The adaptive screening of continuous tone images

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Abstract

Autotypie screening invention started the widespread revolutionary enter of illustration to printed matter in the eighties of the last century. However, the most of digital screening methods allow fine detail and contour quality on a halftone image inferior to that provided by a printer for the line work. Unperfectness of the screening stage in relation to the printer facility results from a compromised meeting the conflicting demands of providing both tonal and spatial resolution. The ideas of screening which is adaptive to an image local area content are discussed as one of a possible solutions of the problem.

Introduction

In the light of modern data processing technologies, the task of pre-press reproduction is to obtain an intermediate image presentation, for example, a bit map which properties minimize losses of original data on its way to a viewer through the printing process. The latter can be interpreted as a communication channel which noise and restricted bandwidth result in a reduction of the output picture tonal range, color content and spatial resolution. In this relation the screening, as a digital pre-press stage, plays a part of an optimal data encoder [1].

The contradictory demands of the autotypie principle - providing both the proper spatial resolution and smooth tone rendering - are met in printing practice as a result of a compromise between these dissimilar quality properties. It is well known in the art that raising the screen ruling value results in higher spatial but lower gradation resolution, while lowering of ruling gives a reverse result. So, for the particular printing technology this compromise is reflected by the empirically found screen ruling value.

The rational reproduction system should selectively exchange, within the picture area, its capacity of smooth tone rendering for the geometric accuracy of the small detail and contour reproduction [2]. In terms of modern digital reproduction technology, such a task can be designated as an adaptive electronic screening or an adaptive multilevel image data binarization.

Early attempts to optimize the half-tone dot structure by changing a screen ruling according to the local area tonal value were concerned with Respi screens providing for ruling greater by the square root of two in a darker area. The type of the Respi screen effect was later, in the early seventies, implemented by one of the Hell’s DC 300 Chromograph electronic screening programs with the greater screen ruling for midtones. The technique of multistage enlarging the screen ruling according to the busyness of a picture finite area was later described in [3].

Image quality and processing limitations in CT reproduction

Modern electronic dot generators construct half-tone dots from a tiny subelements (microdots) within the matrix (Fig. 1e) comprising a unit screen mesh. The sharpness of a full contrast border 1 can be improved in such systems, as it is illustrated on Fig. 1 a,b,c, by enlarging the number of multilevel pictorial data samples 2 taken from an original for each screen mesh. The best result is obtained, as Fig. 1c shows, when each subelement within a mesh is supplied by its own independent pictorial data sample, though for the contour of an intermediate contrast on Fig. 1d it does not work as effectively.

To overcome above problem, the improved "dithering" techniques [4] and so called error diffusion binarization methods [5] were proposed. These approaches are concerned with the reproduction systems referred to as systems of the "fine input / fine output" kind, because of their resolutions relationship. This definition postulates that the input resolution is equal to or at least not less than that of the output. The professional systems with "high end" scanners and imagesetters are generally referred to as of "coarse input / fine output". The latter relationship is inherent to the basic operational mode of CT originals reproduction. Even with a "coarse" input

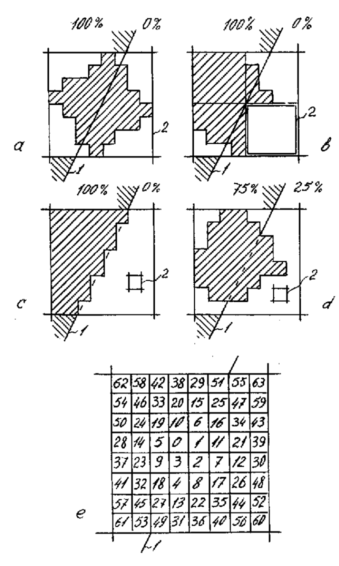

Figure 1. Full (a,b,c) and intermediate (d) contrast contour (1) reproduction as result of the sampling unit area (2) reflectivity value comparison with the weight of subelements within the screen function spatial period (e) for coarse-scan / fine-print (a,b) and fine-scan / fine-print (c,d) systems.

resolution, the videodata file volume for an A2 format four color poster at 200 Lpi comprises as much as 240 megabytes. For the screening methods based on the "fine-scan / fine-recording" concept such a job should require the input file volume of over 10 Gigabyte.

The LW originals to be a layout in the same page are input in special mode of a three to four times greater scan line density, though the data file volume for them stays many times less, due to the bi-level quantization and greater compression facilities.

In [6] we described the technique of the screen function memory addresses correction enabling the halftone dot shifts on contours and thereby the sharper image. The other approach to eliminate the contours destruction in screening is disclosed in Crosfield patent application [7] as a procedure of the coarsely input samples multiplication-interpolation, providing the coarse-scan / fine-print system to fine-scan / fine-print system transformation at the dot generating stage.

Multilevel sampling of LW images

Printing process spatial resolution is much more effectively used in the line work (LW) reproduction both by mechanical and electronic means.

The coarsely input LW reproduction technique, providing for the small details and contours quality which is adequate to the fine output resolution, was described in [8]. Additional data, necessary for the coarsely input image reconstruction at a higher output resolution, are provided by the multilevel encoding of the line matter instead of the traditionally used bi-level one. The sampling areas completely located on pure white or on solid black of the line picture are correspondingly related to the 0 or to the 255th of the quantization levels of the eight-bit encoded videosignal. Meanwhile the sample at which the area is intersected by a contour is referred to the level of some intermediate number proportional to the relative amount of black or white within the area. Thus, for example, a sample divided by the contour line on two equal black and white parts is assigned the value of 127, which means that half the copy corresponding area should be filled by the exposed subelements during recording. These subelements positions and thereby the contour geometry within the area are determined according to the multilevel values of the adjacent coarse sampling areas.

The line test pattern and its copies reproduced with some modification of the mentioned technique are shown on Fig. 2 and Fig. 3. The original test and its reconstruction are shown on Fig. 2a and Fig. 2b on the backgrounds of "fine" and "coarse" sampling grids. The reduced images located beneath are presented for the comparative illustration of:

c) - the image as if it was recorded with the fine output resolution from a data produced by the trivial bi-level input sampling at the low spatial frequency corresponding to the coarse grid of Fig. 2b;

d) - the coarsely input LW image reconstructed according the technique discussed (reduced Fig. 2b image);

e) - the image as if it was input (bi-level) and recorded at the same "fine" resolution. This picture can serve here as an upper quality limit for comparison (reduced Fig. 2a image).

The pictures in Fig. 3, where the original test pattern shown on Fig. 3a spatially non-sampled, clearly reveal another advantage of LW multilevel encoding. Thin lines which are completely lost at the fine input resolution equal to that of the output one (Fig. 3e) are quite faithfully reproduced with multilevel input at as much as four times fewer spatial resolution (Fig.3d). The preference of the multilevel LW images input and processing is also approved by the DTP publishing practice [9].

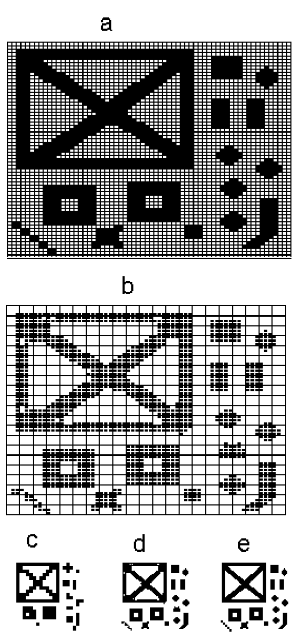

Figure 2. Coarsely scanned line pattern reconstruction (b,d) for the fine resolution output.

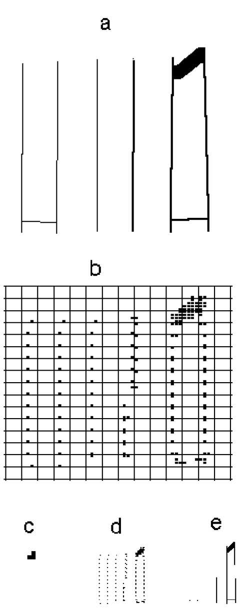

Figure 3. The separate lines (b) reproduction in fine-print system with the use of coarse multi-level (d) and fine be-level (e) video samples.

The above technical solutions allow to combine the CT and improved LW reproduction in the coarse-input/fine-output system, which is especially important for mixed or pasted-up originals. The contours and small details of the CT original stay being, nevertheless, badly damaged by the half-tone dots.

Merging the CT and LW reproduction modes

Adaptive screening technique mutually merges the CT and LW reproduction modes. Their relationship varies dynamically over the picture area according to its local content.

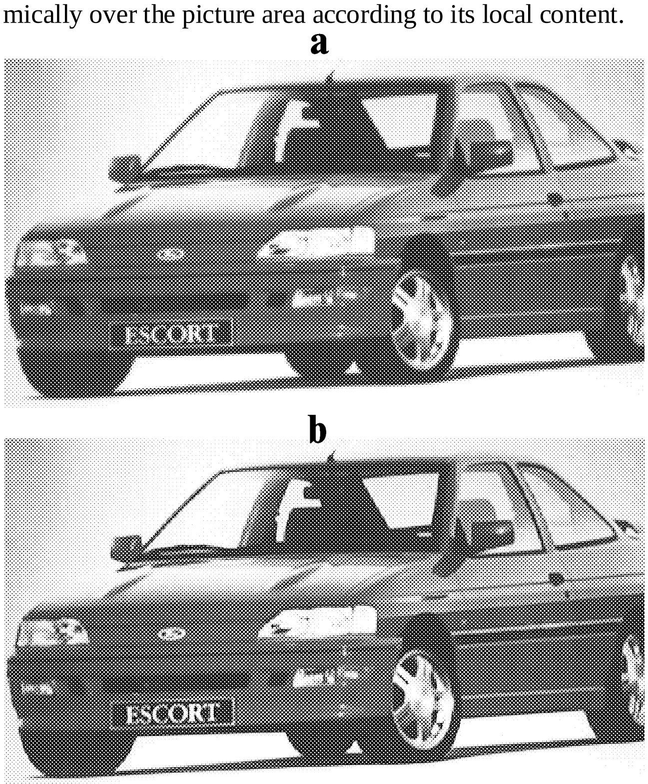

Figure 4. Conventional (a) and adaptive (b) screening with the use of clustered subelement weight distribution.

Fig.4a presents the half-tone image produced by the conventional method, while the Fig. 4b shows the half-tone screened adaptively with the input videodata. The clustered distribution of subelements weights within the screen function spatial period was used for the first of these pictures, providing the 45 degrees screen angle. The same function, but only partially, i.e. to the extent corresponding to the busyness of the local picture area, was applied to the image of Fig. 4b. An additional screen function, generated individually for the each input multilevel data sample from the adjacent sampling areas values, was here also partially used [10].

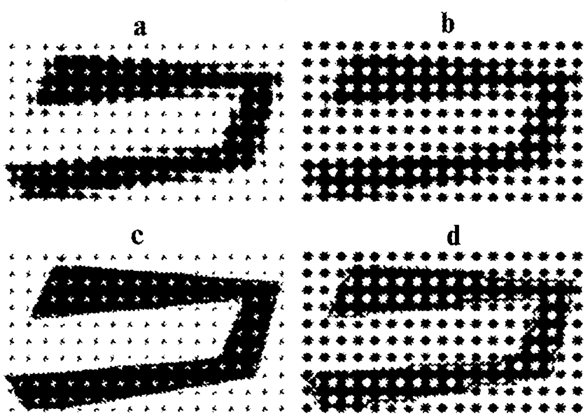

Figure 5. The traditional (a,b) and adaptive (c,d) screening the CT original fine detail of a full (a,c) and intermediate (b,d) contrast.

The principle of an adaptive screening is more vividly demonstrated by the graphic models on Fig. 5. Fig. 5a illustrates the CT original fine detail of a full contrast (95% detail on a 5% background) screened by the conventional technique. One cluster of subelement weights within the screen function spatial period was used here providing the zero degrees screen angle. Fig. 5c shows the same detail reproduced by the method discussed where the use of the traditional screen function was minimized for the non-stationary picture area on behalf of the other screen function. The latter is generated from an adjacent pixel values or selected from a predetermined set on a pattern recognition basis.

The partial use of both of functions is seen on contours of Fig. 5d for the detail of intermediate contrast (75% detail on a 25% background). As it is illustrated by Fig. 5a,b and Fig. 5c,d comparison, the new method improves a contour adequately to its "softness" on an original. Meanwhile this effect can be stressed or attenuated to the certain extent, if necessary.

The variety of sharpening high frequency filters and, for example, the unsharp masking (USM) are widely used for a picture enhancement. These techniques manipulate the multilevel pictorial data values previously to a screening stage. Changing the pixel values provides contour and fine detail contrast increasing by the corresponding enlargement and reduction the half-tone dots on the adjacent dark and light parts of the border. With such a correction, as it is demonstrated by the models on Fig. 6, the border line destruction by the screening process itself remains, meanwhile, the same or becomes even worse, adding nothing to its geometric accuracy.

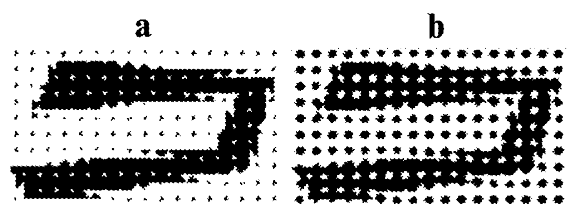

Figure 6. Fine detail of the full (a) and intermediate (b) contrast screened by the conventional technique after unsharp masking the input pictorial data file.

Using the operators of differential kind the adaptive method yields also the better small detail rendition as compared with the interpolation technique. In spite of correcting the stepwise distortions on contour, interpolation is inevitably accompanied by the low-pass filtration or defocusing.

Resulting differences of the techniques discussed are more apparent on Fig.7 illustrating the models of Fig. 5-6 at more realistic, reduced scale.

It should be noted in conclusion that all of the pictures on Fig. 4 - 7, were produced on the most commonly used "coarse-scan" basis of four videodata samples per screen function

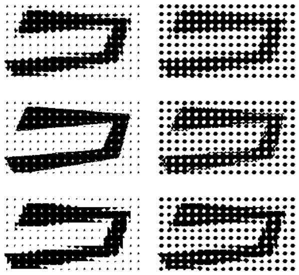

Figure 7. Reduced copies of images of Fig.5-7.

spatial period. As it is seen from above described, the adaptive method can be as well used in application to the non-clustered or irregular (dither, random, stochastic, frequency modulated, etc.) subelement distribution for a picture stationary area.

The new half-tone illustration quality is provided in adaptive method mostly by means of parallel operations. That simplifies adaptive screening implementation in RIPs. On the other hand, a relatively small number of calculation steps also allows for the rasterization in DTP imaging applications.

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References

1. J.V.Kouznetsov, D.M. Alexandrov, Screening technique modification and its effect on halftone print quality. *Proceedings of IS&T's NIP13: The Int. Conf. on Digital Printing.* Nov. 2-7, 1997.

2. J.V.Kouznetsov, V.A.Uzilevski. "Electronnoe Rastrirovanie v Polygrafii", *"Kniga" publishers, Moscow,* 1976.

3. J.V.Kouznetsov et. al. *Certificates of the authorship* SU 832771 filed 25.12.78; SU 1288934 filed 13.01.82; SU 1246408 filed 10.10.82.

4. P.G.Roetling. Electronic halftone imaging system. *US pat.* 4051536 filed 14.03.75.

5. E.Peli. Halftone imaging method and apparatus utilizing pyramidal error convergence. *US pat.* 5109282 filed 20.06.90.

6. J.V.Kouznetsov et. al. *Certificate of the authorship* SU 1634119 filed 12.07.87. US pat. 5229867

7. G.Webb, R.A.Kirk. Producing half-tone images. *European patent application* EP 0342845, priority 16.05.88 GB.

8. K.Y.Wong. Method of coarse-scan/fine-print character reproduction with compression. *US pat.* 4150400 filed 31.03.77.

9. S.Johnson. Making a digital book. *Stephen Johnson Photography, Pacifica, California,* 1993.

10. J.V.Kouznetsov. Method of and apparatus for adaptive screening continuous tone originals. *Patent applications* PCT/RU 94/00256, GB 2300328 A, DE 4498946 T1.