HALFTONING MYTHS AND REALITY. WHAT IS ADAPTIVE TO WHAT IN SCREENING?

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Abstract
Halftone image quality is basically dependent on printing element area, form and placement geometry. So, the screening procedure has always comprised the actual, cornerstone R&D issue of illustrative printing technology. The multiple of currently available, announced or upcoming screening techniques pretend on their practical use. At the same time, the screening technologies estimations are accompanied today by the number of misconceptions. Along with the importance and interest to this matter the great amount of "halftoning myths" does exist. They are herein below regarded in the light of several fundamental positions of halftone imaging and on the basis of myth/reality withstanding. Discussion is completed by overview and particular examples of the, so called, "adaptive" halftoning with an accent on proper defining the image local property for control the screening algorithm variation over a reproduced picture area.
Key words: *screening, halftone dot, printed image, sharpness, definition.*

Introduction

Issues of tone (color) rendition and of fine detail or contour accuracy are used to be to certain extent independently concerned in the imaging science. Screening comprises, however, the unique kind of an image transformation which enables the conflict in providing both tonal and spatial resolution. The trade off is solved in reproduction practice on behalf of the first of these requirements, i.e. by keeping the contrast of a halftone print constant for all the variety of screen frequencies [1, 2].

At such condition, the screen ruling depends on the minimal size of a halftone dot which is steadily available for given type of a job, i.e. for the particular kind of print stock, ink, plate, equipment, etc. Providing this size over the print sheet within a run is therefore the basic criteria of optimal adjustments of a substrate-plate-ink system. It's worthwhile to note, that the ink solid densities, indicating the match to some standard, are just the secondary factors of proper press settings.

Screening has always comprised the actual, cornerstone R&D issue of hardcopy imaging. To provide both as much as possible amount of grey steps and visual uniformity of an image vast stationary areas the optimal geometry of a screen and halftone dot, as well as the way its form transformation along a grey scale were empirically found during over a century of the autotype printing. However, the number of lately suggested digital screening techniques, being aimed to achieve some novel image quality, failed to be practical because of ignoring these experiences.

The quality of a halftone image is basically dependent on printing element area, form and placement geometry. With taking into account such, clear to any printer, fact, not only the RIP vendors but, as well, the producers of a lot of just a related printing equipment and consumables have to permanently suggest their own ways of a halftone dot formation and positioning to accentuate thereby their standing on a proper level of innovation as a moving marketing forth. As result, a lot of currently available, announced or upcoming, screening methods pretend on their use.

In such situation the demand arises for correct, quantitative comparison of various screening techniques efficiency with the other important factors involved to the process being, if possible, kept the same. Use of frequency response curves for special screening distortion parameter was proposed for estimation of halftones sharpness and definition [2, 3].

Screening developments and implementations are altogether accompanied by the number of certain misconceptions and illusions. Along with the importance and interest to this problem the great amount of "halftoning myths" has appeared, which are shared not only by the practitioners, but, as well, by educators and researchers. So, it looks worthwhile to comment, forehand the further discussion, some myths concerned of screening.

Myths of halftone printing

Myth 1: *The frequency response of vision at reading distance is limited by about 150 lines per inch. That's why the halftone frequency of 150 Lpi is appropriate for the most of print jobs [4, 5].*

Reality: Theory teaches that the sampling frequency should be at least twice higher of the input data frequency which is intended to be transmitted or reproduced. So, for presenting of 150 informative lines on one inch of a print the screen rulings over 300 Lpi are required. However, they aren't available in the wide practice being strongly dependent on the size of minimal dot at condition of providing the white level tone value 3–5% [6].

Myth 2: *The number of "grey levels" reproduced on a print comprises the square of the printer resolution and screen ruling ratio (plus yet one else* *level of the non-inked substrate) [5,7].*

Reality: This number comprises just the formally available amount of reflectance factors, i.e. light intensities coming to the viewer from a print. However, the eye deals not with an "arithmetical" but with a uniformly perceptible levels, i.e. with the optical density or CIE Lab lightness. So, the logarithmic or cubic root non-linier transformation should complete such kind of calculation to make its results representative and practically useful.

Myth 3: *The fewer is dot gain the better.*

Tone value increase on a press results in the non-linearity of print characteristic. It's compensated altogether with the, more or less, permanent non-linearity of the multiple other reproduction stages. So, not the rate but stability of dot gain is important.

Myth 4: *Tone rendering depends on the screen geometry. That's why the type of screen should be selected with taking into account the tonal content (histogram) of a reproduced image.*

Reality: Pictures of different kind are usually located on a press sheet or even on a same page. Screen geometry effects on the resulting tone thereby requiring the individual color profile for an each image.

Myth 5: *"Dot-on-dot" CMYK printing would provide higher definition and sharpness than the use of rotated screens [4, 8, 9].*

Reality: The latter is characterized by the greater frequency response because of using four image data samplings of different spatial frequencies and phases for each direction.

Myth 6: *The sharper is the halftone dot on a film the sharper is the halftone image on a print.*

Reality: Sharpness of dot on a film defines the stability of its area (tone value) transfer to a plate within the tolerances of given plate making process and therefore effects on tone value reproduced on a print.

Myth 7: *Fine detail distortion by the halftone dots can be compensated with the use of sharpening filters of prepress software.*

Reality: Input image digital file is once again encoded in screening with the spatial sampling at screen frequency and quantization by the alphabet of halftone dots. So, the effective correction of such distortion should be provided within this second encoding.

Myth 8: *Use of non-periodic halftone in "Hi-Fi" printing eliminates the moiré problem of finding appropriate screen angles for fifth (green), sixth (orange) and seventh (violet) inks.*

Reality: With periodic screening the halftones of these inks are successfully printed at the angles of corresponding complementary process colors. With taking into account the color gamut expanding as the goal of such printing, the moiré appearance just indicates the usefulness of an extra ink when the opposite process color is non-completely withdrawn at given image area.

However, the most persistent and widespread since 90ies stays the illusion of the so-called “stochastic” or “FM” screening. From F. Romano it sounds approximately like that: *“the golden age of illustrative printing will start when some great algorithm will be practically implemented to break a continuous tone into irregularly-spaced tiny dots of the same size”*.

Reality: Halftone dots can be “spaced” just in the highlights. Starting from quartertones they inevitably touch each other forming the larger dots whose shape is far from the best printable one. The use of a “tiny dot” over the whole grey scale makes the system non-stable, i.e. extremely sensitive to the slightest deviations on a press. (It can be seen on an output of the 50% chessboard pattern of minimal printer dots.)

Tone value or tone gradient adaptive screening?

So, the concept of dots amount variation was just partially implemented in the hybrid halftones with the number of dots reduce in highlights for tone range expanding. Such a solution stays within the approach of the auxiliary screen frequency variation in photomechanic Respi screens of 60ies or for digital screening of K-separation in Hell Chromograph 300 of 70ies. In terms of the adaptive screening this way of modifying a halftoning algorithm over an image area can be related to the **tone dependent** ones.

At the same early period of electronic screening the other, **tone gradient dependent** approach was suggested for more effective, optimal use of an imaging system resources and withdrawing the eternal conflict of simultaneous providing both tonal and spatial resolution.

As far as the spatial dispersion of an image tone measure is inherent in any screening procedure, the digital halftoning accomplishes the distribution of an input image pixel quantization scale among the number of adjacent micro locations (microdots) of an output image. That requires at least the order of magnitude excess of a printer resolution in relation to the screen ruling. At the same time, said excess comprises the real reserve for an image quality improvement. That’s why the fundamental objective of image optimal encoding in screening process is to shorten the gap between the printing process resolution and the halftone image definition by more effective use of the imaging system resources. This can be done by introducing in this process the elements of artificial intellect taken, by analogy, from the work of a manual engraver who combines over an image area the continuous tone (CT) and line work (LW) modes. That allows him for reproducing the stationary areas and fine details with correspondingly as much as possible tone levels and geometric accuracy (Figure 1).

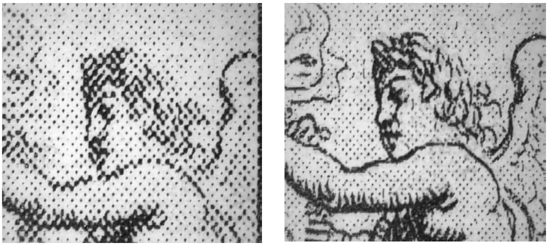

Figure 1. Enlarged fragments of halftones produced with the use of: ABC screening (left); HDHP technique imitating the engraver skills (right)

In **tone gradient dependent** screening procedure the image nature is considered in the closest vicinity of a processed pixel by the differential operator controlling the dynamic, over a picture area, readjustment of the screening algorithm. The first examples of such control use were in the halftone dots displacement toward the darker side of a contour to eliminate its stepwise serration (analogue electronic halftones of PDI scanner of 70ies [10] and their digital version [11]). Modifying the form of dots (their elongation matching direction of a contour) was also suggested [12].

Similar to optimal encoding techniques used in color TV and image data compression applications our later solutions explore within this approach the specific of decrease of HVS sensitivity to tone and color variation with reducing the image detail angular dimension. In our developments of beginning of 70ies, the auxiliary functions generate on detail boundaries the sequence of square root of two higher screen rulings [13]. However, the abrupt changing of dots structure along the contour of gradually fading contrast has appeared distinct for the viewer. To get rid of the stepwise, hence noisy changing of structure there was proposed to seamlessly blend the screens on basis of equation

$$\mathbf{S} = (\mathbf{1} - \mathbf{q})\, \mathbf{S}_1 + \mathbf{q}\, \mathbf{S}_2$$

dividing the input tone value **S** on $\mathbf{S}_1$ and $\mathbf{S}_2$ parts in proportion depending on the local image area content according to its busyness factor **q** [14, 15].

Part $\mathbf{S}_1$ controls any kind of a basic, practically approved algorithm providing the appropriate halftone printability and tone rendition for the stationary image area. The other one $\mathbf{S}_2$ relates to a fine detail and controls the higher frequency screens of shorter quantization scale.

This approach, recently again patented by HP [16], we have further developed with the set of auxiliary functions of the constant, twice higher frequency than basic one but providing the tiles of different form (Fig. 2).

High Definition Halftone Printing (HDHP) technology uses the pattern recognition technique in the closest vicinity of processed input pixel for proper identification of an auxiliary function within a set and for extracting the tile which matches detail geometry [17]. Each non-stationary area is jointly presented within screen mesh by such tile and parts of conventional halftone dot in proportion defined by the busyness factor **q**.

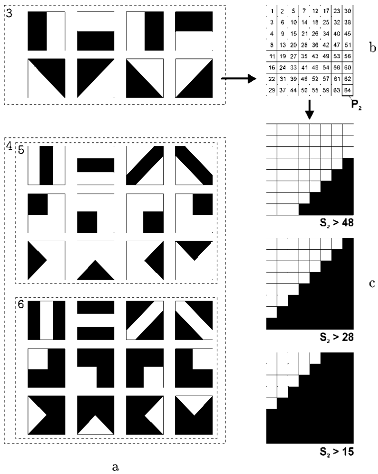

Figure 2. Tile geometries (a); auxiliary screen function (b) for one of them; tiles (c) produced by this function for three tone values S_2.

As it became clear from further experiments, the issues of seamless blending the different dot structures can be also concerned in different way for the boundary and standalone thin line. The constrained use of tiles instead of dots isn't caught here by the eye. That allows for reproducing such line by the ink solid instead of the mix of tiles and scattered dots. From the other hand, the gradual contrast fading along such a line can be quite satisfactorily compensated by just the line width reduce. Grey line of 0.1 mm width doesn't need screening at all and can be printed by solid, for example, with half of an original thickness to simulate its grayness. As result, the standalone thin lines are reproduced by the latest version of adaptive technology with the complete use of a printer resolution [18].

HDHP in Traditional and Digital Printing

The described above selective distribution of the imaging system resources over a picture with taking into account its local area content allows for mutual exchange of printing system facilities in relation of tone/color rendition and contour/fine detail graphic accuracy, i.e. with tonal and spatial resolutions adaptively replacing each other. The technology was tested in lithography, flexography, silkography.

One of print trails has allowed for comparing the HDHP of 175 Lpi with the Agfa ABS (175 Lpi) and Agfa Sublima (210 Lpi, 240 Lpi) technologies. Microphotographs on figure 3 vividly illustrate the higher sharpness and definition with HDHP at175 Lpi than that of, intended for the same purpose, hybrid screening Sublima at as much as 240 Lpi.

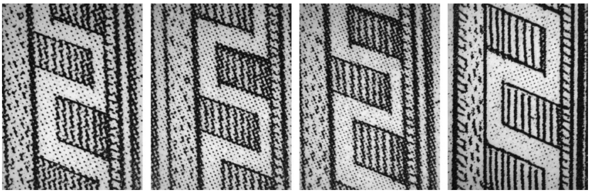

Figure 3. Photographs of halftone print produced at screening factor of 2.0 with the use of Agfa ABS (175 Lpi), Agfa Sublima (210 Lpi, 240 Lpi) and HDHP (175 Lpi) – from left to right.

Over a dozen pictures of different content were printed on same sheet in about 1000 copies at standard printing conditions on offset press Rapida 130. The pictures were positioned in pairs allowing for comparison of quality provided by Scitex Class Screening 175 Lpi and HDHP. The latter has used, as its basic, the screen of the former. So, the stationary image area in each pair has had exactly the same tone and color providing the correct conditions for sharpness and definition comparison (Figure 4).

The same advantages were also approved in silk printing in various combinations of halftone rulings of 85 Lpi and 100 Lpi with stencil grids of 240 and 300 wires per inch for different kinds of print substrate.

To test HDHP in digital printing the test file was prepared with resolution grids and realistic images. One of its parts comprises the EPS file while the other one is TIFF to be halftoned in a printer default mode. The both parts are output on the same sheet. Enlarged fragments are shown on figure 5.

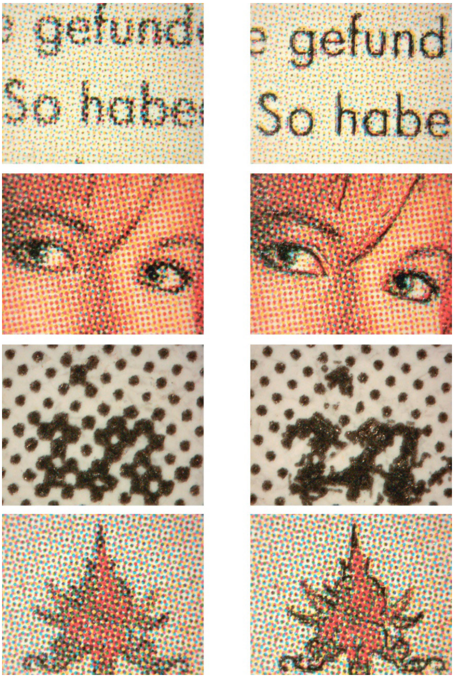

Figure 4. Fragmentary microphotographs of 4-color halftone prints produced at 175 Lpi and screening factor of 2.0 with the use of Scitex Class Screening (left) and HDHP (right)

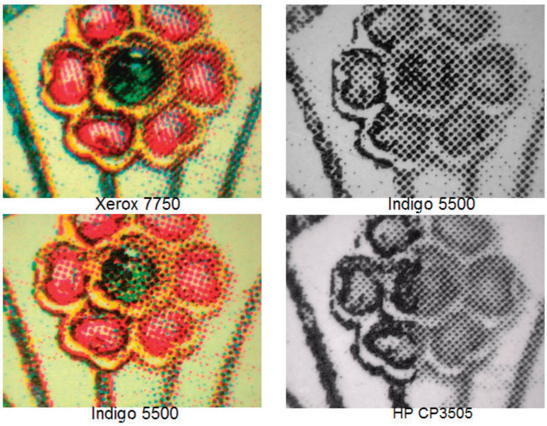

Figure 5. Seamlessly divided fragment of the test file output: in a printer default mode (right); with use of HDHP technique (left)

Conclusions

Screening technologies estimations are accompanied today by some disputable judgments and misconceptions. So, the need exists in objective and, if possible, quantitative evaluation of various halftoning techniques effect on a print image quality.

Tests and realistic images of experimental and commercial printing with the use of adaptively halftoned HDHP image files have vividly shown the following advantages:

- twice higher definition at any screen ruling used for the stationary image area;
- reproduction of black or white thin lines by the ink solid or clean paper instead of the scattered dots in any other kind of halftoning;
- higher appearance of contrast and color gamut accompanying the increase of image sharpness and definition;
- such improvement being provided at a standard volume of an input image data and without special requirements to ink, plate, paper.

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