Combining the Advantages of Alternative Screening Modes with an Image Decomposition on Continuous Tone and Line Matter Constituent Parts

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Abstract: The whole quantization scale of tone value is applied to an each output pixel in digital TV or continuous tone printer for image gradation variation. This scale is level-by-level spatially dispersed for the same purpose between multiples of such pixels with a screening process. That results in conflicting data providing both tonal and spatial resolution of halftones. In adaptive screening, the trade off problem is solved by input image decomposition on continuous-tone and line matter constituent parts with selective varying of the degree, periodicity, linearity, and direction of quantization scale spatial dispersion. Psycho-visual and technical premises of such image decomposition and variants to combine, on this basis, the alternative screening modes are discussed as result of modeling the process and realistic halftone printing.

Introduction

In terms of an image signal processing technique the more or less universal definition of screening, which could embrace the whole variety of these procedures (from photo mechanic projection halftoning up to the digital, for example, error diffusion one), may sound as follows: "The structural transformation of continuous tone image through the spatial dispersion of its tone measure among the output pixels to print them bi-level as result of comparison of dispersed value with an input tone level."

In the digital signal processing environment, where tone measure is a priori quantized, this dispersion directly effects the tone quantization scale applied to an each pixel of an input CT image (Figure 1a). Depending on the resolutions relationship of an input/output media this dispersion can be performed inside or outside of the input pixel area. Thus, for example, when relatively coarse CT image of TV or computer display is intended to be printed on a rather fine stock, such dispersion can be provided within this area with subdividing it to the plurality of smaller output elements. In more typical case of a higher, than in printing, input resolution

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Parameter of dispersion	**Halftone screen parameter**
degree	period (ruling)
regularity	AM, FM (stochastic)
linearity	tone response curve
direction	orientation, geometry, form of a dot

Table 1: Parameters for tone scale spatial dispersion and that of the screen pattern thereby produced.

of a slide photo emulsion the dispersed scale occupies at an output media much greater area than the original scale does, as shown on figure 1(b, c).

The law of dispersion is usually defined by some kind of the so called screen function. The latter can comprise, for example, the matrix of weights which are already dispersed between output pixels (Figure 1 (b), (c); Figure 2) or expressed by the ready-made bit-maps of halftone dot alphabet. It can also be presented in analytical form of instruction for such dispersion (Yamazaki 1982, Sharma 2002) or as the combination of a spot function and threshold function.

Parameters of dispersion and screen pattern properties

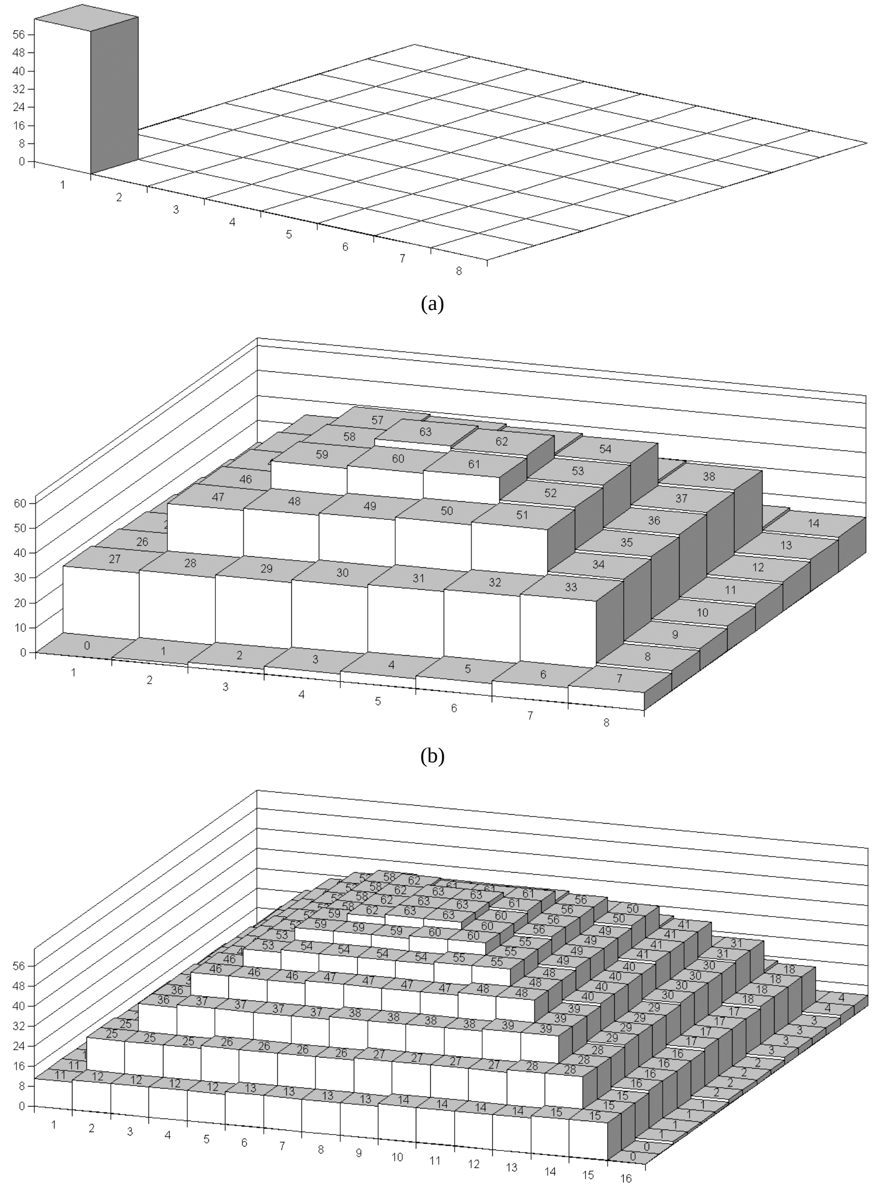
The variation of such dispersion parameters as its degree, regularity, linearity and direction is schematically illustrated by figure 1. The compliance of these parameters with the basic properties of a screen pattern to be formed is shown in table 1.

Tone levels of 8 bit image data may usually comprise optical densities or other uniform values such as CIE Lab. However, the amount of output pixels, made dark or light as result of screening, directly corresponds to visually non-uniform reflectances or intensities. This amount defines the dimension of the other quantization scale involved in the process of digital reproduction. So far, the spatial dispersion of an input tone quantization scale is accompanied by rather strong non-linear transformation of tone measure because of the principal difference of its output metric. In this light the wide spread recommendation (Kipphan 2001, Field 2004) to calculate halftone gray levels by the amount of such pixels as

$$(\frac{output\ resolution, dpi}{screen\ ruling, Lpi})^2 + 1$$

looks non-practical and confusing because it formally lacks anti-logarithmation or cubic root extraction.

So, to ensure uniform response of a screening system to variation of a visually uniform input data the amount of output pixels used for dispersion, i.e. degree of dispersion or dimension of a second quantization scale should be in a certain excess to dimension of an initial scale. As far as at given output resolution the screen ruling decreases with a greater degree of dispersion that implies the conflict

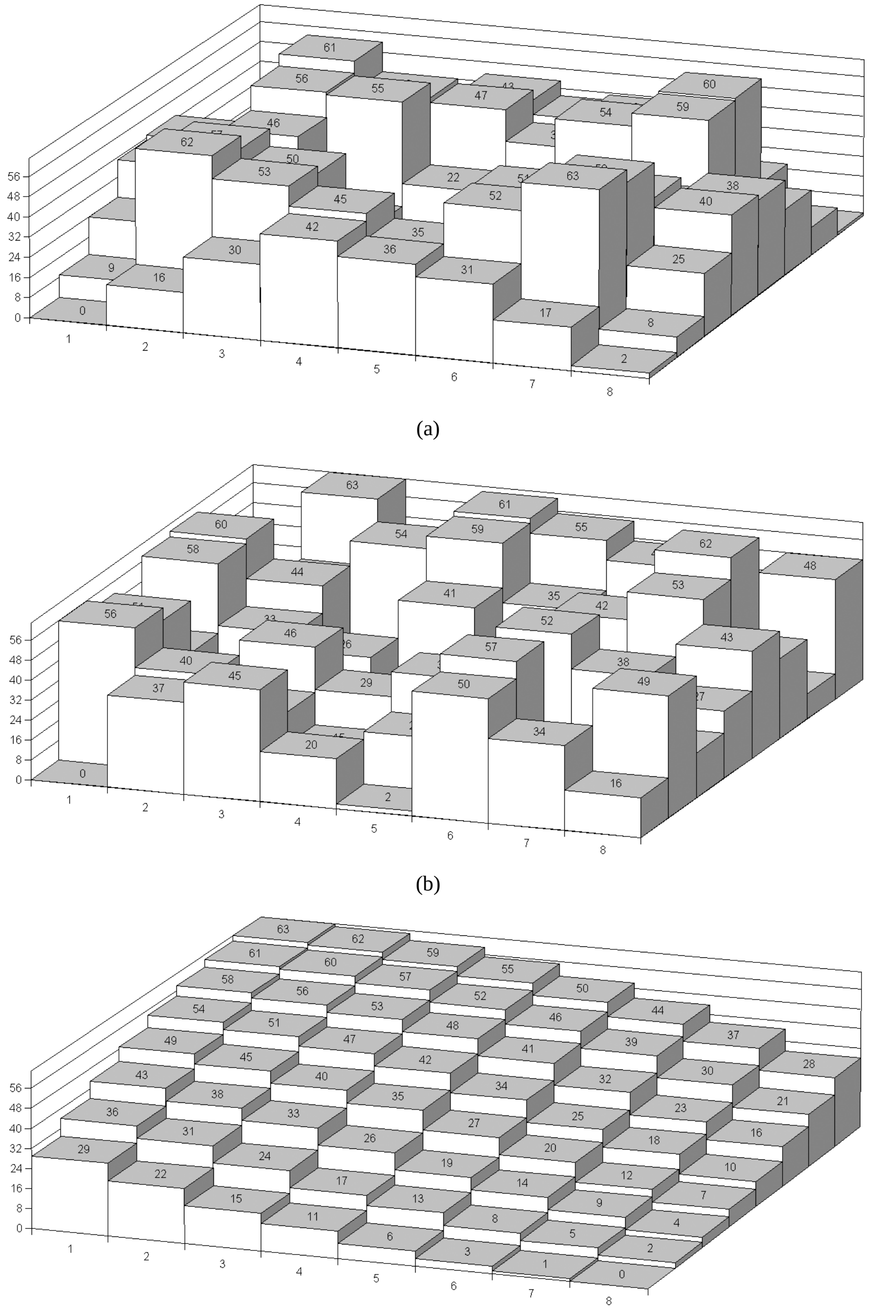


(a)

(b)

(c)

Figure 1: Quantization scale prescribed to an each pixel of a CT image (a); as compared to the scale spatial dispersion of a smaller degree (b) the greater degree of dispersion (c) allows for some non-linear transformation of a scale.



(a)

(b)

(c)

Figure 2: Periodic (a), random (b) and one-direction (c) dispersion.

in providing both spatial and tonal response of the process. With minimal degree of dispersion within 8x8 matrix of output elements equal, for the simplicity, to a number of 64 possible input gray levels figure 1b, there is no room for any further non-linear transformation. Moreover, the input tone data is here liable to losses because of mentioned change in metric. Lossless transformation is possible just with a greater matrix, as shown on figure 1c. This kind of dispersion, being monotonous within its area, provides the periodic (AM) screen pattern. The same kind of a pattern with greater screen ruling or/and with its different orientation can be provided by the periodic (ordered) dispersion illustrated by figure 2a. Each of four screen hills are here responsible just to a certain part of an input tone scale, i.e. to each its 1st, 2nd, 3rd or 4th level. Figure 2 (b) illustrates the random dispersion which results in non-periodic (stochastic, FM) pattern.

The direction of dispersion can be of central symmetry in a matrix (Figure 1b, 1c, 1a) to create the round, elliptical, diamond, etc. shape of a halftone dot. Dispersion in just one direction providing the black to white transition within a matrix area across the straight line inclined at 45 degrees is illustrated on Figure 2c.

Adaptive dispersion

Irrespective of form of its presentation the particular screen function or algorithm is usually applied to the whole CT image. It's performed without taking into account the local image area content and with just beforehand defining the overall screen pattern properties such as:

- visibility of this pattern at finite resolution of an output;
- frequency and contrast of the various possible kinds of moire;
- stability and continuity of tone/color rendition;
- degree of color shift due to separations misregistering;
- effective range of tone gradation, etc.

However, these quality issues of a screen pattern and an output halftone have no effect on the reproduction accuracy of an image high frequency content, i.e. its contours, textures and fine detail.

That's why, in electronic retouching the part of this content, related to detail of the highest contrast, is sometimes extracted from the input data, then enhanced in bi-level (line work) mode on the level of output resolution and applied back to the input file. To the pity, that doesn't effect the most of the high frequency data as far as it comprise the constituent part of a CT image and, as well, needs to reproduce its gray value. This need is, meanwhile, not so critical, as compared with tone rendition requirement for the stationary image area, because the color visual threshold for this kind of a data is rather coarse. To the contrary, the demands of greater definition and sharpness are predominant here to preserve as high as possible geometric accuracy of detail.

With taking into account these circumstances there is purposeful to vary the dispersion parameters and, in particular, its direction selectively, in accordance with the contour and fine detail geometry of an input image.

In our adaptive screening technology – High Definition Halftone Printing HDHP – in addition to any kind of a basic screen function, which matches the above listed requirements, the set of complimentary functions is used (Kuznetsov et. al. 1998, 2002, 2003, 2004). Being presented, for example, by matrices with dimension of just 6x6 output pixels these functions are characterized by the limited degree of spatial dispersion as compared to at least four times greater (12x12) dispersion space of basic function. The latter is applied to a stationary image area by the same way as in traditional screening. So, for this example, the output quantization scale of 144 levels is dynamically (over an image area) replaced by the scale of 36 levels on behalf of a twice higher system frequency response to tone jumps. Moreover, each of these complimentary functions allows for anisotropic dispersion providing the specific geometry of output tiles (quasi-halftone dots). This geometry may correspond to straight light/dark transitions, thin lines, angles, etc., of the different orientation, contrast and polarity. Such tiles more precisely match the fine detail geometry of an original image than conventional halftone dots resulted from the symmetric dispersion. They can also create on a print the thin line with width of just one output pixel. In traditional halftoning this is available only for the lines of full contrast with resolution of an input data file many times greater of the commonly used one, i.e. provided at sampling factor of 2.0.

Further strategy

In spite of the vivid improvement of halftones produced by the current version of the HDHP, the latter doesn't explore the whole advantage of our adaptive screening approach. As far as the adaptive dispersion is provided here in a limited, for example, 6x6 matrix, the variation margins of above described dispersion parameters are, in their turn, somehow a priori fixed. For example, the degree of dispersion is just twice reduced with this size of a matrix thus allowing only to double the definition, sharpness and graphic accuracy of a halftone as compared with conventional techniques. From the other hand, the smaller matrices would limit such important parameter of dispersion as its geometry variation.

However, since the halftone principle invention there already over a hundred years exists the order of magnitude gap between resolutions of a printer and screen. To completely close this gap its purposeful to provide the dispersion which could be arbitrary in coordinates of an input and output sampling grids as schematically shown on figure 3 for some arbitrary contour. With such kind of dispersion, to the contrary to existing techniques, the any excess in input data resolution (sampling factor greater than 2.0) becomes useful because it will provide the adequate increase of a halftone definition up to the level which is restricted just by the output resolution of a printer. Halftones produced by the conventional and HDHP technologies at sampling factor of 2.0, as well as with the use of an arbitrary dispersion are given at figure 4.

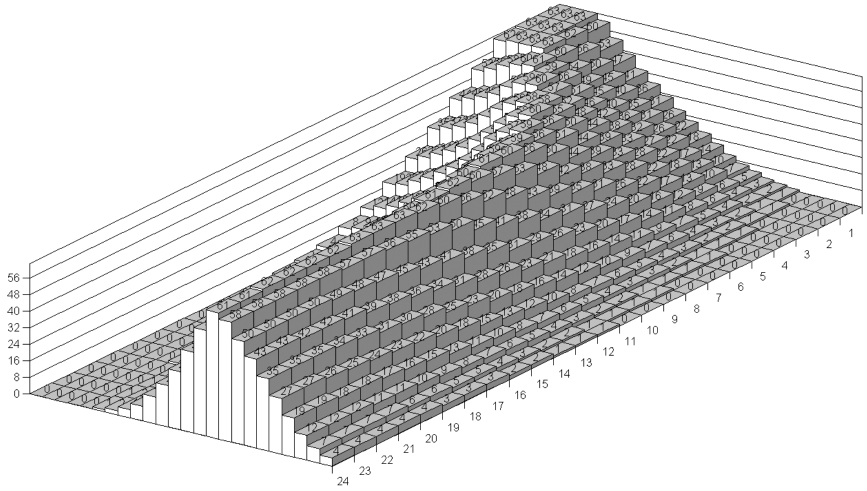
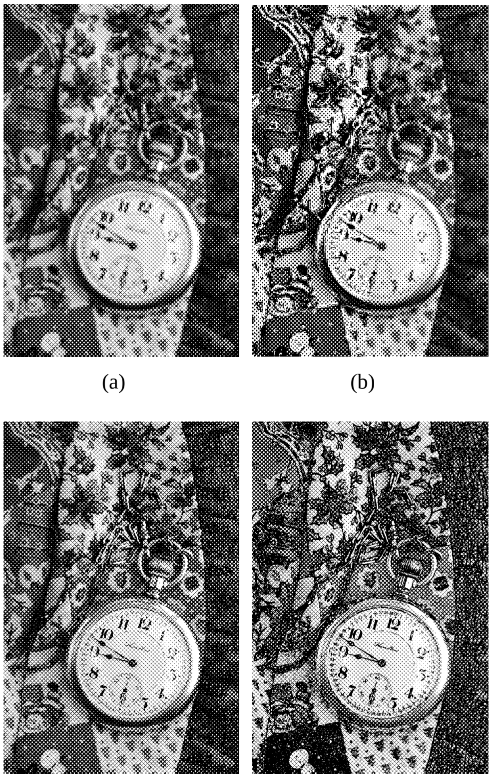


Figure 3: Adaptive dispersion for the contour of arbitrary geometry.

Generating the instruction for such adaptive dispersion or even creating some complimentary bi-level output data in accordance with the local and, may be, initially excessive image area content bents for another image enhancement techniques. They are usually provided in the various imaging applications before sending file to a RIP. So, with creating instruction for dispersion in such application the input image file becomes substantially free of its initial high frequency content. That opens the great facility of its compression and creating the effective image data file format for the prepress workflow with the rest of the screening (for the stationary image area) to be performed in usual way within a RIP.

- its useful to discern the screening procedures in the light of the spatial dispersion of tone measure quantization scale;
- parameters of such dispersion are directly correlated to that of a produced screen pattern;
- non-linearity of dispersion is compulsory because of the changes in tone data metric inherent to the digital screening process;
- as concerned of its degree and geometry the arbitrary dispersion allowing for free adaptation to the local image area content looks the most effective.



(a) (b)

(c) (d)

Figure 4: Halftones produced by the conventional (a) and HDHP (b) screening technologies at sampling factors of 2.0; the same image produced from an input file of 6 times greater resolution by the traditional screening (c) and with the arbitrary dispersion (d).

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