Does the Halftone Print Still Need a Photographic Quality?

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Abstract

Many patented screening techniques were brought to the market during the last decade as a challenge to the conventional ones. The "photographic quality" prevailed in their advertised advantages to indicate on a higher definition of prints thereby produced. However, for example, in FM and error diffusion screening the increase of spatial resolution is accompanied by the structural non-uniformity and loss of tone rendition. Lower printability has to be compensated by reduction the NSR of a printing system, i.e. by the use of a finer, hence costly, consumables and plate-ink-paper interaction. That resulted in poor practical implementation of these techniques in spite of their availability in the pre-press software and equipment of the most vendors.

To the contrary, resolution and sharpness are improved in the Adaptive Screening technology with no effect on the printability of a halftone structure. For the stationary image area it stays exactly the same as in a widely used conventional methods. At the same time, the halftone dots or the parts thereof no more exist at contour and fine detail and don't destroy the latter. As our experimental printing shows, the effect of an improvement is different for various kinds of jobs and printing conditions. So, this effect is to be discussed with taking into account:

- the sampling factor (SF);
- screen ruling value;
- dot pattern geometry for the stationary image area.

Introduction

Screening, i.e. the transform of a continuous tone original to a halftone print provides the image micro structure comprised of just two gradations corresponding to paper with ink and paper without ink. All the shades of gray are simulated by those two areas relationship at condition of the separate printing elements (halftone dots) could be ignored by viewing. Screening is used in the most of print media imaging technologies: both in the traditional printing, and in the digital (non-impact) one. The way it is performed completely determines the properties of a printed image: definition, sharpness, tone rendition, etc., as well as the important operational parameters such as printability, the amount of pictorial data required to be processed, stored or transmitted, the time of processing, complexity of a hard/software to be used and the like.

FM, stochastic, error diffusion, etc. halftoning methods are often associated with cardinal improvement of illustrative printing. This myth started a decade ago with showing magnificent, "photographic" quality prints, with marketing a great amount of non-periodic screens and ended by their seldom practical application. Non-periodic systems enable somewhat higher resolution as compared with conventional periodic ones. However, they are mostly applicable to the unique printing conditions lacking the deviation of ink or toner interaction with a substrate. Still existing myth of the overall quality improvement by non-periodic screening is therefore based nowadays on the hope of a progress in increasing the stability of the printing technology. Nevertheless, such a progress would allow, as well, for the higher rulings of periodic screens. That is just what currently takes place for printing at certain stability or noise level: 100 lpi – for web news printing on relatively rough papers and 200 lpi – for sheetfed coated, glossy stock.

Moreover, if the conditions for satisfactory tone rendering and for uniform image structure are provided in non-periodic system, the further effect of finer detail, for example in error diffusion method, can be achieved just by many times greater volume of a data scanned at the input. Problems of the correct comparison of traditional and novel screening techniques we have discussed at NIP 13 and NIP15[1, 2].

Ink or toner based printing operates with the smallest particles which are about ten times larger of grain in photographic emulsion. So, the realistic way of bringing the print quality up to the level of photographic one is in the continuous tone printing of the kind using an "ink mist" or of Elcography[3]. But it's difficult to suggest that the latter can in foreseeable future replace the halftoning in a great number of its various applications.

In this light the image quality improvement within the facilities of sustained printing technologies should be regarded as the effecting their existing resolution potentiality. The latter stays unused since the halftone principle invention at the end of 19th century. Resolution of a halftone print is about ten times less than of printing itself. 200 lpi print reproduces the

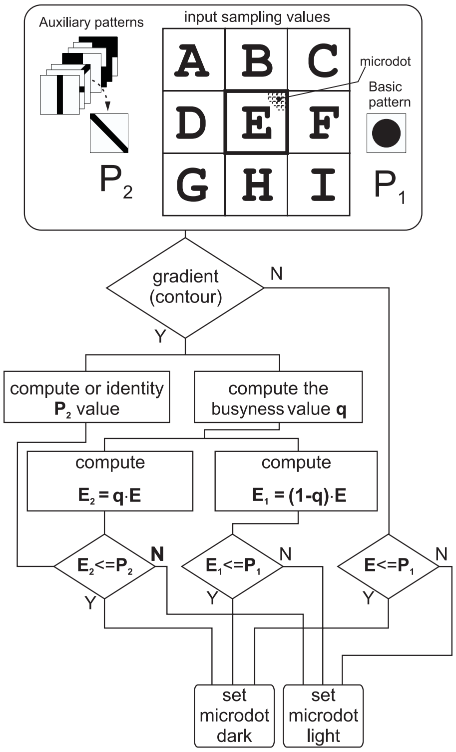


Figure 1. Procedures of the adaptive screening process.

original frequency not higher than 100 lpi . However, the printing technology, enabling 200 lpi screen, has resolution of about 2500 dpi with ability to operate by the printing element (minimal halftone dot) of about 25 μm. This facility is sacrificed in the most of halftoning techniques for the sake of an appropriate rendition of tonescale.

Adaptive process provides the both via gradual mutual replacement of two different reproduction modes: continuous tone (CT) and line work (LW); one proposed for the tonescale of a stationary image area, and the other to save as much as possible of edge and geometry of fine detail. The relationship of these two techniques is dynamically varied over a picture in accordance with its local area content.

Printing elements are modified in a way that they no longer destroy the fine detail and contours of an image. As result, the essential improvement of halftones is achieved increasing the printed illustration informative content. The greater resolution and sharpness of an image results, in its turn, in appearance of a higher contrast and saturation[4, 5].

As compared with existing alternative techniques the adaptive screening doesn't need:

– higher resolution of a scanner, platesetter or a printer;
– higher volume of an input image file;
– platemaking or printing technology modification with the use of more expensive equipment and consumables for there is no decrease of the halftone printability inherent to non-periodic systems.

Principle of Adaptive Screening

Basic procedures are shown on figure 1 where the upper block defines the input data to be processed in adaptive screening. They are:

- the "window" of 9 multilevel (8 bit) sampling values A-I of an image file obtained by scanning a CT original;
- the basic screen function values P_1 for an each current output microdot, they are proposed for a stationary image area;
- the weighting values P_2 of an auxiliary screen functions providing the output microdot pattern which matches the geometry of border or fine detail of an image.

Each sampling area of input values A-I corresponds to approximately a quarter of a screen mesh of basic screen pattern and is comprised of plurality of microdots to be set dark or light as result of the process.

Basic screen function can be presented in various forms such as a screen hill of the microdot weighting values (P_1), a combination of spot function and threshold function, a set of bit maps with clustered or dispersed distribution of dark and light microdots, etc. This distribution for the stationary part of an image can be also calculated "on fly" with taking into account the microdot coordinates within a mesh and value E of sampling area related to the latter. That is used to be done, for example in error diffusion and other methods[6, 7].

Similary, the auxiliary screen patterns can be calculated[8] for the central area of a window or selected[9] from predetermined set depending on the relationship of the sampling values of peripheral areas. The exemplary set of such functions and patterns provided by one of them are shown on figure 2.

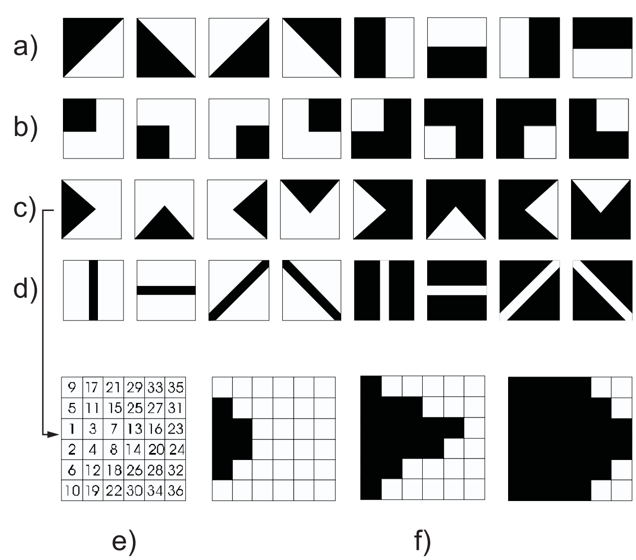


Figure 2. Geometries of the 32 anxiliary screen functions (a-d), one of them (e) and its realisations for three gray level(f).

When there are no certain difference between values A-I the screening is performed by some of common techniques. Each microdot within the area corresponding to sampling value E is set dark or light, for example as result of comparison of this value with its weight P_1.

At presence of a contour its strength is estimated by the busyness value q and the auxiliary values P_2 are selected or calculated with taking into account the pixels values A-I relationship in the neighborhood.

Percent (of microdots) E which is to be set dark within a processed pixel area is subdivided on two parts by calculating

$$E_1=Eq \text{ and } E_2=E(1-q) \qquad (1)$$

Normalized q factor varies, for example, from zero for continuous parts of an image up to a unit for the b/w sharp edge. Microdots are set dark after comparison in the both of pairs: P_1 and E_1; P_2 and E_2 . [8]

Gradual mutual replacement of CT and LW reproduction modes in a manner defined by this kind of equations comprises the essential feature of an adaptive screening. Our first experiments have shown that, being concealed across the contour or border, the simple switching from one to another mode may result in noise for the longitudinal detail direction. Contrast or strength of an original contour can gradually change along the latter and the stripes can be continuously dissolved in the background. So, even the stepwise changing of printing elements structure and geometry causes the visible artifacts.

This was discussed in the retrospective analysis of an adaptive screening approach given in[10]. At TAGA 2002 we presented some concerns of basic and auxiliary screens selection, detail detecting, busyness estimation and thin stripes reproduction in the adaptive halftoning[11]. Unic facility of this method to restore at an output the individual stripes many times thinner of an input sampling area was discussed at NIP13 [12].

Some further research results of this technology are given below.

Resolution testing

Resolution of periodic halftones is limited by their screen ruling. Spatial frequencies of an original which are lower than half of this value, are theoretically reproduced on the print at condition of sampling the input copy at a frequency twice higher than screen ruling. The latter relationship is used to be defined in practice as “screening” or “sampling” factor – SF. Due to low pass image filtration by screen frequency the SF values higher than 2.0 do not add image quality except of some increase in sharpness for contours of a maximal contrast.

This filtration is eliminated in adaptive screening process. So, it’s reasonable to suggest that its resolution should be at least the same as provided by the non-periodical screen using the dispersed (dither) matrix of microdots.

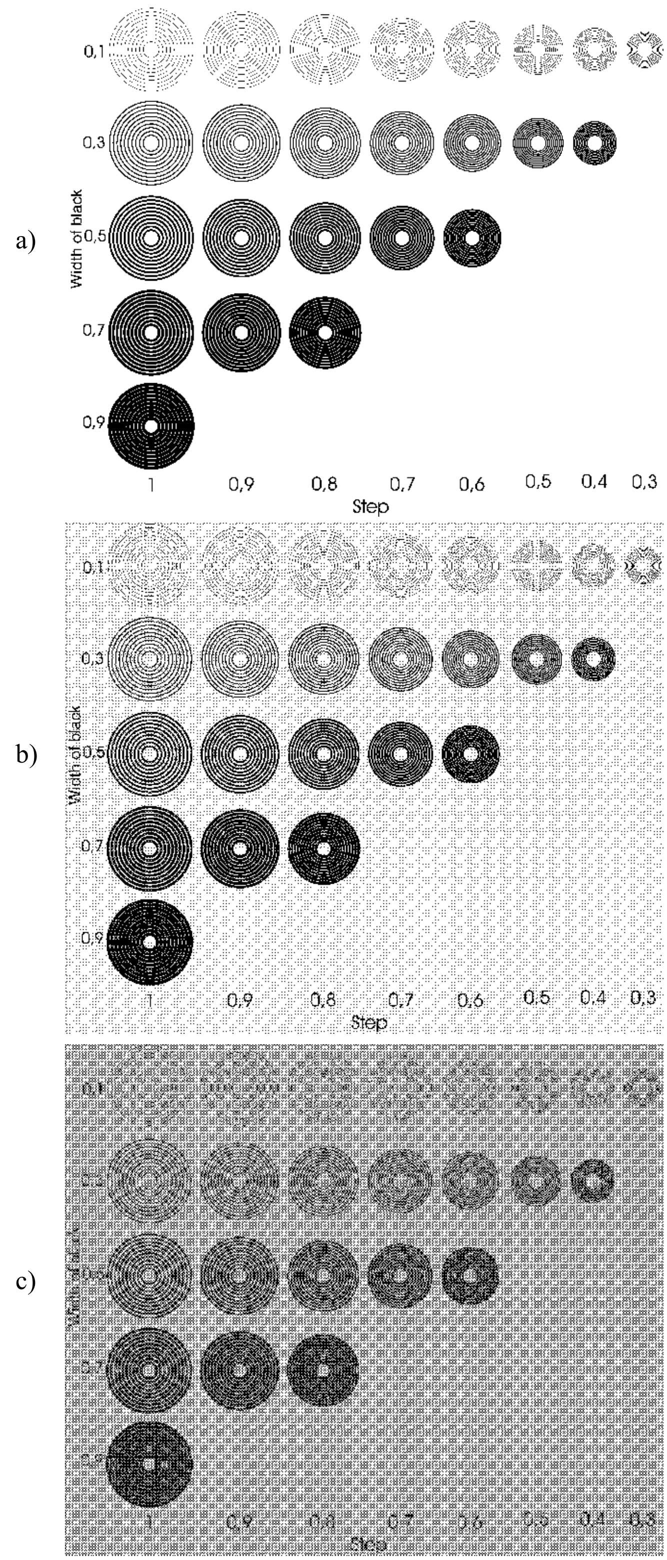


Figure 3. Reproductions of the resolution test in fine scan/fine print system (SF12.0) at 1270 dpi output. a) – as the line work; b) – as the CT original fine detail of maximal contrast (5 % and 95 %); c) – as the CT original fine detail of intermedeate contrast (25 % - 75 %).

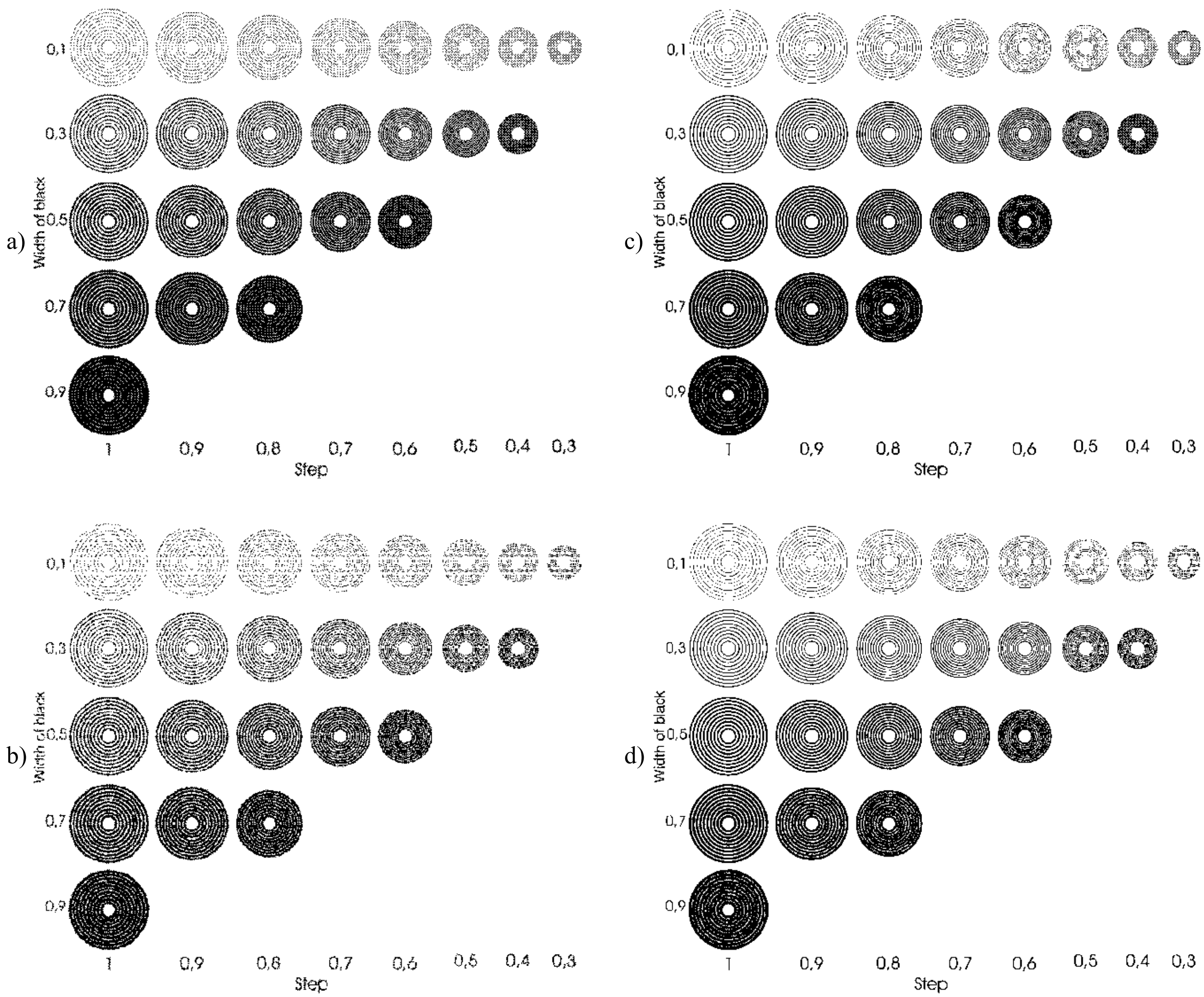


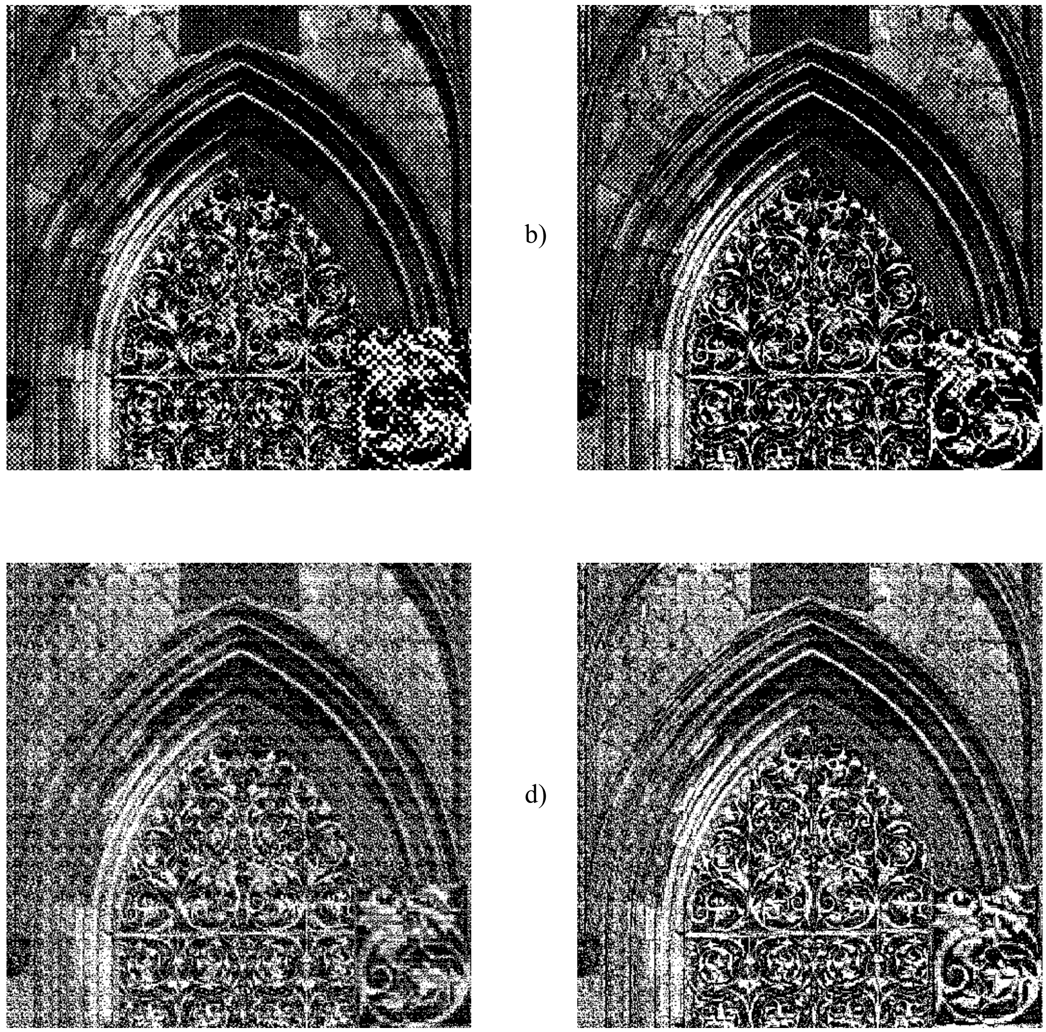
Figure 4. Traditional (a, c) and adaptive (b, d) screening with the same SF of 2.0 using one cluster (a, b) and dither (c, d) matrixes of 12x12 microdots.

To compare the resolution of adaptive screening and of the other methods the test of figure 3 was used. It is comprised of concentric circles varying their period in horizontal direction of a test image from 100% to 30%. The width of a circle line changes in a vertical direction. Position a) of figure 3 shows this test as a line work reproduced in LW mode at resolution of a printer about 1200 dpi. It can be taken as an upper limit for comparison with other reproductions of test on this and other figures. This picture can be also considered as a result of any kind of traditional screening at SF 12.0, i.e. in the so called «fine scan/fine print» mode, when for an each output microdot of a 12x12 screen mesh there is proposed an individual multilevel sampling value of an input file.

Figure 3b and 3c show the same test interpreted at the input as line matter of some intermediate contrast a CT original. This contrast was defined on figure 3b as 95% ink coverage for lines and as 5% coverage for gaps, i.e relating to the typical effective range of a halftone dot area variation in halftoning process. So, the test can be interpreted in this variant as the fine detail of maximal contrast of a CT image.

In spite of the same, 36 times of usual, excess of an input data, the further decrease of a halftone resolution is seen on figure 3c which dark and light stripes were assigned at the input to the output percentages correspondingly of 75% and 25%.

Reproductions of figure 4 were produced with an input file volume corresponding to a standard SF value of 2.0 with assigning to dark and light details of a test the enhanced ink percentages of 100% and 0%. Pictures a) and c) comprised here the halftones of original image (Figure 3a) screened in traditional way with the use of clustered (periodic) and dither (non-periodic) matrixes of microdot distributions. Due to the lack of above mentioned low pass filtration at halftone dot



a) b) c) d)

Figure 5. Low resolution (635 dpi) outputs at SF of 2.0 by traditional (a, c) and adaptive (b, d) screening with the use of periodic (a, b) and non-periodic (c, d) pattern for continuous parts of an image.

frequency, figure 4c, using dither matrix, shows about twice higher resolution than figure 4a. The same effect (Figure 4b) with better sharpness is achieved by adaptive method when the periodic halftone pattern is used as a basic screen function to ensure the most commonly adopted printability of a system.

Periodic halftones are replaced by non-periodic ones, in spite of better tone rendition of the former, for some imaging applications of especially poor output resolution, for example ink-jet. This is done because of the inappropriately low ruling of periodic screens available at output resolution of 200-600 dpi. Screens lower than 100 lpi and especially multicolor rosettes thereof are very visible. So, the same test was reproduced on figure 4d by the adaptive method incorporating the dither microdot pattern for the stationary area instead of periodic one of figure 4b. As compared with figure 4c, test on figure 4d shows the further resolution and sharpness improvement with the use of FM screening in adaptive method.

Realistic low resolution images were produced with the use of regular (a, b) and FM (c, d) patterns, by both of the methods (Figure 5). Dot structure is not acute on figures 5c and 5d as compared to 5a and 5b due to the use of dispersed matrixes. In its turn, the mosaic pattern resulted by the latter on figure 5c is replaced on figure 5d by an auxiliary patterns, matching the geometry of an image detail in a greater degree.

Some imaging applications, for example an output of in-home digital photography, lack the volume of an input data due to relatively low camera resolution. Therefore, it's rather difficult to support there even the standard SF of 2.0. However, in professional printing, using high resolution input devices and powerful data processing equipment it is possible to use nowadays SF greater than 2.0 at condition of its giving an adequate improvement for thousands illustrations printed from given image file.

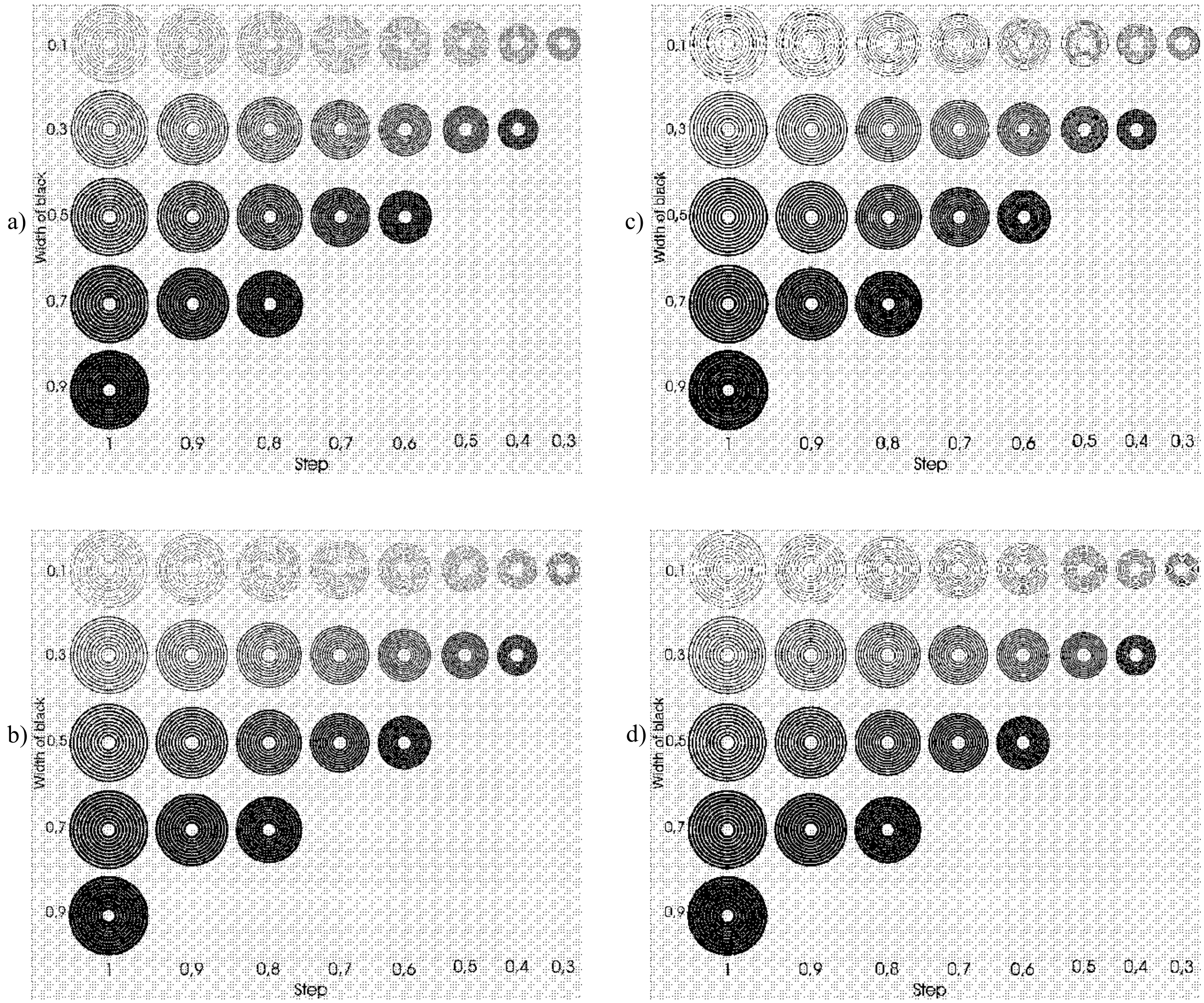


Figure 6. Traditional (a, c) and adaptive (b, d) screening the detail of maximal contrast (5% and 95%) at standard /SF 2.0 for a) and b) and quadrple to it excess /SF 4.0 for b) and d) / of a volume of input image data.

In traditional screening this improvement has no much clarity for it somehow effects just the detail of the highest contrast. This is shown by figure 6 with 5% for white and 95% for black. Test a) and c) were reproduced here at SF of 2.0. and 4.0. Test b) of this figure shows that the same as on test c) and somewhat greater effect is achieved in the adaptive method at 4 times less volume of an input data. Moreover, test d) adaptively produced with the same excess of this data shows the further improvement in sharpness and resolution.

With SF of 2.0 the resolution of an adaptive process is theoretically just twice higher than in conventional periodic screening (Figure 8). However, at higher volumes of an input data the adaptive method enables potentiality of bringing its resolution up to the level of a printer itself. Test a) and c) on the left of figure 6 less differ from each other than b) and d) produced by the adaptive method.

Conclusions

“Photographic” challenge to halftone printing is not in some “stochastic” or FM technology but in continuous tone printing. However, it is difficult to foresee the commercial implementation of CT printing for wide variety of imaging applications.

Practical way to increase the quality and informative content of an image in sustained printing technologies is the effecting their resolution potentiality which was staying unused during over a century since the halftone principle invention. FM screening gives about twice higher use of this potentiality as compared with the periodic one. However the former isn’t widely, used due to its low printability.

Greater effect of quality improvement is provided by adaptive screening method in spite of its using periodic, hence, printable halftone dot structure for the stationary image area.

Figure 8. Traditional (a) and adaptive (b) periodic screening (SF 2.0, 1270 dpi, 105 lpi)

The use of a non-periodic microdot structure in adaptive method provides, as well, the image quality improvement in low resolution output devices as compared with existing FM techniques (Figures 4 and 5).

Excess of an input volume of image data is more effectively used in the adaptive method than in common screening techniques (Figure 6).

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Biography

Yuri Kuznetsov got a Ph. D in Leningrad Bonch-Bruevich Institute of Electric Commenication in 1976 and a Dr. Sc. in Printing Technologies and Equipment from the Moscow State University of Printing in 2000. He is professor, head of Graphic Art Technology Department in St. Petersburg State Universityof Technology and Design. He is an author of over 60 publications, patents and 3 books in imaging for printing technology.