Quantization Frequencies in AM Screens

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Abstract

AM screening (halftoning) often suffers from periodic patterns in single separation. Since these disturbing patterns become stronger as the printer's resolution decreases, they pose a real challenge to laser printers & inkjets as they compete against offset presses.

We present a formula for predicting the frequencies and amplitudes of these disturbing patterns, based only on the geometric structure of the screen. An automatic filter, based on this formula, was constructed. This filter passes only 4% of the potential screens, without the need to construct the screen matrices, and without print, thus reduces testing time drastically. At the next stage, the method was generalized to handle interference between the screen and machine frequencies.

This filter became a vital tool in screening development for HP-Indigo machines. It served us well in the construction of all of our latest high ruling screens. Currently, this tool is also used to generate an AM screen for the commercial inkjet developed by HP-Vancouver, and the results are promising.

A patent application was submitted, concerning both the filter and the fine geometries which it passes (international application PCT/IL00/00079, publication number WO0158140, filed on 06/02/2000).

The Source of the Problem

The construction of AM screen consists of placing clusters of pixels, known as halftone dots, in the centers of cells (see fig. 1, at the end). In most cases, when color printing is requested, the cells are not aligned with the pixels grid. The result, as seen from fig. 1, is variation between halftone dots. Different halftone dots undergo different quantization, according to the different alignment between the cells and the pixels grid. There is variation in the shape of the halftone dots, and variation in the spacing between them. These variations are the source of the above mentioned patterns.

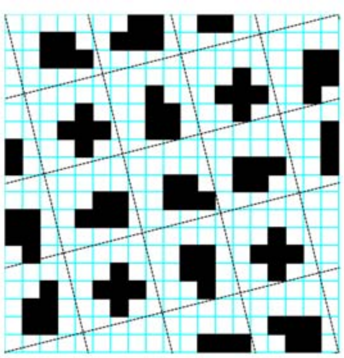

Figure 1: AM screen. The pixels grid is marked by cyan lines; the cells grid is marked by dashed lines. Note the cells are not aligned with the pixels grid.

Quantization Vectors

To analyze these patterns we define the quantization vector: it is a vector from the ideal center of the cell, to the nearest pixel junction (see fig. 2). The quantization vector determines the way the cell is aligned with respect to the pixels grid. In other words, the quantization vector determines the quantization of the halftone dot, in the given cell. Thus variations in quantization vectors produce variations in halftone dots. Note the quantization vectors are determined solely by the **geometry** of the screen, namely by the angle, line ruling (lpi), and the resolution (dpi) of the printer.

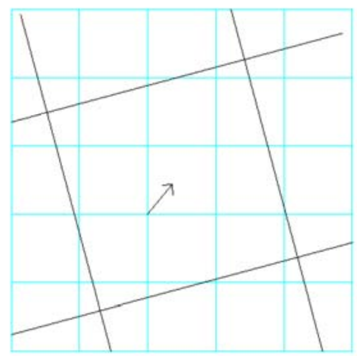

Figure 2: Quantization vector

The Main Idea

For each cell we have a different quantization vector, thus we get a 2D signal of vectors. Periodic variations in the quantization vectors are expected to generate periodic variations in the halftone dots. So it is appealing to search for frequencies in the quantization vectors signal. We call such frequencies **quantization frequencies**. Fig. 3 presents a graphic display of the norm of the quantization vectors, for a given screen geometry. A strong net pattern is seen. The same pattern was seen on print, which demonstrates the correlation between quantization frequencies and patterns on paper.

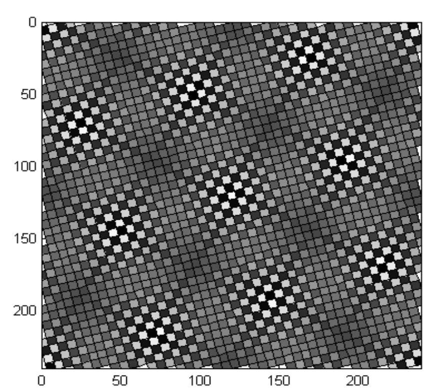

Figure 3: Graphic display of the norm of quantization vectors. The net pattern was seen on print.

The Fundamental Formula

We were happy to find a closed formula for the quantization frequencies and amplitudes (no need for FFT). The technique used was 2D aliasing of a sampled error signal. The formula, for the y component, is:

$$\vec{f}_n = (n \cdot \frac{\hat{Y}}{a}) \bmod (\vec{V}^1, \vec{V}^2) =$$

$$\{((n \cdot \frac{\hat{Y}}{a}) \cdot \vec{V}_1) \bmod 1\}\vec{V}^1 + \{((n \cdot \frac{\hat{Y}}{a}) \cdot \vec{V}_2) \bmod 1\}\vec{V}^2$$

$$A_n = \frac{1}{n} \cdot \frac{i \cdot a \cdot (-1)^n}{2\pi}$$

Where a is the pixel size, $\vec{V}^1, \vec{V}^2$ is the reciprocal basis to the cell basis

$n = \pm 1, \pm 2, \ldots$

As can be seen, the frequencies come in harmonics, while the amplitudes drop as 1/n. Due to the aliasing effect (the 'mod' operator), higher harmonics can produce lower (and more disturbing) frequencies.

Tests

This formula was put into intensive testing. The results are:

1. The formula is very successful in predicting patterns seen on print (both frequency and amplitude).
2. Different screening techniques, applied to the same geometry, produce the same pattern frequencies. Thus the geometry is indeed the cause of the patterns.
3. Geometries free from low quantization frequencies produce fine screens.

Applications

Once we identified the problem, the obvious solution was to construct a filter. The target of the filter is to find screen geometries free from low quantization frequencies. The input is the screen geometry, how many harmonics to check, and a bound on each harmonic (clearly, as the harmonics number increases, the bound is less restrictive). The output is whether the geometry has passed or failed. This filter became a vital tool in our screening work. We use it prior to constructing any screen. It filters out 96% of the potential candidates, without building the screen matrices, and without any print tests.

It is worth while to emphasize that this method is applicable to all AM screens. You don't need to know the specific halftoning technique used, the machine can be a laser printer, inkjet, etc. All you need to know is the screen angle, line ruling (lpi), and resolution (dpi) of the machine. The formula can also be generalized to include non-square grids.

This method can also be used during the design phase of a new machine – What should be the resolution which will enable fine AM screens? What machine frequencies might cause interference with the screen (see the next paragraph)?

Screen \ Machine Interference

The same mathematical technique can be used to study interference between AM screens and machine frequencies. Printers often have some inherent frequencies, which produce some periodic non-uniformity. A common example is the frequency of the laser array in laser printers, and the frequency of the nozzles array in inkjets. When this frequency is sufficiently high, it can interfere with the screen, generating disturbing low frequency patterns. It can be shown that the above formula for quantization frequencies is a special case of the screen \ machine interference, where the inherent frequency is the pixel's frequency.

HP-Indigo laser printers use laser arrays consisting of several beams, differing by power, spacing, etc. Again, the formula predicts the screen \ lasers interference patterns accurately. We now use a second filter, which filters out screens susceptible to this kind of interference.