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Evaluation of Print Mottle by Stochastic Frequency Distribution Analysis

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ABSTRACT

Print Mottle is perhaps one of the most disturbing factors influencing overall Print Quality. Mottle has traditionally been evaluated by estimating the reflectance variation in the print. Although the amplitude of the reflectance variation is probably the most important aspect of print mottle, other aspects may also influence the perceptibility of mottle. Since the human visual system is optimized to fit the conditions prevailing in its surroundings, it is also important to consider aspects such as mean reflectance factor level, spatial frequency content, structure of the mottle, and color variations. The Stochastic Frequency Distribution Analysis (SFDA) algorithm measures the two dimensional rate of change in luminance values, in print applications SFDA mathematically describes the uniformity of ink transfer to the substrate surface by producing a number proportional to the visible, it also provides horizontal and vertical mottle orientation measurements. SFDA is used to measure a wide variety of mottled images including, ink jet print, toner adhesion, toner quality, paper formation, ink penetration, offset and rotogravure. The algorithm is sensitive to the spatial distribution and relative size of skipped and lightly printed sub-visible areas that are correlated to mottle.

I. INTRODUCTION

Print mottle may simply be defined as the occurrence of non-uniformity in print density in a printed area that causes perceptually disturbing variations in reflectance from the print. When the human eye inspects a mottled surface it recognizes changes in the luminance from one area to another. Small repetitious areas that have a consistent variation within them are called "Texture". Texture is the primary and smallest visible component of mottle. Without texture a visible surface would be smooth and featureless. The uniformity of the texture distribution, or degree of mottle, can vary across a wide range of spatial frequencies[2].

The previous way to evaluate print mottle was done through visual assessment. But due to the difference of individual visual system and the recognition differential, personal visual perception was very subjective and the precision and efficiency of this way was very low. So aiming at personal visual evaluation problem developed the SFDA Algorithm for visual perception, which probably was completely feasible way to assess print mottle in the experiment. SFDA emulates the human intellect by analyzing the content of a digital image through spatial distribution of the image texture. The digital image resolution plays a vital role in mottle measurement, especially for halftone images. Therefore with very high resolution, SFDA can allow the mottle measurement even in the sub-visible range. Print mottle is basically a visual phenomenon and any means of instrumental evaluation is expected to simulate the visual perception effectively. SFDA measures print mottle in such a way that it corresponds well with the way in which it is perceived by human observers. Different instrumental techniques employed for the evaluation of mottle include, stochastic frequency distribution analysis (SFDA), STFI, and wavelet analysis.

SFDA first determines the properties of the image texture and then the spatial distribution of the texture. The digital image resolution, the number of pixels per unit measure, is an integral part of the SFDA measurement, and, at high resolutions, can allow the mottle measurement to operate in the sub-visible range. At any level of magnification, it is the spatial distribution of the transitions from one luminance level to another, or texture distribution variations that determine the degree of mottle. On 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.

II. STOCHASTIC FREQUENCY DISTRIBUTION 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 digital image. All digitized images are composed of picture points that accumulate to themselves the characteristics of the pixel or picture element to be printed or displayed and the dimensions of the square target are also expressed in picture points (pp) [1].

The matrix of targets covers the entire area to be inspected and subdivides it into a uniform pattern of targets each containing exactly the same number of image picture points. In the SFDA 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.

1.1 Working of SFDA Algorithm

Step-1:Formation of Square Contiguous Targets

[3]The SFDA initially will divide the image into square contiguous target areas having same pixel dimensions. The targets are all square and their physical dimensions follow a binary progression, i.e. 2, 4, 8.Pixel dimensions of the target areas are sensitive to the variations present in the image. A smaller target area will provide more accurate results as compared to larger target areas.

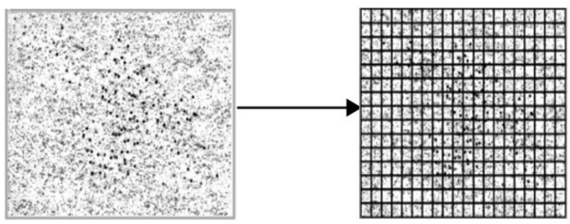

Figure-1: Mottled image (left) having square contiguous target areas (right)

Step-2:[2]Calculation of Standard Deviation (s) and Mean luminance (M_{TL}) values

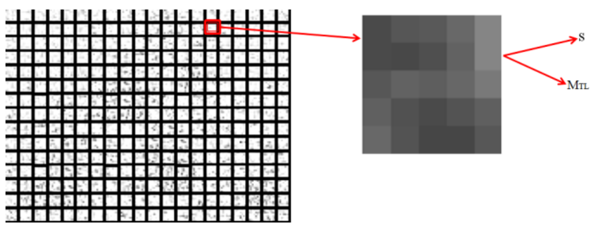

Figure-2: Mottled image with contiguous targets (left) an isolated target been magnified (right)

$$s = \sqrt{\frac{\sum (P_L - M_{TL})^2}{n}}$$

Where,

P_L= Pixel luminance value

M_{TL}= Mean Luminance for the pixels in the target

n= number of pixels

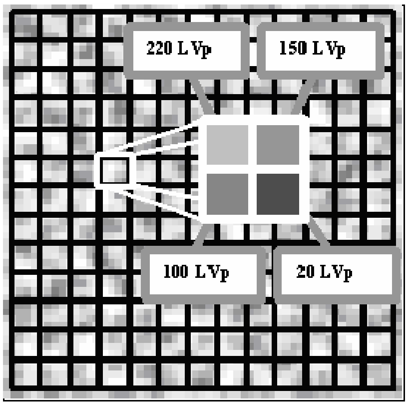

Figure-3: Extraction of pixel luminance values from the single target.

The two dimensional standard deviation, "s", is computed for the pixel luminance values in the square target and subsequently Mean luminance values are been calculated. Both together provide rate of change in luminance values of that particular target. Similarly, 's'values and 'M_{TL}' values are calculated for all the target areas and stored in the database separately.

Step-3: Creation of Databases

As the image has been scanned the luminance values of the pixels are been recorded and stored in different databases. Initially database is used to store pixel luminance values of (LV_P)of the target area and subsequently it stores standard deviation (s) and mean (M_{TL}) values of each target area as shown in figure 2 and 3. The Database further stores other intermediate data required for mottle calculation.

Step-4:Calculation of Mottle number for one larger target

Mottle = K x (σ_S x M_S x σ_m)

Where, σ_S = The standard deviation of the "s" values

M_S = The mean of the "s" values

σ_m = The standard deviation of "M_{TL}" values

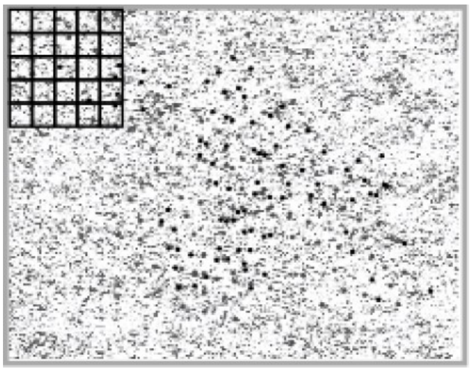

Figure- 3: A mottled image having one larger target consisting of 25 smaller targets.

The standard deviation (s) and mean luminance values (M_{TL}) are extracted from the database and this data is used to compute the standard deviation of the "s" values, the mean of the "s" values and standard deviation of "M_{TL}" values. These calculations are combined to calculate the mottle for that particular target area.

Step-5: Calculation of Final Mottle number-Spatial Distribution

Spatial Mottle = K x (σ_O x M_O)

Where,

σ_O= Standard Deviation of Large Target Mottle numbers

M_O= Mean of Large Target Mottle numbers

Where K is a scaling factor.

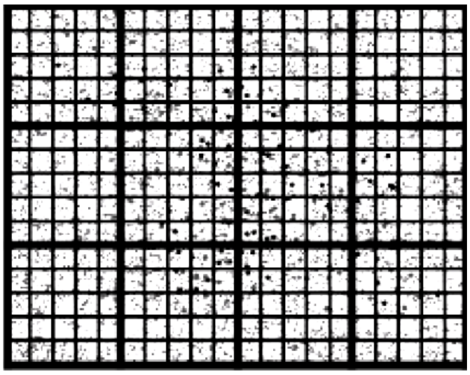

Figure-4: Mottled image divided into larger targets each having 25 smaller targets for spatial distribution.

The database provides the values of σ_S, M_S and σ_m. Finally, the spatial mottle has been calculated by using the above formula.

Spatial Distribution

The mottled image shown above has got texture distributed unevenly. So, in order to measure this uneven distribution of texture it is necessary to measure all the areas of the image. In spatial distribution analysis, the mottled image is divided into larger targets and each larger target is analyzed individually providing accurate mottle measurement.

APPLICATIONS

1. Verity IA-SFDA Algorithm is used to measure wide variety of mottled images for offset, rotogravure and inkjet applications.
2. SFDA is also used in the measurement of surface topography, Missing dots, Dot sharpness.
3. The algorithm satisfies the paper industry need to have a solid method of measuring optical formation and calendar blackening.

V. CONCLUSION

The SFDA mottle method has demonstrated its ability to objectively measure mottle in large and small printed areas.

The print mottle for both halftone and solid areas can be easily analyzed and improved through SFDA.

The SFDA has proved to be versatile as it is used in measurement of surface patterns such as, topography, visible solid tone print mottle, and half-tone print mottle. It is also used for measuring Missing dots and Dot sharpness etc.

SFDA algorithm works with wider range of image resolution.

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[2] Stochastic frequency distribution analysis as applied to mottle measurement, Roy R. Rosenberger, Varity IA LLC, Appleton,

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