line,
Large Area.

Characteristics of each structural element and composition of criteria of their evaluation and interaction in reproducing different variants of the image are given.

The present systematic approach for general fundamentals of various types of image would be useful in evaluating quality of digital printing.

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Biography

Oleg R. Kharin (b. 1946) graduated in 1978 from the Vilnius's (Lithuania) State Technical University. 1965 – 1984 – researcher at the Institute of Electrography in Vilnius. 1984 – 1997 – chief of the department of Institute of Electrography in Vilnius, since 1997 Deputy Director General on Science – Scientific Research Phototechnical Institute on Slavich Co. Director (Nifti – Slavich, Pereslavl – Zalessky). Dr. of Techn. Sci. (1990). Cca 70 publications and patents. Contact fax. + 7 (08535) 2 16 56.

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