Reducing Patterns in the FM Part of Tile-Based Hybrid Screens

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Abstract

Hybrid screening is very popular in modern printing systems. It allows the rendering of halftone images with higher line rulings than traditional AM, because FM-based screening is introduced for the highlights and shadows. AM- based screening is employed until the dots become too small to be reproduced. At this point, instead of further reducing their size, dots are gradually removed from the regular lattice, hereby avoiding the problem of normal AM-based screening. Still, another problem arises when an image with a constant tone is reproduced with a tile-based hybrid screen. The tiles have some dots removed, so when identical tiles are repeated strong patterns become visible. In this paper several techniques are proposed that will reduce the visibility of those patterns.

Introduction

Most reproduction devices are not capable of reproducing a continuous range of tones. They can either print ink or not. Several techniques are developed to simulate continuous tones on this type of devices. Those simulated continuous tones are called halftones. Halftones are obtained by printing more or less black points in the same area on paper. A distinction can be made between two major classes of methods for distributing a given number of dots over the area. FM screening, stochastic screening or dot-dispersed screening tries to spread the printed dots as homogeneously as possible over the surface. AM screening or dot-clustered screening will group single printed dots together in larger dots. The darker the image is, the bigger those dots will be. FM screening has the advantage over AM screening that it better can render the high frequencies in the image. The lower frequencies on the other hand will be rendered more noisy by FM screening. To ensure that AM screens render higher frequencies better, higher line rulings can be used. A problem here however arises at the highlights and shadows. A tone is rendered by putting a fixed number of dots, all of the same size, in a given area of paper. The bigger this fixed number is, the smaller those dots will be. For very high line rulings those dots will be that small in the highlights that they will not print.

Recently hybrid screening became popular. This type of screening combines the advantages of both types of screening. In the mid-tones a high line ruling AM screen is used. When dots (or holes) reach the limit of being printable, the size is no longer reduced but the number of AM dots will be decreased. So we have no longer an AM screen but an FM screen.

Many devices interact with the computer via a Postscript™ interface. In order to handle high resolutions Postscript™ is equipped with a tile-based mechanism that can render a continuous tone image into a halftone matrix in a very effective way. A tile is a set of thresholds to which the continuous tone values of the image are compared [1]. If the continuous tone value is smaller than the threshold, the pixel is made black. In the other case the pixel remains white. This tile is repeated in the horizontal and the vertical direction so that the whole image is covered.

When designing a tile one should make sure that the next expected row for the bottom row is the top row and the next expected column for the right column is the left column. When repeating the tile over the image the seam should not be visible. For FM tiles (or masks) an extra difficulty arises because dots are placed in a random order creating always some unbalance that will cause a pattern becoming visible when the tile is repeated in horizontal and vertical direction.

In this paper a number of techniques will be proposed to minimize the visibility of the tile replication in the FM part.

Order of Dot Withdrawal

In the FM part of the screen fixed AM dots are taken away in order to get less reproducible dots on the same area of paper (frequency modulated). A first method of determining a adequate dot order withdrawal is based on Ulichney’s void and cluster method. When the first dot is taken away an unbalance is created in the dispersion of the dots. A circular gauss convolution mask can be used to assess the unbalance in every pixel of the tile. The pixel of the convoluted tile with the highest value is the most dense cluster, the pixel with the lowest value is the most empty void. The next AM dot to be taken away is the most dense cluster. Taking this AM dot away changes the density all over the tile causing a new most dense cluster to appear. This can go on till all AM dots are withdrawn.

A problem here is selecting the most suitable σ. Ullichney found a σ = 1.5 pixel generating the most pleasing halftones. Several researchers claimed that the ideal σ depends on the principal wavelength. Ulichney[5] invalidated this and proved that a σ of 1.5 was suitable for all tones as long as the accuracy of the numeric representation is high enough. Using larger screening tiles can be an advantage in reducing the visibility of patterns. Ullichney stated that the extent R of the gauss mask for double precision floating point can be approximated by:

$$R \approx 37.7\sigma$$

in case of a relatively large principal wavelength. For a small principal wavelength this formula is

$$R \approx \sqrt{104 \ln 2\sigma^2 + 1}$$

For very large tile sizes (> 128 x 128) a fixed σ for all tone levels will not be applicable anymore (as can be seen in figure 1). For the smaller tiles a fixed σ = 1.5 x period of the screen can be used.

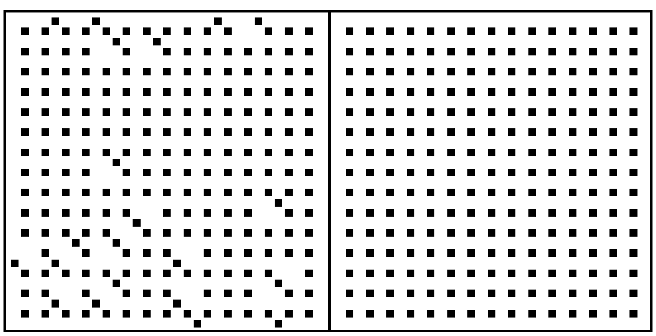

Figure 1: Classical void finding filter with fixed σ = 1.5 x period doesn't work for large tiles as can seen in the left image. A second algorithm to determine the dot order will give the correct recursive tessellation order (right tile).

A second algorithm was developed that works always, regardless of the tile size, line ruling or the principal wavelength. For every AM dot a set of distance bands is defined in which is stored how many AM dots are already withdrawn at a distance between the upper and lower limit of the band (let's call it the distance histogram). Every time a new pixel is withdrawn its distance to the not yet withdrawn AM dots is calculated and the distance histogram is updated. The number of bands depends on the tile size. Every integer combination of m periods horizontal and n periods vertical is kept as a center of a band. The upper and lower limits are taken in the middle between two neighboring band centers. The next AM dot to be withdrawn is the one with the lowest number of nearby withdrawn AM-dots. If all AM dots have the same number of the most nearby withdrawn AM dots the one but nearest bands will be compared and so on till a difference is found.

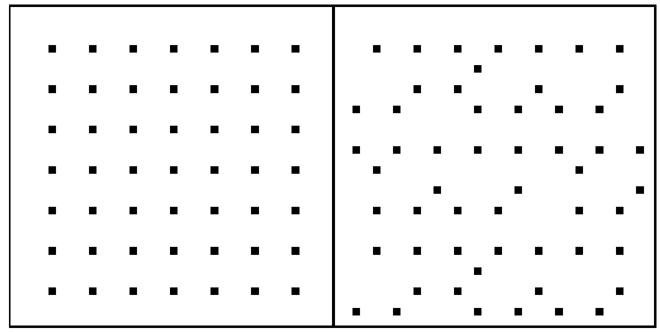

Figure 2. The pattern caused by AM-dot withdrawal also depends on the size of the tile. The left image is rendered with a tile that contains 4 by 4 AM-dots. The tile of the right image contains 5 by 5 periods. For the second tile recursive tessellation is not possible.

The resulting pattern is not only dependent on the line ruling, the resolution of the imager and the chosen algorithm but also on the tile size. Compare both images from figure 2. The right image is rendered by a tile with a size of 5 periods by 5 periods while the size of the tile of the left image is 4 periods by 4 periods. For the left tile both described algorithms will come to the same dot order, which is identical to the dot order obtained by recursive tessellation described by Bayer.[3] In the case of the right tile a nice homogeneous distribution is not possible for all tones. This can lead to unwanted patterns like the left image of figure 3. This tile was generated for the black channel of Agfa's 180 lpi Sublima Newspaper. For specific tones disturbing dot patterns became visible. By selecting the proper tile size recursive tessellation can become possible. As can seen in the right image of figure 3 this not necessarily leads to pleasing patterns. But the dot order is well known and will never lead to unexpected patterns.

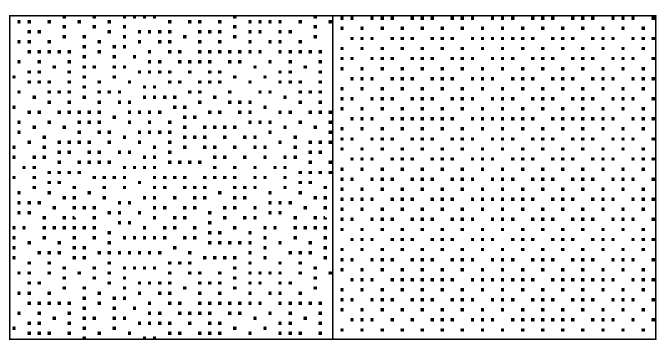

Figure 3. Unpredictable patterns will show up when the tile size doesn't allow recursive tessellation (left image).

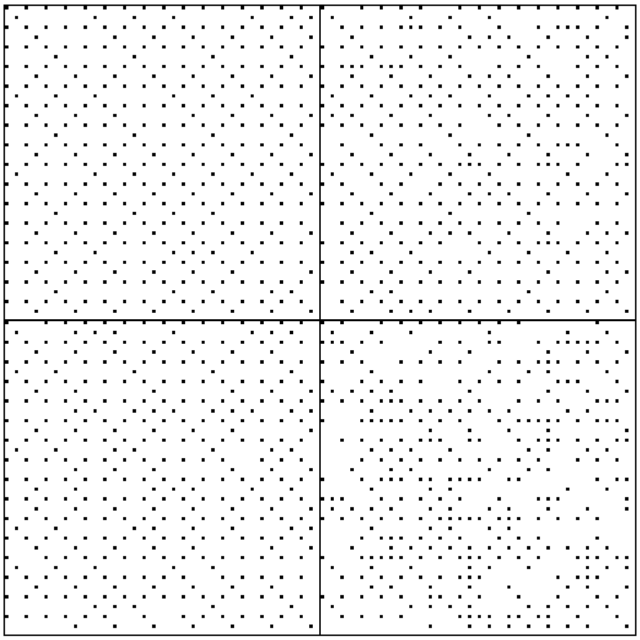

Figure 4. Adding noise to the dot order can break up the patterns caused by recursive tessellation. A first method of adding noise is here applied for different parameters. For the upper row p_{swap} = *0.1. For the bottom row* p_{swap} = *0.5. The maximum swap distance is 50 for the left column and 200 for the right column.*

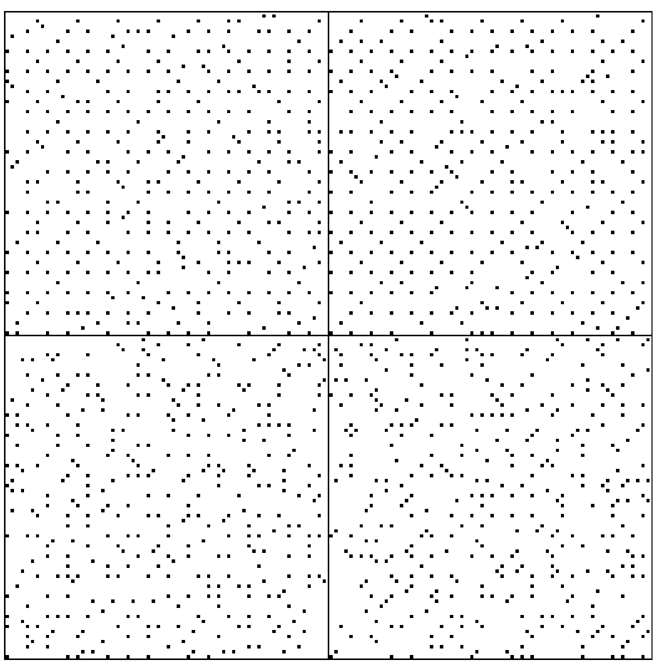

Figure 5. A second method for adding noise to the dot order. Maximum swap distance is 8 for the left column and 32 for the right. The swap probability is here also 0.1 for the upper row and 0.5 for the bottom row.

In order to get rid of the square or diamond shapes caused by recursive tesselation, a dot order noise component can be added. A first method is very easy. After the recursive tessellation order is obtained, every AM dot is swapped with a low probability p_{swap} by a AM dot lying at a randomly obtained distance limited to a certain maximum swap distance $d_{swap\ max}$ further in the series. The effect on the right tile of figure 3 can be seen in figure 4 for different values of p_{swap} and $d_{swap\ max}$.

A problem of the previous method is that two pixels that are swapped are not necessarily lying in each other's neighborhood. In order to be effective for all tone levels the maximum swap distance $d_{swap\ max}$ should be dependent on the principal wavelength of the actual tone.

This can be avoided by a second, more computational intensive method. Here an ordered list for every AM dot of the $d_{swap\ max}$ most close by AM dots is made. Again an AM dot will be swapped with probability p_{swap} with a randomly chosen AM dot out of the list obtained as such. The results are shown in figure 5.

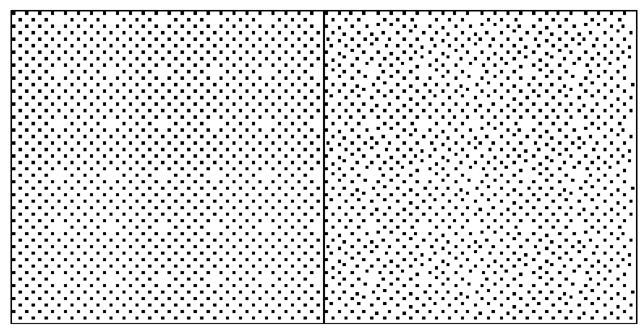

Figure 6. When only a few AM-dots are withdrawn the empty spaces become very visible when the tile is repeated. Adding positional noise can make the pattern more pleasing.

Positional Noise

Changing the dot order will not help to decrease the visibility of patterns caused by the withdrawal of AM dots in all cases. When from a completely filled AM lattice the first dot is withdrawn an empty space appears which becomes very visible when the tile is repeated (figure 6, right image). Agfa patented a method in which every AM dot is moved over a small randomly selected distance limited by a maximum move distance $d_{move\ max}$. Again this maximum move distance $d_{move\ max}$ should depend on the principal wavelength of the actual tone. It can never be larger however than a part of the period of the AM lattice to guarantee a normal AM part of the screen. Hence this method will only be effective for relatively small principal wavelengths. The effect of the positional noise added by this method can be seen in the right image of figure 6.

Conclusion

Several techniques have been proposed that can be used to decrease the visibility of patterns caused by tile repetition of tiles in which an unbalance is created by the withdrawal of AM dots out of the regular AM lattice. An improved method has been described, performing better for a relatively large tile than classical void and cluster methods. It is stated that by controlling the tile size one can generate more predictable patterns. Noise components are defined that can be used for decreasing the visibility of those predictable patterns. The described methods are used with success in Agfa's recently released Sublima screens. For 1270 dpi newspaper CTP imagers line rulings of up to 180 lpi are made possible by the use of hybrid screening.

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Biography

Rudi Bartels got his masters degree in electronic engineering at the Catholic University of Leuven in 1987. Till 1996 he did research in the image processing group ESAT-PSI at the same university where he designed a system for chromosome karyotyping with an artificial intelligent interface. He defended his Phd in September 1999. In 1996 he started working for Agfa- Gevaert where he first implemented the ColorTune color management application on Macintosh platform. Since October 1998 he is responsible for the halftone screening research in the graphical division (BGGS) at Agfa-Gevaert.