CLASSIFICATIONS OF SCREENING METHODS

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Abstract: In image processing, graphic arts, computer science and computer engineering there is a lack of a common basis for understanding and comparing screening methods. There is need for a common frame of reference and point of departure. This paper suggests a new structured way of classifying screening methods that can serve as a basis for relating different methods to each other. The taxonomy has been put to test by the classification of a set of well-known methods. The classification also points out new areas for research by describing screening categories that are yet unused of.

Keywords: Screening, Halftone, Imagesetting, Analysis, Geometry

Objective and Background

From the beginning screening was a craft that only few mastered. The impact on graphic arts was great. For the first time pictures were possible to print despite all the limitations of the printing process. At this point in time quality was not very high but it was constantly improved upon as time went by. In the early twentieth century the techniques were discussed in a more scientific way that resulted in the Neugebaur equations for colour printing. Despite its limited prediction power for the outcome of the print, it became quite well-known as it was one of the first serious models for multicolour printing. Much work has been put into the derivation of similar formulas for improved rendition of colour.

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When the teletype was changed for black and white CRT screens as input to computers, available equipment did not yet permit analogue modulation by the electron gun (limitations of economy, not technology). So, the problem was again how to display pictures on bi-level devices. Limb, Knowlton and Bayer introduced the split dot (Limb, 1969), (Knowlton, 1972), (Bayer, 1973), (Jarvis, 1976). Its theoretical motivation was treated scientifically by several people (Bayer, 1973), Floyd, 1975), (Jarvis, 1976), (Allebach, 1977), (Allebach, 1979), (Saarelma, 1989). The periodic nature of screens made Fourier expansion a natural choice for the analysis. It was shown that certain requirements on the spectral distribution lead to screen cell templates like the ones Bayer introduced.

The advances in digital typesetting equipment soon made it feasible to expose small enough dots to make printable screens possible and digital screening took off as a discipline of its own. New printing presses that allow direct to plate technology will soon allow for an unprecedented precision that will make new screening processes possible. The only limiting factor today besides the paper is the required computer power. This obstacle will disappear within short however. Much progress have been seen in the equipment but also in the scientific foundations. Ulichney, for example, gives a thorough treatment of error diffusion methods in (Ulichney,1988). New areas include global and local optimisation procedures and new computation structures such as neural networks (Bernard,1990).

Screening technology has a long history in comparison with the computer (if we exclude Babbage). The area of digital screening has not yet seen its real limitations. Utilising the properties of human perception it will be possible to close in on the physical limits of paper and other media. A suitable scheme for classification will improve the communication and dissemination of the fundamentals of new screening research among scientists and practitioners.

The basic problem

In a bi-level reproduction process the inherent problem is the modulation of the output for the rendition of continuous tone images. For comparatively fine screens, the acceptance of its appearance depends on the poor spatial resolution of the human eye while coarse screens rely on the more inexplicable way the human visual system treat regularly textured structures as homogeneous. Different strategies are required in each case depending on the press, paper and ink characteristics. For example, the ad hoc belief that the more the higher frequency components of a screen dominate, the better it is, is only valid provided that the micro dots are small enough not to be discerned by the naked eye (Saarelma,1989).

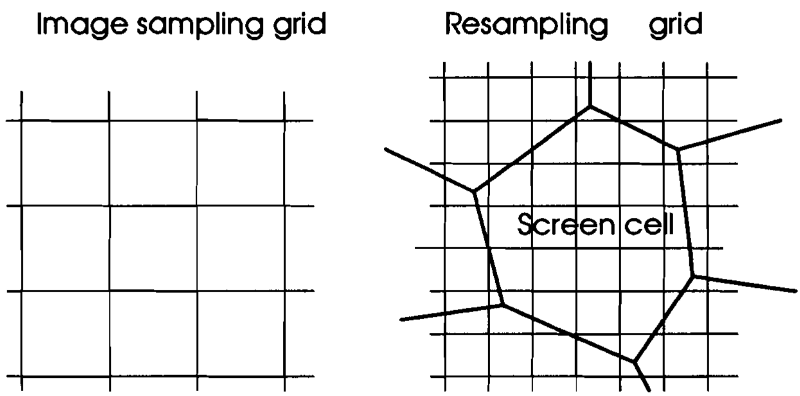

Figure 1. The sampling grids and general screen cell

Figure 1 displays the principles of the screening process. The original data is scanned and stored as a digital array of pixels. The higher the sampling frequency is the more details of the image are captured. Depending on the desired size of the output and the actual screening method used, the originally captured data is resampled to suitable scale. The screen cells are then formed and the bi-level image is generated.

Standard screens are almost always formed by a regular structure, a regular tessellation of the plane. The size of the screen cell varies from a single pixel to several hundred pixels.

However, it is not at all self-evident that the screen cell should be a simple and regular polygon arranged in a regular array. The general case is shown in figure no 1. Neither is it self-evident how to use the image data in the screen cell. For example, the simple solution to use the integrated density as the only parameter to control the cell content will not allow for sub cell structure to be used (even if the basic sampling structure would). The integrated density over the screen cell is what the observer can see, provided that the screen rule is sufficiently high. It can be obtained by the following formula.

$$D_{\text{int}} = -{}^{10}\log\left(\iint_{\text{screen cell}} 10^{-d(x,y)}\, dxdy \right)$$

Where D_{int} is the integrated density over the screen cell and $d(x,y)$ is the density in each sample point. Admittedly the integrated density is the most important image measurement that is used. It does not, however, give any indication as to the local texture of the image. Structures like lines and edges can be enhanced by pre-processing the image with any of the available edge enhancement methods. Alternatively measurements of texture properties can be introduced and used in the formation of the dot itself. This could result in super resolution with respect to the screen cell which is not possible with conventional methods.

Resolution and scale

The first characteristics of a screen procedure are the different resolutions that are involved. We have to distinguish between several different scales and resolutions. The fundamental resolution is that of the sampling density of the digital image. The information of the image is sampled with a certain period in two dimensions. This resolution sets the upper limit on the quality of the reproduction. It is obvious that one cannot reproduce more information than was acquired during the digitisation process. The scale of the image depends on the sampling but also on the screening method.

The resolution of the output is another of the basic resolutions that are important. The digital screen is built from micro dots, the pixels of a digital bitmap if you will. For obvious reasons there is no sense in using a bitmap with higher resolution than can be output. This is called the micro dot resolution. Ordinary laser printers have a typical resolution of 300 micro dots per inch but professional equipment may have resolutions exceeding one or two thousand dots per inch.

Regularity

Regularity is a very important issue in the making of the screen. The complexity of screening algorithms is usually less for regular screens than for irregular ones although this is not always the case. Another aspect of regularity is the appearance of the screen. The human visual system may disregard the actual dots even if they are clearly above the visibility threshold. A tint, for example, is treated as a homogeneous area by the visual system provided we are not focusing our interest on scrutinising the dots of the screen themselves.

The human visual system also discriminates very well between areas on opposite sides of a texture edge. It is still an open question to what extent this fact is relevant for the appearance of a screen. Very different types of regularity are probably more conspicuous than more similar ones.

Taking a look at very common screens they are regular on at least two levels. First they are composed of screen cells that are positioned in a regular grid with a certain spacing and at a certain angle. We will call this the macro level of regularity. Second the screen cells themselves are composed of regularly arranged micro dots in the form of a screen dot. A tint will obviously appear very regular with this kind of screening procedure. We will call the latter the micro level regularity.

Dot aggregates

The human visual system sets limitations on the screening process and so does the output process, be it output on a CRT screen or an offset printing press for example. The differences are large when it comes to different media. The output from a CRT screen depends on the gamma factor and in case of a colour screen the shadow mask and the spectral emission properties of the tube as well. Printing on paper requires knowledge of the mechanical and optical dot gain with respect to ink and press. In this context we will refrain from the discussion and simply state that some reproduction procedures cannot print scattered micro dots and therefore only closed formed aggregates of micro dots are applicable.

The form of the dot aggregates is important especially with respect to its implications for the dot gain. HQwever, the discussion of this is also beyond the scope of this paper.

Classification

There are two levels of scale that characterise a screening method. Clearly bi-level reproduction requires a global distribution of the two available densities in order to reproduce the actual tones of the image. This can be arranged in a regular or irregular structure. "Ordinary" screening with a repetitive array of screen cells is of course regular in this respect whereas methods based on error diffusion are irregular. In the latter case the position of every dot in the reproduction is data dependent and no other structure is present. On the micro level the distribution within the screen cell can also be either regular or irregular. Screening methods that in some way utilise all the data corresponding to the screen cell are irregular in the sense that the reproduction of the cell is highly data dependent whereas other methods use predetermined screen patterns that are selected according to the actual integrated density. Irregularity does not imply closed form dots. For example the Bayer type of screening is regular on the microscale although the micro dots are wide apart. The following simple classification is relevant for all screening methods

Type I screens are dominant in printing with ink on paper while type III have been popular for output on computer displays and to some extent on xerographic printers. Type II screens use a regular array of cells but adjust the form of the screen cell dot pattern according to the inherent data patterns.

Regularity		microscale	
		regular	irregular
macro-scale	regular	I	II
	irregular	III	IV

Fig. 2. Micro- and macro scale regularity

The classification reveals that some forms of screening have not been used before. Type IV screening which is irregular both on macro and micro scale is lacking despite the fact that this is perhaps the most natural one according to the properties of the eye. Since the eye is much less sensitive to the absolute level of grey in regions of texture than in large fairly homogeneous regions it seems plausible that an increase in detail could be obtained if small dots were used in those areas. In areas of higher homogeneity larger dots could be used to produce an increased number of distinct grey tones. This points to the problem of screen cell tiling. Obviously there has to be a trade off between optimal screen cell size and the possibility to tile them on the plane.

Conclusion

A simple classification procedure has been proposed. Typical popular screening methods has been tested as to their classification within the proposed method.

A new type of screening procedure that has been use in handmade screens, figure 3, has proved to be missing a digital counterpart as yet. The new type of screen that takes additional properties of the human vision into account should prove to be useful when near optimal screen have to be used due to low paper quality.

Fig 3. Handmade screen

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