PREDICTING HALF-TONE PRINT MOTTLE USING DIGITAL IMAGING & STOCHASTIC FREQUENCY DISTRIBUTION ANALYSIS

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ABSTRACT

A spatially sensitive stochastic frequency distribution analysis software algorithm, operating in a graphic arts quality scanner based image analysis system, has been applied to offset printed images. The algorithm reports and is sensitive to the spatial distribution and relative size of un-printed and lightly printed sub-visible areas inside a large solid print area. It has been discovered the algorithm predicts the spatial distribution of half-tone dot definition, size, circularity, and average luminance, and as a result, the uniformity of substrate surface ink receptivity. Several examples of this method in use are provided with illustrations and a suggested measurement scale.

INTRODUCTION

Mottle is the non-uniform reflection from a printed surface or transmission of light through a translucent specimen. When the human eye inspects a mottled surface it recognizes changes in the luminance from one area to another. These changes, or transitions, can vary across a wide range of spatial frequencies. Cognition occurs when the human intellect determines which mottle pattern forms specific images of interest. At any level of magnification, it is the spatial distribution of the transitions from one luminance level to another that determines the degree of mottle.

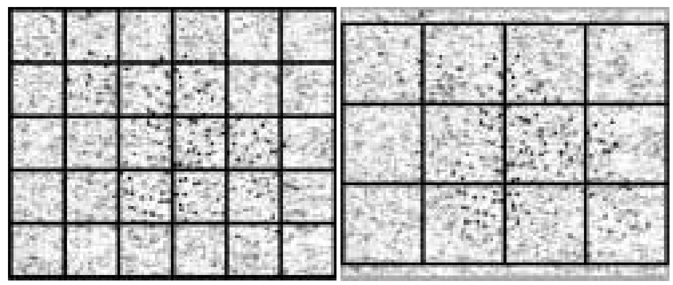
In the inspection of printed images containing half tones the current practice is to evaluate mottle by directly measuring the circularity, size, and luminance value of the discrete printed dots. An attempt is then made to relate these measurements to mottle. Because of the high resolution and magnification required, the apparatus currently employed in dot measurement examines only relatively small printed areas.

Printed areas occupy thousands of square meters and, among other criteria, paper and film print quality is based upon the uniformity of ink transfer across the entire printed surface. Mottle can occur in spatially diverse areas. As a result, It can be inferred that the evaluation of large images is better than small in detecting and measuring mottle. The automated image analysis method discussed in the following can measure mottle in large areas as well as small.

STOCHASTIC FREQUENCY DISTRIBUTION ANALYSIS

All digitized images are composed of picture points that accrue to themselves the characteristics of the pixel or picture element to be printed or displayed. This analysis method uses the picture point color luminance value (LV) and the x & y location in the image in a special statistical analysis.

Stochastic derives from the Greek word "stokhos" for the pillar or stake used in ancient times as a target for archers. Stochastic Frequency Distribution Analysis (SDFA) employs a contiguous virtual matrix of small square digital target areas within a the digital image. The matrix covers the entire area to be inspected and subdivides the inspected area into a uniform pattern of targets each containing exactly the same number of image picture points. The degree of variation among the picture point luminance values within each target and the variation among the targets themselves determines the degree of mottle. The goal of the mottle "archer" in this case is no variance in the luminance values for each target. The "score" or luminance value variance within each target is then used to determine the degree of variance among the targets.



A B

Figure 1. The same base image is shown in A and B but with a matrix of two different size targets overlaying each. The variance of the picture point luminance values within each target is calculated. The degree of variation among the target picture point variances is then calculated. Using different size targets provides a measure of mottle spatial distribution.

As shown in Fig.1, the size of the target used in the examination can be used to determine the spatial distribution of the mottle. Using a range of target sizes on the same image provides a measure of mottle spatial distribution.

For example, to measure sub-visible mottle such as the "graininess" of the ink deposition that may be caused by variations in the calendering operation, coating filler, or coating chemistry, an image may be acquired at 2000 ppi. This image would then be measured with a target matrix in which each target is 100 micrometers square and contains 49 picture points. Because the picture point inside the scanner camera is gathering light from an area approximately 12.5 micrometers in diameter, variations within that small area will cause a change in the luminance value reported. It is conceivable at an image resolution of 2000ppi a void or lightly printed area as small as 3 micrometers in diameter, inside what is to be a uniformly covered area, will change the reported luminance value at that point. Given sufficient luminance roughness or variation inside the target area, the reported variance would change for that target area.

Half-tone mottle is a visible phenomenon that does not require the high resolution necessary for sub-visible measurements of graininess. For instance, to predict half-tone mottle, an image can be acquired at 500 ppi and measured with a target that is 300 micrometers square containing 25 picture points. At 500 ppi the scanner camera picture point is gathering light from an area that is about 50 micrometers in diameter, slightly larger than the offset dot 30 micrometers diameter. The luminance values from a total of 25 picture points in the target area provide the database necessary to derive a frequency distribution or variance analysis. The variance among all the targets covering the image area then provides the mottle at a spatial distribution determined by the target size.

Target size for tests:
Unassisted, the human eye can detect variations in luminance values in areas as small as 1mm square. When inspecting for visible image variations such as half-tone mottle it is therefore advisable to relate the visible to the sub-visible by measuring at a variety of spatial distributions at least one of which is visible. For half-tone mottle it was determined experimentally target three target sizes with width and heights of 0.3mm (7pp), 1.0mm (19pp), and 2.5mm (49pp) worked very well at an image resolution of 500 ppi (197pp cm) and are reported in the following data.

APPARATUS & MATERIALS:

The Image Analysis System: All specimens were processed using Verity IA 2000 Mottle analysis software in a high speed personal computer. The computer was supplied with a large 256 MB memory that enhanced the processing of large images generated by an AGFA DuoScan graphic arts quality full color flat bed scanner. This particular scanner incorporates axially symmetric dual specimen illumination bulbs. The dual bulb construction eliminated image shadows caused by paper cockle, protruding fibers and heavy ink. Although an imaging resolution of 500 ppi was used on all these tests, the scanner camera was capable of optical resolutions up to 2000 ppi.

Printing presses and papers:
1 - A Heidelberg M-100B web offset printing press was used with a light weight coated stock # 5, Printed with Kodak plates and Flint ink with Day International 9500 printing blanket.

2 - This same press, plates, and ink was used to print a 50# uncoated offset stock.

3 - To generate the single color back-trap mottle example cited below heavy weight flat sheets, 18 point cover stock, were printed on a sheet fed press Heidelberg Speedmaster 74 with Sun Chemical Naturalith II inks. Kodak 830A printing plates were used with Day International Patriot 3000 4-ply compressible blankets.

Color Images, Color Bands, and Image Math:
Inside a color scanner the color image is acquired with a digital camera usually having three rows of sensors, red, green, and blue (RGB), arranged in ranks one above the other. The individual RGB sensors are compacted horizontally to a density defined as the resolution expressed in North America as points per inch (ppi). When an image acquisition session is complete, the scanner driver software realigns the RGB picture point sensor rows to superimpose one upon the other and compute the color vector for each sensor point before the image is filed away, displayed on screen, or transferred to the image analysis software.

In a sense, the color picture point sensors create three separate images, or color bands, that record, as a numeric value, the intensity of the light striking the sensor dedicated to that picture point location. In all image processing these three values are within the luminance vector so they can be reproduced and analyzed as a color image.

The mottle algorithm takes advantage of the color separation by analyzing each band selectively, depending upon the color being examined, or by combining the digital luminance values in each image mathematically to amplify the mottle pattern in situations where the pattern may be difficult to extract. The separate RGB color luminance values range from 0 to 255, from dark to light respectively. These numeric luminance intensity values can be divided and multiplied together to create new images and provide a potential tool for the analysis of multicolor back-trap .

TRIALS

To test the ability of the SFDA to measure mottle, several experiments were structured using printed areas of various sizes. It was determined that an area, approximately 25mm x 25mm, worked well and rapidly with the SFDA algorithm allowing many sheets to examined rapidly thus assuring a good statistical sample for a series of press trials. In all cases the areas evaluated were printed one side only. The solid print area from which the test area was extracted was separated from other color print areas and large enough to accommodate the 25mm by 25mm test section.

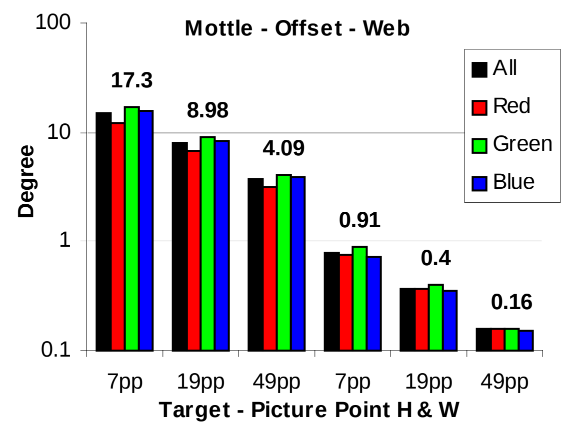
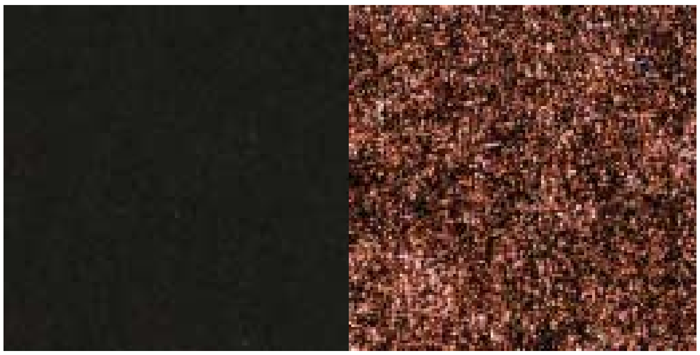


Figure 1. Logarithmic plot of offset web press SFDA mottle measurements on a 100% black area printed one side only. Three different size targets operated on the average of all color bands, then the red, green, and blue bands in order. On the left are the results from 5# LWC. On the right are results of the same test on a 50# uncoated web. (pp = picture point)

A B

Figure 2. A 25 mm x 25 mm area of a solid offset 100% black (one color) printed on a 5# LWC stock, slightly magnified. "A" is the original digital 500 ppi image. "B" is the original after a single pass by a hyperlog filter that exaggerates the pixel tone differences.



A B

Figure 3. A 25 mm x 25 mm area of a solid offset 100% black (one color) printed on a50# uncoated web offset, slightly magnified. "A" is the original digital 500 ppi image. "B" is the original after a single pass by a hyperlog filter that exaggerates the pixel tone differences.

On the offset web press:

A single color print of 100 % Black was printed on 5# LWC and a 50# uncoated offset paper. The results of this test are shown graphically in Figure 1. The target was applied in three different sizes to the average of all bands and then to each of the color bands separately.

Figures 2 & 3 illustrate the subtle mottle within the black area that is not apparent until the image is enhanced. The SFDA measurements reported in Figure 1 were from the original un-enhanced image.

Observations: Web press, 100% Black:
By visual inspection of the full print area surrounding the test area, it was determined there is a direct relationship between the mottle measurements reported in Fig. 1, and the degree of visual half tone mottle present. In this case there did not seem to be any particular advantage to using the SFDA mottle measurements from each color band as the results seemed to be proportionally equivalent to those in the average of all bands.

As shown in Fig. 4 & 5, microscopic examination of the 100% solid black areas evaluated supports the contention that the

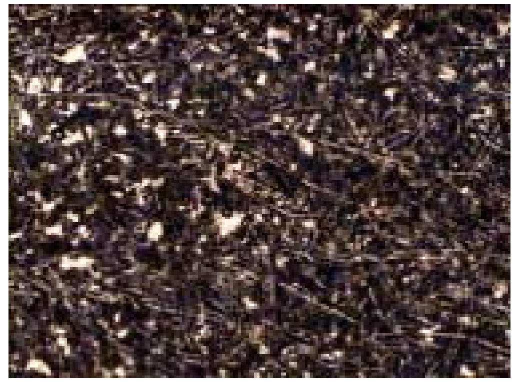


Figure 4. A 120 X microscopic view of the same 100% black on 5# LWC as in Fig. 2. Pits in the paper coating show up as white areas where the ink was not transferred.

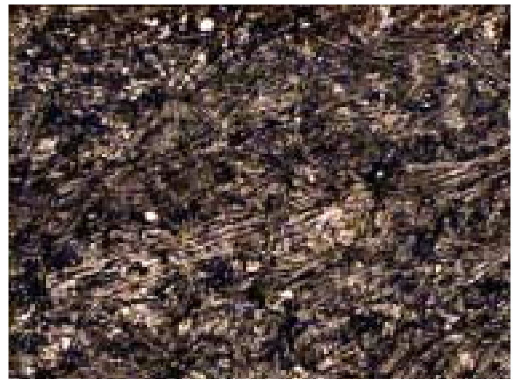


Figure 5. A 120 X microscopic view of the same solid offset 100% black printed on a 50# uncoated web offset shown in Fig. 3. A comparison to the 5# LWC in Figure 4 shows a marked decrease in the pits or voids.

small SFDA mottle target is responding to the voids in the ink coverage attributed to the pits or cavities present in the paper coating. It is these voids that will also show up in the half tone mottle as missing or poorly formed dots.

On the sheet fed press:

The sheet fed press was used to test the ability of the SFDA algorithm to measure the effects of multiple blanket exposures on ink laid down in an early unit of the press. Also, to test SFDA on multiple applications of the same ink to the same area in the last two units of the press. The dynamic interaction between wet ink applications is of interest to the ink chemist.

Sheet fed press - Multiple blanket contacts
In this experiment an area of the sheet was printed with a 100% cyan on the 2nd unit where it comes into contact with 4 more printing blanket surfaces before exiting the press. It is believed that some of the ink does pull back off on to the blanket due to the variable rate of ink penetration into the paper and this evaluation would serve both the ink chemist and the paper maker.

Sheet fed press - Multiple ink applications to same area
Another area of the same sheet was printed twice with a 100% cyan, first on unit 5 and again on unit 6. The intention is to

observe the effect of multiple applications of ink and the interfacial tack of the wet ink without multiple blanket exposures.

Observations: Sheet Fed press, 100% Cyan:
The SFDA algorithm was applied to the finished prints in three different sizes. The results are shown in Fig. 6. As shown in Fig. 7 & 8, each image was analyzed as the average of all bands, and then each of the color bands separately.

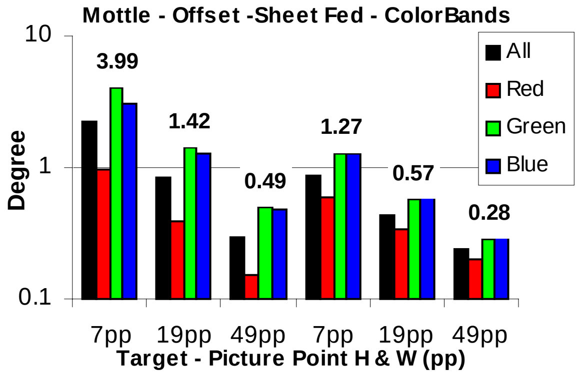
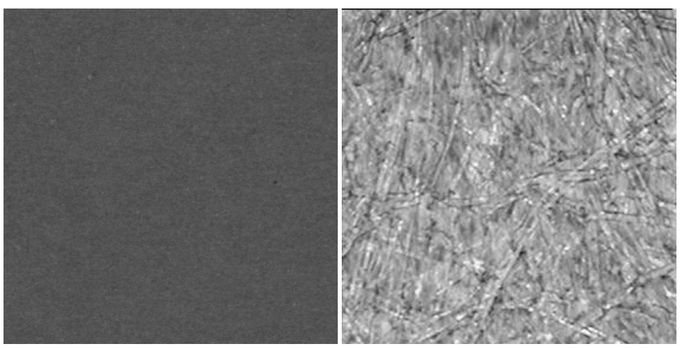
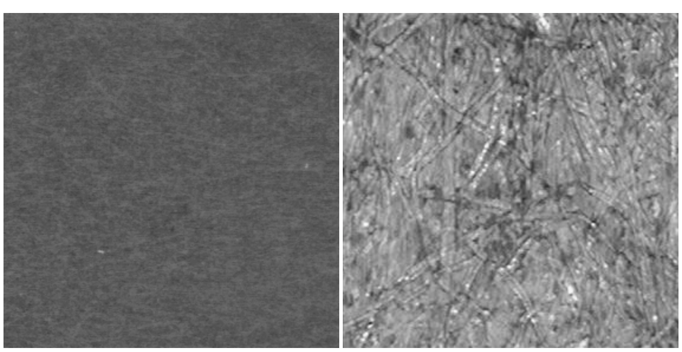


Figure 6. Logarithmic plot of offset sheet fed press SFDA mottle measurements on a 100% cyan area printed one side only an 18 pt cover stock. Left (3) are results from print on unit 5 and overprint at unit 6. Right (3) are from an area printed at unit 2. Three different size targets operated on the average of all color bands, then the red, green, and blue bands. Value is shown is the green band.



A – 100% Cyan Unit 2 **B- 120X of A**

7pp =0.86, 19pp =0.44, 49pp =0.24 (pp:Picture Points, W&H)



C – 100% Cyan, Units 5 & 6 **D- 120X of C**

7pp =2.27, 19pp =0.85, 49pp =0.29 (pp:Picture Points, W&H)

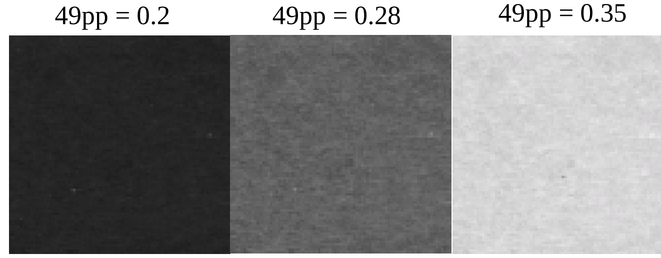
Figure 7. The digitized gray scale images with magnification. The SFDA mottle at three different target sizes is shown below each image set. The SFDA was run on an average of all color bands. The increased SFDA mottle can be observed by comparing "B" and "D".

There is a distinct difference in response from the two types of printed images. Fig 7 provides a microscopic view of each print. There is considerable visual mottle apparent in the magnified view of the image printed twice at units 5 & 6, over the single print at unit 2. The small target provides the highest sensitivity to the variation. There appears to be a linearity to the measurements but a careful evaluation shows that each color band responds differently. For example the single print at unit 2 shows the measurement of the green and blue bands is equivalent with the small target but as the size of the target increases the blue band measurement rises in comparison to the green band. Just the opposite is true of the double print. The cyan ink reflects both the green and the blue light and absorbs the red and the substrate show-through is a variable changed by the print conditions.

Conclusions
Stochastic frequency distribution analysis provides an objective means to evaluate the influence of press, ink, and paper upon half-tone mottle. It also provides a method to evaluate the effect of ink formulation and properties, blanket performance, effects of multiple applications of wet ink, and the response of the paper to press conditions.

SFDA has possible additional applications to multi-color back-trap measurement by using digital imaging and computation power to combine color bands through ratios.

Red Band	**Green Band**	**Blue Band**
7pp = 0.6 19pp = 0.34 49pp = 0.2	7pp = 1.27 19pp = 0.57 49pp = 0.28	7pp = 1.29 19pp = 0.67 49pp = 0.35



Red Band	**Green Band**	**Blue Band**
7pp = 0.96 19pp = 0.39 49pp = 0.15	7pp = 3.99 19pp = 1.42 49pp = 0.49	7pp = 3.03 19pp = 1.28 49pp = 0.48

Figure 8. At the top is the digitized image of the 100% cyan single ink print (unit 2). At the bottom is the digitized image of a 100% cyan double ink (units 5 & 6). Both images are separated into their component RGB color bands shown here in gray scale. Below each color band image are the results of three SFDA target sizes used to analyze each. The dimensions are in picture points (pp) target height and width).