# The Processing of Fine Detail for Digital Halftone Printing

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## Abstract

Along with tone and color rendition, the quality of a printed half-tone is determined by its sharpness and definition. At least three periodic processes change the continuous tone image into small fragments during reproduction. The scan lines of the input and output devices and the pattern of the halftone all limit the frequency spectra of the b&w image, and with 4 color printing there are three additional halftone patterns for the C, M and Y to interfere. Beginning with image capture, the resolution of the sampling process establishes a trade off between maintaining fine detail and the volume of input data to be processed.

Currently there are a variety of tools available to enhance the detail in an image. Unsharp masking and other filters are used to compensate for the lack of scanning resolution or to enhance detail beyond what was available in the original image. We have developed adaptive halftone screening technology because none of the existing techniques for improving image detail compensate for the loss of detail created by the halftone screening process itself. We will discuss here the effects of our screening technology in relation to the content of the original image, to the type of printed product, to the amount of correction and the viewing conditions.

## Introduction

From the invention of photoengraving to the digital halftoning of today the conflicting demands of providing smooth tone rendition and fine line detail have been met by choosing a screen type and ruling that was optimized for each printing technology. Experience shows, that spatial resolution, i.e., the image definition and geometric accuracy of its fine detail, are sacrificed in order to provide smooth tone rendition of the non-detailed area of the image. With 200 Lpi screening standard for commercial sheet fed printing the value comes down to 150 Lpi for web printed magazines, to 85 Lpi for newsprint and even lower for some low resolution printing. This reduction in screen ruling is made necessary by factors including the coarseness of the stock and the interaction of the plate ink and paper in each of these printing environments.

Nearly 100 years experience has shown that the range of tone values in all print environments and technologies can be maintained between a 3-5% highlight and a 95-97% shadow area[1][2]. Smooth tone rendering with no visible banding for all picture contrast is the goal. The low resolution at lower screen rulings is ignored until the halftone pattern itself becomes unacceptably visible. 60 Lpi on newsprint is close to such limit, but with four color process it is unacceptable because the rosette size is greater than the screen mesh of the individual separation. Attempts to use so called FM screens, without rosettes, must face the problems of their lower printability, their higher sensitivity to the tolerances of plate, ink and paper interaction.

Considering the 200 Lpi rulings for commercial printing it is worthwhile to notice that even here the resolution of plate making and printing (about 2,000 dpi) doesn't directly relate to the halftone's sharpness and definition because of the specifics of the halftone process. The highest spatial frequency (100 ppi) of a continuous tone original reproduced by such a screen is an order of magnitude less than the spatial frequency achieved in the line work image of the same press run. However, the 1/1000 inch (25 micron) thick line, if reproduced as part of a halftone image, would be both visible and carry information at normal viewing conditions. As it was already discussed [3], the conclusions about sufficiency of 150 Lpi with reference on limits of Modulation Transfer Function of vision or on already achieved "photographic" quality for some kinds of prints are very disputable. Finer detail is still desirable not only for prints with lower screen ruling but for postage stamps and post cards as well. It is especially important to preserve as much as possible of the fine data for work such

[1] For those who have managed to maintain the 1-2% dots in a press run over the entire sheet in their attempt to deal with "stochastic" halftoning, is recommended an increase of the screen ruling [1], which would be about one and half times for this example, to get a standard minimal dot of 3-5%.

as the reproduction of paintings when size of a picture is reduced from a few meters to that of a page in publication.

There is still great need to improve halftone definition, sharpness and fine detail and great opportunities to do it. Our presentation is targeted to the use of our adaptive screening technology and its relationship to the other high spatial frequency correction techniques.

## Adaptive screening

According to the US patent classification, halftoning procedure is considered to be adaptive when the pictorial content in the surrounding area is taken into account to dynamically change the screening process parameters of a given area. Adaptive methods are known where halftone dots are elongated in the direction of a contour [4] or where they are shifted to its dark side to minimize the stepwise distortion of a contour [5]. Screen ruling can also be increased in a local area to enhance the detail of a border without effecting the overall tone rendition because it preserves the basic screen frequency for the stationary image areas [6]. Even though the error diffusion method is non-adaptive in its basic idea, it is related to adaptive methods by this definition, when, for example, its threshold value is locally dependent.

Our adaptive method is intended to compensate for the low pass filtration involved in the screening process over the whole range of halftone rulings in use. As shown on Fig. 1, this method combines the traditional halftoning technique based on clustered or dispersed microdot distribution within a screen mesh and the line work mode, which was earlier [7] proposed for effective encoding in coarse scan/ fine print facsimile system. This mode uses a set of auxiliary screen functions (halftone dot alphabets) of the kind shown on Fig. 2. Instead of the usual, symmetrical halftone dot or its part the character from such an alphabet is substituted in the output bit map at the location of a sharp tone transition (contour line), or thin stripe, etc. to perfectly match its configuration (linear, angular) of both polarities (negative, positive).

The set of tiles has been empirically determined and are not uniformly used in our adaptive screening process. As the histogram on Fig. 3 shows, the tiles most called for in the image Fig. 7 (b) are the tiles intended for straight borders (Fig. 2 a). The zero numbered column on this histogram indicates rather low use of the basic function (screen hill) because of the relatively low amount of this picture area with tone gradient values which are ignored by the adaptive screening procedure. About five times fewer the angular tiles (Fig. 2 b, c) and tiles (Fig. 2 d) proposed for stripes are used[2]. Nevertheless, in spite of such "on

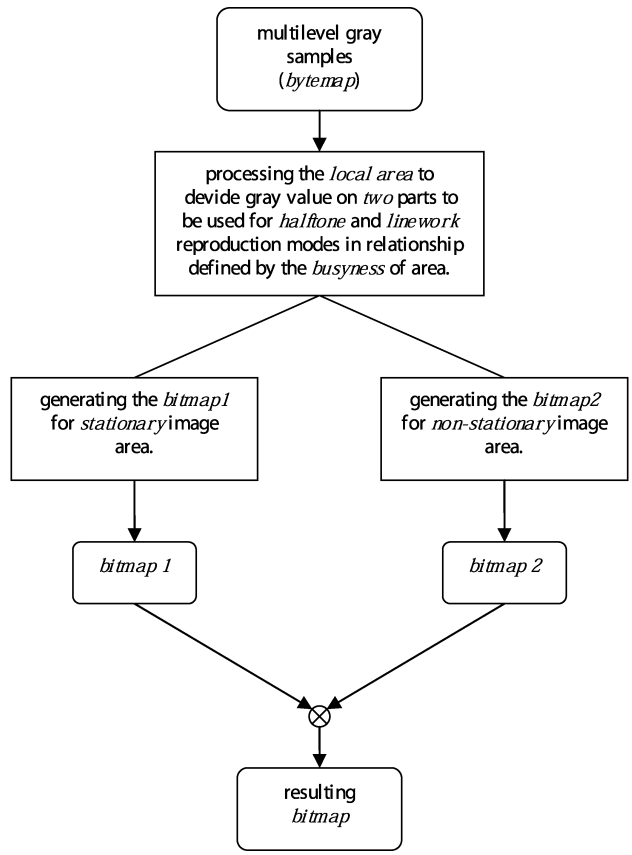



*Figure 1*: *Adaptive screening procedures.*

demand" non-uniformity, this set of auxiliary screen functions can't be considered excessive because all of the geometries are successfully identified in the adaptive process and all the tiles are used as histogram Fig. 3 shows. Moreover, as it was already noted [8], the additional tiles of the kind shown on Fig. 2 (a) but inclined at about plus - minus 22,5 and 67,5 degrees are desirable for these adaptively screened images to remove still noticeable stepwise distortion of borders at these angles.

One of the features of this adaptive screening approach is to provide the facility to merge two screening modes while continuously changing the portion of their use during image processing. This allows for delicate handling of the details of various contrast and border transition continuity. Just switching from one to another mode would inevitably result in visible artifacts arising along the stripes and contours which gradually dissolve in a background or continually fade in their contrast..

The other important features which will allow this adaptive technique to become the common form of printing technology are its printability using standard press con-

[2]Tiles of Fig. 2 (d) are used for the stripes which are narrower than the input file sampling (pixel) area and located within it. Thin stripe partially covering both of adjacent pixel areas is processed twice with the use of two corresponding tiles of Fig. 2 (a).

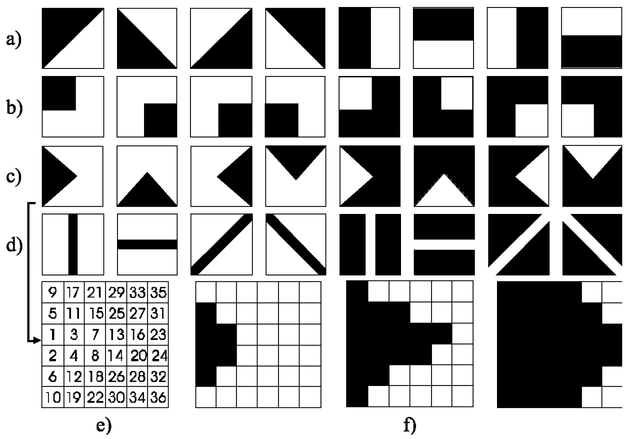



*Figure 2*: *Geometries of 32 auxilary screen functions (a - d), one of them (e) and its realisations (tiles) for three gray level(f).*

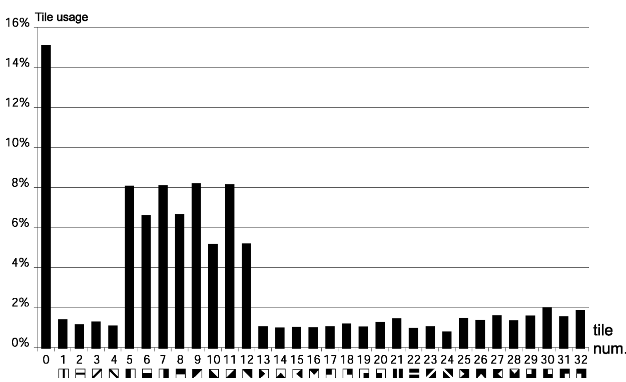



*Figure 3*: *Diagram of use the auxiliary screen functions of Fig. 2 in the adaptive halftone images of Fig. 7 (b)*

ditions and a tone rendition which is inherent to all the screening technologies which have proven themselves in industrial use over many years. The halftone pattern of the stationary picture area is presented in a identical form as that generated by any existing RIP or other screening application.

## High spatial frequency corrections in image file processing application and at screening stage.

To discuss and compare the efficiency of various screening methods it is important to keep all other conditions involved in the reproduction process the same. One such important condition, in respect to fine detail content in the final print, is the original image definition or the resolution of its input file. Two alternative reproduction modes can be used in this relation: fine scan/ fine print and coarse scan/ fine print.

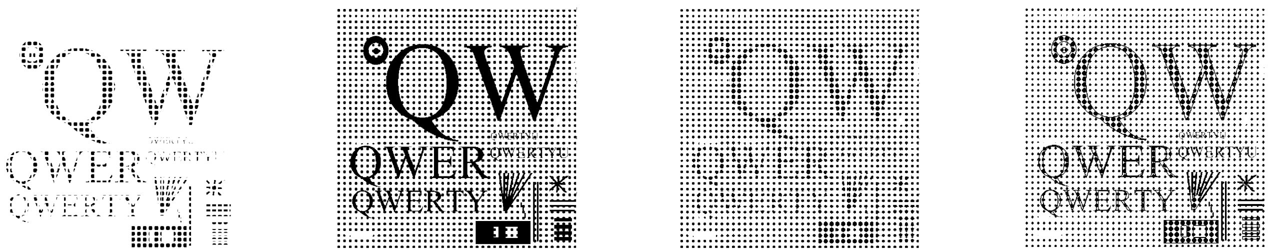
### *Fine scan/ fine print*

The first of these modes is more common for line art and is intended to use printer resolution for providing better quality at output. As compared to continuous tone work the volume of an input file is not as critical here because there is just one bit per pixel encoding, for monochrome images and there are greater data compression facilities available. This mode can also be applied to continuous tone copy but only of smaller sizes, taking into account the growth of the number of bytes is squared as image dimensions increase. Excess input resolution, providing, for example, the independent multilevel (from 0 up to 255) tone value for an each microdot of an output, automatically allows for precise cutting off of the unwanted part of halftone dot along the detail edge in most screening applications, as schematically shown on test images of Fig. 4 (a, b). To the pity, as illustrated by the model of Fig. 4 (c), this is not the case with the greater portion of fine data in a typical continuous tone image where both the detail and its background are not completely black or white. According to its destination the screening creates, at both sides of an edge, the halftone structures for two tone levels corresponding to gray values of background and detail. This is performed without taking into account the presence of an edge itself, especially when the latter comes between halftone dots of both structures and creates no line which could somehow assist the eye to catch the sharp tone transition. Meanwhile, the excess input pixels allows creating such a line artificially, as a component of final bit map (Fig. 4 d). This should be done with an adaptive screening process because the effect of the standard filters, of the type of an un-sharp mask, results only in changing the sizes of halftone dots on both sides of the edge without creating such a line (Fig. 5 b).

### *Coarse scan/ fine print*

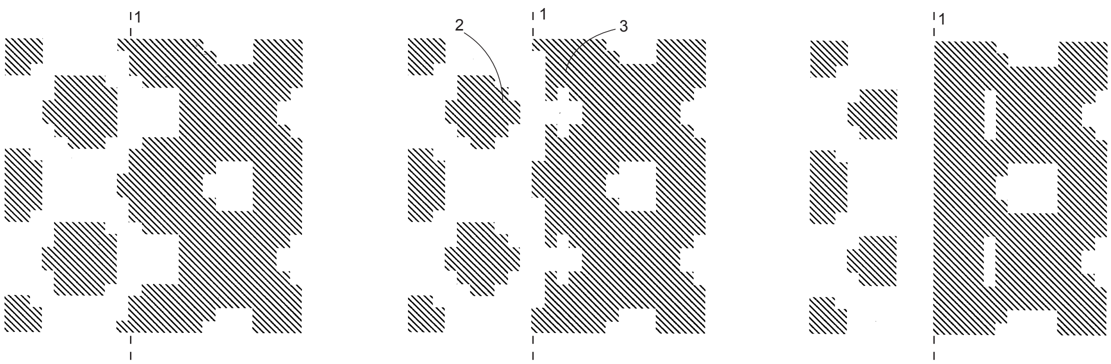
In commonly used coarse scan/fine print mode, with about four input pixels per mesh of a final screen being the standard, the low pass image filtration still has a place on the scanning stage. A halftone dot, or just four fragments thereof constructed by raster processor, damage the line of a contour independent of its contrast (Fig. 6 a, d).

Step-wise distortion of an edge is to some extent suppressed when the input pixels are multiplied (replicated) within a RIP to match the resolution of the printer. However, this multiplication, being performed through interpolation, cannot by definition, create detail enhancement (Fig. 6 b, e). In contrast to this kind of multiplication of the input file, high frequency correction can restore the fine data of an image in a certain band of its spatial spectra with taking into account the specific of halftone process, i.e. by the adaptive screening (Fig. 6 c, f).



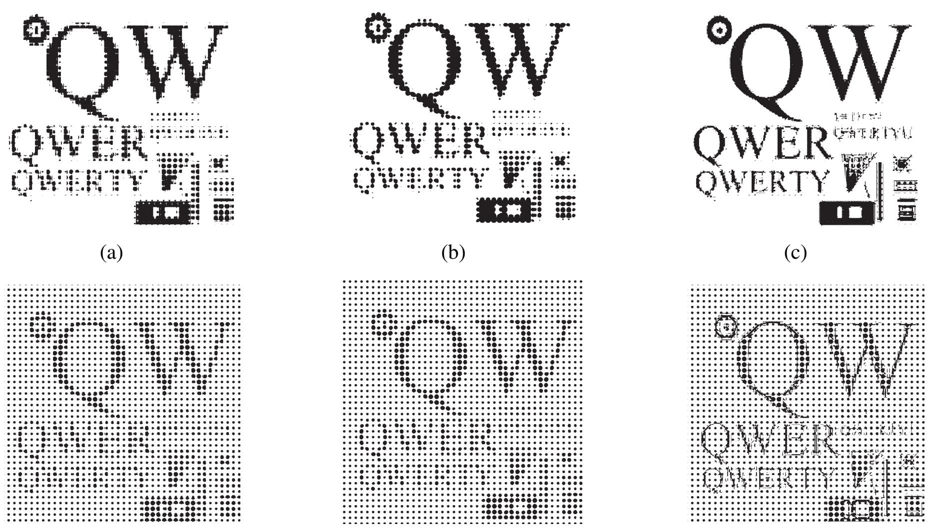
(a) (b) (c) (d)

*Figure 4: Traditional (a, b, c) and adaptive (d) halftone of test image with different density relationship between its detail and background (fine scan/ fine print mode – one multilevel sampling value for each microdot of output).*




(a) (b) (c)

*Figure 5: Screening the edge (1) of intermediate contrast by the conventional method without (a) and with the use of USM filter (b); by adaptive technique (c). USM (b) makes the nearest to edge dots (2, 3) correspondingly smaller or larger, while the adaptive screening (c) precisely restores line (1) of a contour.*



(a) (b) (c) (d) (e) (f)

*Figure 6: Traditional (a, b, d, e) and adaptive (c, f) halftones of the test image of full (a, b, c) and intermediate (d, e, f) contrast; previous to screening the interpolation of input file – (b, e). (Coarse scan/ fine print – four input samples per screen mech.)*

(a)

(b)

*Figure 7*: *Prints of traditional (a) and adaptively screened (b) images.*

*Fine detail improvement in relation to basic screen frequency and original copy content.*

As was already mentioned, the effect of adaptive screening is in the main different from that provided by an un-sharp masking procedure. However, the way to apply this new screening option is to a certain extent similar to the use of the other high frequency corrections. Our research and experimental printing of test images has proved that fine detail improvement in the adaptive halftone is not an alternative to, but rather complementary to, that of USM. The latter, as well as aperture correction, compensates for the low pass filtration of input scanning whereas the adaptive technique compensates further the lower filtration inherent to a screening stage.

The similarity of these two high frequency correction options can be noted in following relations:

- improvement achieved for the image depends on the fine detail content of the original image as well as on the screen ruling at output;
- the degree of effect on the image quality by these options can be controlled with this detail taken into account;
- both of these options can be used by default at some optimal, non-overcorrecting settings.

When the original has no fine detail by its nature or looses it during the preparation stages there is no content to apply high frequency correction on. This may also happen with the presence of such detail in an original image. It can be the case when the degree of edge detail sharpness and thin stripes thickness relate to a restricted band of image spectra which is much lower than the scanning and screening frequencies. However, with the same image to be printed on a coarser stock and with twice lower screen ruling the adaptive halftone technique could be indispensable to save such detail. A certain degree of USM can be recommended in such a case, especially if the scanning frequency is just twice that of the screen ruling to minimize the input data volume.

It's well known from practice that in any kind of high frequency correction the trade off exists between the sharpness/definition of informative data and the enhancement of unwanted textures or artifacts. One of our adaptive halftones of an old painting shows amazingly greater detail, compared to one printed using conventional screening, the fabric of the old canvas appeared in some picture areas. Our "educated" customer appreciated it, but what would a lesser "educated" customer say? Nevertheless, believing that extra definition for the same cost is always desirable, it could be concluded that adaptive screening can in the near future be considered as the "default" option or norm of printing technology. It may happen in the same way as USM is currently the default used in most scanning devices, however at its minimal settings. Problems of object moire, textures and artifacts suppression should be related to the "filter" instrumentation and sophisticated retouching facilities of pre-press software applications.

## Conclusions

There is still a great need to improve halftone print definition, contour sharpness and fine detail.

In spite of the non-uniform use of auxiliary screen functions (types of tiles), the empirically determined set should not be regarded as excessive.

Our adaptive screening is not an alternative to, but complementary to the available high frequency filters and to the fine scan/ fine print reproduction mode.

Similar to other filtration techniques, the effect of adaptive screening on image quality depends on the specific content of the original image and on the screen ruling of the output.

## Acknowledgements

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## Biography

**Professor Yuri V. Kuznetsov** has a Ph.D from the Bonch-Bruevich Institute of Electrical Communication. Until 1982 he worked there as a team leader in the Graphic Arts Laboratory on the development of electronic reproduction systems. He received a Dr.Sc. degree in Printing Machinery and Technology from the Moscow State University of Printing. He is currently the Head of the Graphic Technology Department in the North-West Institute of Printing of the St. Petersburg State University of Technology and Design. He teaches courses and does research in Prepress Image Processing, Printing Quality and Color Management. He holds over 20 patents, has written more than 30 papers on topics relating to imaging for printing. He has also authored three books, the most recent of them "Image Processing Technology in Printing" was published in 2002.