Does Still Some Philosophy Exist for the Halftone Frequency Selection?

Jury V. Kouznetsov
Sankt-Petersburg Institute of the Moscow State University of Printing
Russia

Abstract

Being a fundamental parameter in TV system the number of strokes of TV screen doesn't depend on its size and is strictly determined by the broadcast standard. To the contrary, information content of a print is squared with the increase of a picture linear dimension as well as of its halftone frequency. Carrying the same data volume the image of 140 Lpi occupies twice less of a page area as compared to the 100 Lpi one. Ruling of a halftone for given job is taken within the most common range of 60 - 200 Lpi from a set of the numbers which were empirically found at times of photoengraving. Digital pre-press of to day can provide flexible adjustment of a ruling value. Performance of an ink - press - paper system is subject to a great variety of factors therefore the standardization of frequencies is problematic for halftone printing as compared to electronic media. Ideas of determining screen ruling for particular printing conditions are discussed with taking into account:

– conflicting demands of providing both spatial and tonal resolution;
– formal and effective tone range of a print;
– noise level of a printing process;
– unity of the extreme dot area meanings for different screens;
– behaviour of vision as the low pass filter with an adaptive spatial frequency threshold.

Keywords: halftone, frequency, screen ruling, dot area.

Introduction

In terms of the signal processing technology a regular screen grid plays a part of auxiliary oscillation to be amplitude modulated by the pictorial data to carry it to a viewer through the printing process. This discrete intermediate presentation is later on subjected to the demodulation (descreening) process when viewer appreciates a halftone print as a continuous field of tone values. Spatial frequencies of an original image which are twice less of a screen ruling are guaranteed to be detected at least with a minimal contrast.

Following parameters of a halftone structure are the most important in providing the final print quality:

– screen ruling;
– form of halftone dots;
– geometry of dots location (orthogonal, hexagonal, etc.);
– orientation of a screen on an image.

All of them are selected with taking into account such factors as:

– specifics of pictorial data and their visual interpretation;
– printing process limitations;
– easiness of ignoring the screen when a halftone print is viewed.

Within the scope of the first of these factors the effective (perceived by viewer) content of an original image, which is presented by halftone copy depends, for example, on an angle at which screen is superimposed on this image [1].

In respect to printer limitations, along with the other factors, so-called printability is considered. This criteria estimates similarity of an inked pattern at some ideal presentation, such as on a bit map, to that on a final print [2].

Appreciate a Picture or a Screen Thereof?

Descreening process fidelity can also be discussed in various relations. Frequencies of all of the commonly used halftones (60 – 200 Lpi) are located within the margins of visual response. So, vision just pretends not to see the halftone dots thus playing a part of a partner in tricking the viewer when presenting to him a discrete bi-level image instead of a continuous one. Moreover, ability of vision not to notice the screen is changing at coming from a high quality print to a poor quality one. Regular patterns with frequencies under 100 lines per inch are appreciated as pictorial data on a 200 Lpi halftone. Same frequencies of newspaper print are however thrown out by vision as belonging to an auxiliary, screen structure. So, in terms of signal processing, vision plays a part of a low pass filter with an adaptive spatial frequency threshold. Such a conclusion can be confirmed by a customer’s surprise when he is asked to give his attention to a specific dot structure of a halftone image. It often happens that being far from problems of printing technology he is used to take such an image as a usual photograph. In this light it can be also supposed that the periodic screen is with less effort filtered off by viewing as compared to non-periodic one containing low spectral components of the same order. With changing rules of the game for a non-periodic halftone the eye is confused to detect if a cluster of randomly located elements belongs to the carrier structure or to the pictorial data.

These compromises have place at the viewing stage of reproduction process for the lack of facility, by the reasons discussed below, to provide the halftone frequency higher than that resolved by vision. It could completely eliminate the demodulation problem as it has place when viewing the photographs because of fine granularity of their emulsion. So, being based just on a spatial response of vision the motivation of halftone frequency choice is rather disputable.

Formal and Effective Range of Tone Values

Gradation of a halftone is measured by the relative area (S) of a printing element in accordance with autotypie principle. When full range of 100% is assumed the impractical infinite absolute sizes of dots are to be used for tone variation near extreme points of this range. Real printing is however based on the minimal inked and blank areas of a finite size, which approximate values are in Table 1 for the different types of editions.

Table 1. Sizes (d_{min}) of minimal halftone dot or blank area and screen rulings (L) for the various types of printing

	d_{min}, µm	L		S_{min}, %
		Lpi	Lines/cm	
newspapers	80	60	25	4
	50	100	40	
magazines	40	130	50	
	33	150	60	
commercial	29	175	70	
	25	200	80	

These sizes correspond to the minimal printed and non-printed elements, which are steadily and uniformly provided over a paper sheet within a run. They can be taken for some equivalent of noise level of an ink-press-paper system and comprise basic parameters of its optimal operation for halftone printing. The other recommended values, such as densities of solids, print contrast, dot gain, etc. are just resulting from an effective dot area range, which is available for these extreme sizes.

Gradation curve (1 on Figure 1) thus occupies just a part of the formal range corresponding to the optical densities of a solid ink and clear paper, i.e. to the dot area S of 0 and 100%. Tone values, which relate to the gaps 2 located between the upper and lower ends of these ranges are absent on a print for the lack of smaller dots or blank areas to reproduce them.

For graph 3 of Figure 1 the optical densities of solid and paper, i.e. dot areas of 0 and 100% are assigned to “white” and “black” levels of an original image. Due to such mistake of a scanner operator there will be no original detail reproduced in the intervals 4 and 5 of highlights and shadows. False contours may also appear where the areas of clean paper and minimal dots or of solid ink and minimal non-printed element contact each other, i.e. for the points 6 and 7 indicated on Figure 1.

Assigning of the lightest gradation to a paper density is sometimes used as a special case of “specular or drop-out highlights”[3]. It is reasonable when $D_{org.min}$ corresponds to some shiny, completely reflecting detail of scene to be reproduced and therefore there is no gradation within its interval 4 (Figure 1).

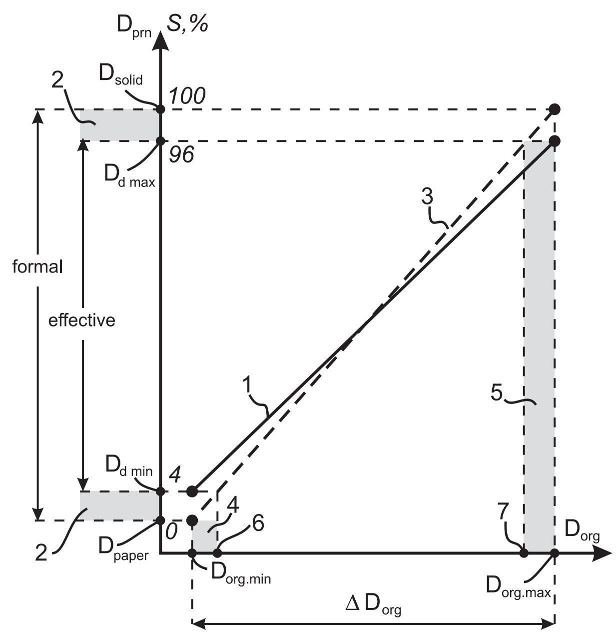

Figure 1. Tone curve positioning for the effective (1) and formal (3) range; non-reproduced intervals – 2, 4, 5; points of the false contours appearance – 6, 7.

The so-called contour capacity[4] of halftone printing can be discussed with taking into account the effective density range. It is estimated by the number of combinations by two of steps, which are visible on a wedge printed within this range. In a contrast to the photoengraving technology the digital imaging facilitates providing such an equicontrast step wedge at condition of a free contact of its adjacent fields. Amount of visible steps between them can serve as an optimization criteria for the ink-press-paper system. In development of this concept the extreme step wedge can be considered. In theory, it contains such a number N of still visible steps which, if are enlarged by one with reducing each of the other by 1/N of its colorimetric difference, will result in transforming the step wedge to the continuous tone bar under the standard print viewing conditions as schematically indicated on Figure 2.

Figure.2 All the steps disappear in the extreme wedge (a) if the number N of its fields is enlarged by one (b)

With an extreme wedge once created the ΔE constancy of its adjacent fields can be further on checked thus telling if this or other perceptual colorimetry is "good enough" [5] for the purposes of prints quality estimation. The digital printer is linear and optimal as providing the maximal contour capacity when the differences in tone values used for generating the patches of an extreme wedge are constant. So, any deviation in operating conditions of a printing system will result in the loss of some steps within this wedge.

As is well known from practice, expanding of an effective tone range within a formal one under the given printing conditions can be achieved just by reducing of a screen ruling and therefore by the corresponding loss of resolution. From the other hand, providing higher resolution by increase of a halftone frequency reduces the contrast and the contour capacity of imaging. For the example illustrated by Figure 1, twofold frequency increase results in effective range of 68% instead of 92% because the relative value of minimal halftone dot and non-printed area becomes as much as 16%.

Improved halftone techniques were suggested to satisfy both of these demands. They provide variation of a screen ruling [6], dot shift [7] or deformation [8] of dots in non-stationary image area according to its bysiness or local contrast. There is also adaptive screening [9] proposed, which in optimal way combines the CT and LW reproduction modes for the better use of output printer resolution , which at least ten times exceeds that of the input or CT file.

Screen Ruling Value

Selection of proper screen ruling for conventional halftoning thus faces a problem of finding the optimal relationship between important but conflicting (in their realization) image properties of tonal and spatial resolution. Exchange for the mutual compensation of dissimilar parameters looks , at the same time, rather indefinite from the point of view of qualimetry.

Key for determining an optimal ruling value can meanwhile be found from the statistics of more than a century of halftone printing at suggestion that the relationship of conflicting parameters discussed stays the same for different types of printing. For all of them the relative minimal dot or blank area is estimated as 3÷5%. So, it is quite reasonable to assume that, for example, the value of 4% expresses empirically found compromise of tonal and spatial resolution.

At such an assumption the simple equation can be suggested for determining the frequency of halftone. If, for example, dot has a square form, as is shown on Figure 3, $d^2_{min} L^2 = 0{,}04$ and therefore the screen ruling

$$L = 1/(5\ d_{min}), \qquad (1)$$

i.e. comprising an inverse of five dimensions of minimal available dot. This relationship of d_{min} and L is also used for the data of Table1.

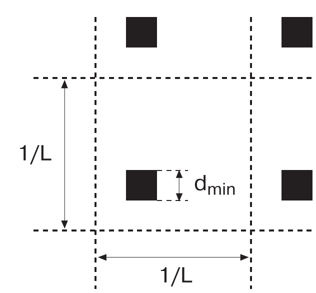

Figure 3. Minimal halftone dot in a screen mesh for tone value of 4%

Based on some logic, this approximate rule is intended for an average statistical content of CT original. At the same time, modern RIPs and DTP imaging applications facilitate the screen ruling variation from illustration to illustration in the same edition. Some of CT images contain no vast areas, where the smooth tone rendition would be critical, but have a strong fine drawing, which contours and small details should be reproduced with high geometric accuracy. Tonal resolution of such pictures can be to some extent reduced for the sake of higher spatial one and therefore the screen ruling is used to be taken somewhat higher of recommended above. And, to the contrary, for images with large areas of smooth tone variation the ruling value is taken a little lower.

In the light of discussed, the ISO [10] recommendation to use for prints of 200 Lpi a 5% highlight dot and 3% dot for 100 – 175 Lpi looks rather disputable. Following this advice the same absolute size of minimal dot is to be used for 200 Lpi and 150 Lpi halftones. So, the question arises: Why should tonal resolution be to certain extent sacrificed in behalf of a spatial one for the commercial printing as compared to the newspaper or magazine production?

With no philosophy of the appropriate screen value selection, which is based on the halftone structure printability and effective tone range, the confusing statements and non-correct estimations can be easily done as concerned of the printer operation and illustration quality. This is, for example, widely met estimation of the gray levels number available in printing by the amount of bits in a bit-map of screen mesh. Even for an idealistic printer, which provides exactly the same patterns of elements on bit-map and substrate, such values are presenting just reflectances of an original image but not the equicontrast, and hence perceptually more effective, levels of luminances or optical densities.

The 1 or 2% dot steadily provided on prints are sometimes used to be shown to a customer as the evidence of a high standard of printing. However, it would be more reasonable to increase the screen ruling twice with corresponding improvement of an overall picture quality.

In the light of above described, the typical example of non-correct comparison of irregular and periodic halftones was given in EC&I [11]. “Stochastic” screening based on printing elements of 21 and 14 microns was compared there with conventional one of 100 and 200 Lpi. With taking into account that minimal dot sizes were in fact less than 10 microns on those prints the regular screen of over 400 Lpi should be used for correct estimations. When compared to such conventional prints the non-periodic halftone advantages comprised of screen and rosette absence, so-called “photographic quality” or the like would be not evident.

Conclusions

With conflicting demands of providing both spatial and tonal resolution the effective tone range of halftone printing should be taken into account in the optimizing of ink-printer-substrate system.

Contour capacity within an effective range of halftone imaging can be used as optimization criteria of a printer operation.

Balanced relationship of dissimilar parameters of resolution and tone rendition in halftone printing is expressed by the unity of extreme dot area meanings for the variety of screens used in practice.

Appropriate value of halftone frequency commonly comprises the inverse of five dimensions of minimal available dot, which is uniformly provided over a paper sheet within a run for given printing technology.

With no philosophy of choice of an appropriate halftone frequency there is no correct basis for the comparison of traditional screening techniques with modified ones.

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