Screening technique modification and its effect on halftone print quality

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Abstract

Densitometry, spectrophotometry, profile making and other means comprise the powerful instrumentation for providing the proper quality of color reproduction. Various color strips and bars are effectively used for a printing stage normalization according to the recommendations of a standard. Effect of the screening process on a resulting quality is, however, mostly concealed within a total halftone imaging estimations. At the same time, the screening stage share in such parameters of a final print as tone rendition, dot gain, resolution, fine detail distortion, structure uniformity, moire characteristics, etc. can be evaluated with a minimum or even no relation to the other processes involved in an image reproduction. The problems are discussed of a proper selection the screening technique for a particular job or printing technology, of determining the basic parameters and their estimation criteria, of defining the development directions in digital screening technology.

Objectives of a new screening techniques development and application.

In the light of modern digital data technologies the task of pre-press reproduction is in providing some intermediate image presentation, for example a bit map, which properties could minimize the losses of an original data content on its way to a viewer through the printing process. The latter can be compared with a communication channel which limitations reduce tonal range, color gamut and spatial resolution of an image. In this relation the screening, as a digital pre-press stage, plays a part of an optimal data encoder.

The whole data processing system is rational, if the properties of a data source, namely of the CT original, and that of the system on its input side, as well as the system output properties comprised in a halftone print and properties of vision are in conformity with one another (Fig. 1). The reproduction process imperfection within the above concept is schematically outlined as a data stream alignment. System includes a data source at the input and vision at the output. Arrow 1 on this picture indicates the data, which is objectively contained by the halftone illustration but cannot be appreciated by a viewer due to the human vision limitations. Arrow 2 is referred to such kind of an original data, which could be transferred by a printing process and appreciated by a viewer, but was lost earlier due to imperfection of the reproduction stage.

An excessive data indicated by the arrow 1 is concerned, for example, of an eight bit encoding the image. Formally, such an encoding predetermines 256 levels of gray which finally results in about a hundred on a print. That ensures a smooth tone rendering for the large areas which are most critical in viewing with the slightest variations of tone or color. For the small detail such a precision also has place as provided by the halftone dot sizes. However, the halftone dots not only create an image but as well destroy its contours and fine details. The ability of vision to appreciate the small detail tone variation is comprised of just a few levels. So, the most of effort concerned with providing the same amount of 256 gradations for fine detail remains unused by a viewer.

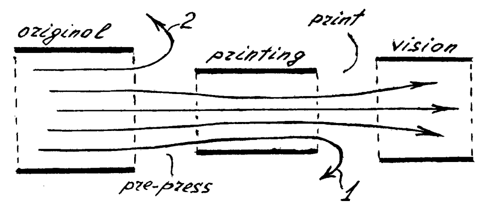


Figure 1. The CT original data stream alignment in a digital printing system

In contrast to one given above, an example from the color television technique, an industry with a comparatively short tradition, will not come amiss. Occupying the channel with a bandwidth initially determined by the demands of the b/w TV, the color TV uses color subcarrier frequencies which are much lower of a brightness component frequency. That results in poor color content or even its absence for small detail with no dramatic influence on the overall TV picture quality.

When revolutionary technical changes transform a traditional industry, it often happens that the certain product quality is sacrificed for the sake of higher productivity, lower costs, some other product property, etc. The basic process facilities for obtaining such a quality sometimes remain unused for a long time, in spite of their successful application during the craftsmen phase of the technology concerned. This fact is illustrated by an example of a data indicated by arrow 2 and corresponds to the geometric accuracy of small detail and contour reproduction. Since the halftone photography invention, for over a hundred years the plate making and printing stage resolution have being completely used just in LW reproduction. Fine detail dimensions at the commercial halftone print of today stay about 5-10 times greater of that provided by manual engraving and some other techniques of the last century. The 100 Lpi screen ruling is based on minimal halftone dot sizes of about 50 microns, which corresponds, for example to 500 dpi resolution of a digital press. Meanwhile the minimal original copy detail reproduced at a print comprises just a half of a millimeter resulting in the whole reproduction process resolution of about 50 lines per inch.

Screening efficiency criteria

To solve the problems of the kind described a lot of effort was undertaken and a certain progress was achieved by the electronic screening developments of the last two decades. The screening techniques were created providing a selective, within an image area, interchange their capacity of smooth tone rendering for the geometric accuracy of a contour and fine detail. The screening procedure varies according to the local properties of an image, its so called busyness to satisfy the conflicting demands of providing both tonal and spatial resolution [1].

The other screening efficiency improvements are concerned of the screen visibility reduction and suppression of all kinds of moire.

For the both of above development directions the resulting halftone can be periodic or non-periodic as well.

Among the parameters which determine a screening system efficiency there should be mentioned:

- tone rendition and its control facilities;
- dot gain characteristic;
- resolution;
- fine detail and contour geometry distortions;
- visual uniformity of the halftone structure;
- moire characteristics on a color print;
- algorithms complexity;
- data volumes to be used.

What kind of screening to use ?

As result of intensive research and development of the late the great number of screening techniques is currently available on the market. According to some experts estimations, it was for about a hundred up to the time of last Drupa. With such an amount, a problem arises of the proper selection the one for this or the other kind of job or printing technology. The certain difficulties are also caused by the lack of technically defined criteria and correct basis for the various screening systems efficiency estimation and comparison.

When discussing efficiency of the particular screening process one often faces the problem of correct technical definition. The great amount of new terms are currently involved in the field of screening. Sometimes the trade marks of the kind of *Excellent Screening, Singing Screening, Dancing Screening* or the like are used as terms. Common technical terms such as *rational, irrational, random, dither, diffusion, stochastic, FM, AM* are mostly used without proper definition or explanation of their application to screening. As result of some "academic" discussion it was recommended to call the non-periodic halftones as a *stochastic* in America and as a *FM* in Europe. It happens sometimes that a certain term gets different meaning not only in various countries but in two departments of the same firm. But, as far as at first was the Word, the correctly defined term comprises an important basis for further deeper understanding.

The projection and contact screening of the past and the earlier electronic screening have had not so many alternatives. They were taken as a granted, traditional and familiar procedures. Their properties and facilities were well known to a lot of professionals from the everyday practice. That's why, may be, not so many of those skilled in graphic arts were curious enough to find answers to such questions as:

Why is the screen on b/w print or that of the black ink on a color one used to be turned at 45 degrees ?

Why has the regular screen an orthogonal but not, for example, hexagonal structure ?

Why does the screen frequency for the given printing process comprise 150 Lpi, but not 147,5 or 153 ?

How to choose exact screen ruling value ?

Why is it used to say *the dot gain* but not *the dot reduction*?

Is it good to define the dot gain as "film to print" dot area variation ? Or would it be better to discuss it as the "bit map to print" coverage variation?

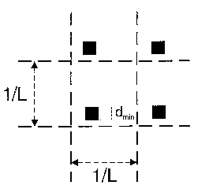
In spite of have being successfully used for about a century in printing, the orthogonal sampling grid and its 45 degrees rotation were explained as an optimal much later and in the other industry. Namely as the result of developments in digital TV. The basic result of this theoretical research couldn't however be used in TV because of some of its specific limitations. But it stay to the great extent still unused in electronic pre-press too, in spite of its effectiveness for the image quality improvement at the input sampling stage was theoretically proved about two decades ago [2,3].

Screen ruling

The screen ruling value is a result of some compromise in providing two dissimilar illustration properties such as tonal and spatial resolution. It is well known from the art that lowering the ruling gives greater number of gradation and higher contrast but limits definition of a print, while rising the ruling gives a reverse result. At a first glance, the problem of a screen value optimization for the certain printing technology looks rather indefinite. The question seems to be of the kind of analytical finding an optimal relationship of salt and pepper quantities in food for the conformities of their usage can be taken only according to taste and experience.

Effective density range of halftones is based on minimal dot and blank areas of 4% or 5% for all of the variety of screen rulings from 75 to 200 Lpi. So, it would be reasonable to suggest that these extreme values comprise in particular an expression of above compromise as being empirically found from over a hundred years of an autotypie practice. From the other hand, the press stage print ability in relation to a halftone reproduction is determined by the minimal absolute sizes of printed and non-printed elements which are steadily and uniformly provided over a paper sheet within a run. The other recommended press parameters, such as the densities of solids, print contrast, dot gain, etc. are just a derivatives of the effective dot area range, which is available within the particular technology limitations. That's why, with taking in account, for example, 4% value of a minimal dot area the screen ruling can comprise an inverse of 5 minimal available halftone dot dimensions (Fig.2).

Based on some logic, this approximate rule is intended for an average, statistical CT original. At the same time, modern RIPs and DTP imaging applications easily provide the screen value variation from illustration to illustration on the same page. Some of CT images contain no vast areas where the demand of smooth tone rendition would be critical, but have a strong fine drawing which contours and small details should



$d^2_{min}L^2 \approx 0{,}04$

$L \approx 1/5d_{min}$

$d_{min} \approx 1/5L$

L lines/cm	d_{min} µm
80	25
70	29
60	33
50	40
40	50
25	80

Figure 2. With a various screen rulings the approximately 4% highlight dot is used which expresses the empirical alternative in providing two dissimilar and conflicting properties of a halftone image

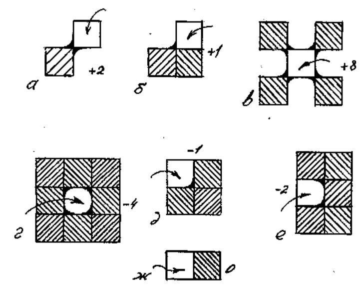


Figure 4. Dot gain value depends on printed area geometry as producing from +8 to -4 extra inked areas with a single microdot (not hatched) addition.

be reproduced with a high geometric accuracy. For such pictures a tonal resolution can be to certain extent sacrificed for the sake of a spatial one and the screen ruling can be taken somewhat higher than that recommended above. And, to the contrary, for the images with large areas of smooth tone variation the ruling value can be lower.

AM and FM principle application in screening

The earliest electronic FM halftones were published by the RCA Graphic Arts Laboratory in IEEE Spectrum in 1968 [4]. Printing elements nowhere touched each other and had a constant area through over the tonal range (Fig. 3). Nowadays the term is used for the systems of combined AM/FM modulation as is shown on the picture.

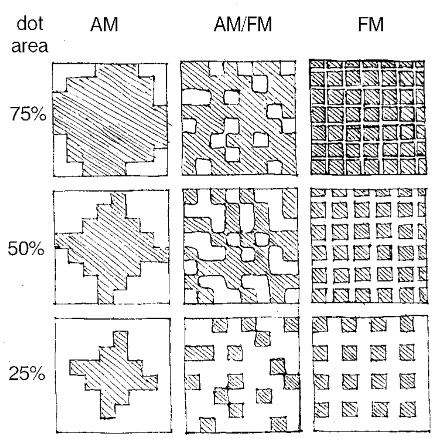


Figure 3. The unit area coverages in AM, AM/FM and FM halftone methods

From the point of view of a programmer, who manipulates the amount of bit values within a bit map, it can be exclusively the *frequency modulation*. But printer receives instead of two dots only one, twice larger dot, when a couple of subelements or microdots touch each other. Moreover, he gets also the great variety of dot gain values depending on geometry of these subelements contact (Fig. 4). Additional areas appear in all kinds of intermedeate images and prints due to the multiple reasons depending on a physical principle used for an image formation. Resulting halftone coverage differs dramatically from that of idealistic (bit-map) presentation due to an absolute value of such an additional area (Fig. 5). The greater amount of an adjucent element contacts results in the loss of dark gradation in non-periodic screens as compared with reqular (AM) ones.

To the contrary, the theoretical FM system (at the right on Fig. 3) is characterized by the absence of a mechanical dot gain. For a printing element of a given size the ink supply, pressure at blanket and some other of a press or a printer parameters can be adjusted in such a way as to provide the same dot area on paper.

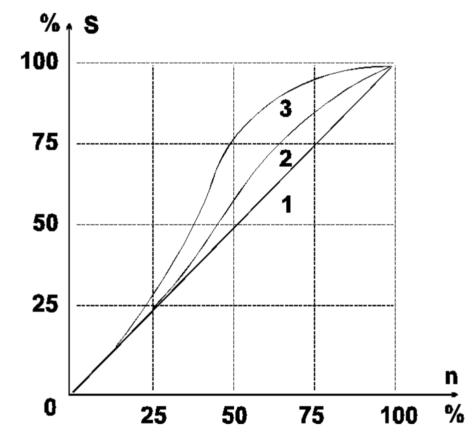


Figure 5. Coverage "S" nonlinear relates to the number "n" of randomly located microdots due to the additional inked areas formation when adjacent microdots contact each other:
1 at idealistic (bit-map) presentation;
2,3 at low and high recording resolution.

As far as for an original density response there is a spatial period varied in FM, the image resolution depends on the local tone or detail contrast of an original. So, for the proper resolution estimation there should be used a test enabling not only the variable frequency and orientation but, as well, the contrast variation of a patterns thereof.

Some screening systems use the FM principle just to a certain extent, with an auxiliary purposes of quantization noise, moire, etc. suppression while producing a trivial periodic halftone structure of the kind shown at the left on Fig.3.

Gradation

As was already mentioned, the printing stage is adjusted according to its own criteria which is independent of any of the pre-press parameters. The halftone structure printability means its *ability to be printed* with the use of this or the other

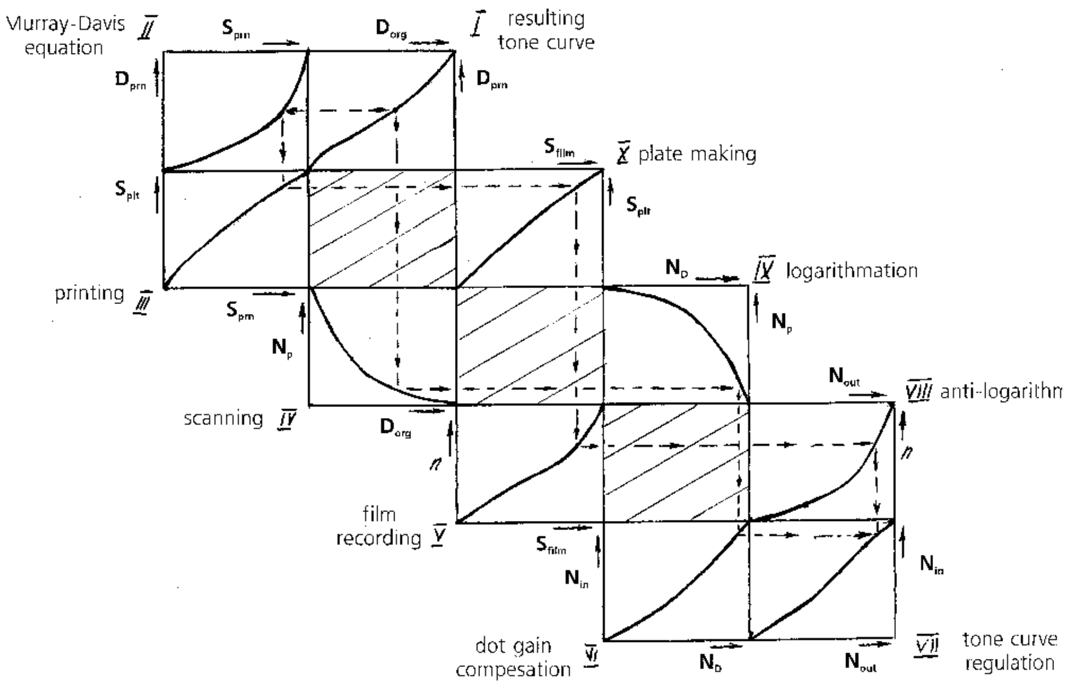


Figure 6. Original to print tone transformation in printing

but optimized printing routine. In the same way the printability of an original image can be discussed as its ability to be reproduced by the given graphic arts technology. Printability of a screen is expressed by the amount of an equicontrast steps it can provide on the given printer. This amount necessary value is somewhere between 64 and 128. So, with taking in account 256 quantization levels of a standard equicontrast signal, there is left not so much room for its nonlinear transformation.

As compared with technology of the past, modern graphic arts reproduction still has many stages. The pictorial data is transformed many times on its way from an original copy to a print. It is presented as optical signals, electric signals, analog and digital, multi-level and bi-level, as relative coverages of a bit map, film, plate, blanket and paper. The whole process is often disconnected geographically. As Fig.6 shows, this succession stays rather long in digital printing too, being shorter by just a couple steps of film recording and plate making.

The multi-quadrant diagram of Fig. 6 demonstrates the various stages relationship and their mutual conformity, makes comprehensive enough the ideas and facilities of control, regulation, calibration and normalization at an each step. Curve 1 presents the task and as well the result of process and is given from the top (by an editor or by a client). The seventh quadrant relates to a control stage. Here is provided the regulation of an input and an output signals relationship to solve the above task with taking in account tone value variation at each of the other steps. It is the same curve which input and output quantization level numbers N an operator manipulates on a monitor in this or other imaging software application. As shown by the dotted line, the latter curve is just a product of all of the other ones.

Electronic reproduction stages (quadrants 4-9 on diagram) conformity to printing technology is performed by such a screening procedure which provides extreme amount of tonal steps within the effective density range of a printer. The gray levels number inevitably decreases resulting in an image quality deterioration if the above conformity is disturbed due to some of a printer characteristic variation. The conformity is restored by a halftone dot alphabet replacement or by a spot and/or threshold functions (quadrants 5 and 8) modification on a press "fingerprinting" data basis.

In this light the concept of an open screening system providing user a flexible facility of a screening tonal curve modification is very actual. That makes it possible to perform all the necessary pictorial data nonlinear transformation at a screening stage. The currently used transformation is losses resulting for it is applied to a multilevel video data previously to screening. This concept concerns not only of DGC procedure (6), but also of the basic functional tone correction (7) according to a reproduction task designated in the first quadrant.

Resolution and data volumes

The spatial resolution of all of the electronically produced halftones, in a contrast to mechanical ones, is not exclusively determined by the screen ruling value. Fine detail and contour reproduction quality also depends on the input sampling and screen function frequencies concealed from the viewer and is indirectly determined by the output device resolution. That is why each new system should be properly tested in this respect.

Along with the halftone image other properties, the printing elements form, orientation and mutual placement determine such a qualities like the screen structure visibility, object or/and color moire contrast and periodicity. The entire efficiency of screening is not thoroughly defined by the produced dot pattern regularity or irregularity.

Important question of the correct comparison basis arises, when the facilities of some of new screening technologies are discussed in relation to the already used ones. If, for example, non-periodic halftone is compared with a regular one, the screen frequency choice of the latter and the right understanding this frequency value selection are urgent. Otherwise, as it often happens, not the screening systems are compared, but some HI-FI printing with an ordinary one.

There should be mentioned, in conclusion, yet one else important criteria of screening efficiency estimation. That is the size of an input image file to be processed, stored or transferred through the local or external network. One should remember that the input videodata volume in some screening systems could be up to a hundred times greater of that commonly used.

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