

Application of Digital Imaging to Measure Print Quality

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Abstract

The printing industry has placed a major thrust to understand and manipulate print quality. One of the important aspects of poor print quality in high speed printing is color density variation in solid areas, known as mottle. We describe applications of digital imaging for reproducible, objective measurement of mottle. We quantify the variations in print density using a digital image analysis system, which includes a Flatbed scanner, a Macintosh Power PC, and the NIH image program. Print mottle was correlated to the local standard deviation of the lightness values divided by the local mean of the lightness values.

One of the major difficulties in communicating the results of mottle measurement is that different detectors interpret color differently and light sources on the scanners vary, thus affecting the color consistency between scanners. Employing a Color Management system to the measuring technique allows the measurements of the digitized images to have universal values. Calibration of scanners allows different locations using different scanners at different times to obtain and compare mottle values using the same relative scale.

A number of field examples will be presented to describe the evolution and application of the technique.

Introduction

An important aspect of poor print quality in high speed printing is color density variation in solid print areas, which is described as mottle. Traditionally, these variations were visually assessed. These assessments were influenced by subjective factors of human vision, such as fatigue and variations in color interpretation between different people. Therefore, an objective method of mottle measurement was needed to identify the sources of mottle and plan corrective action.

A method is proposed that scans the sample in a specified area, converts the image into digital lightness or grayscale values, and defines print mottle as the standard deviation in lightness values divided by the mean lightness values of the scanned image. This method has been confirmed using a set of standards developed by Heidelberg¹ that were visually assessed by a number of experts. Some of these efforts will be described.

Similar to the different color interpretation between human observers, different scanners have different light

sources and detectors, causing different color interpretation. However, these scanner differences can be overcome by the use of a Color Management System. A commercially available device calibration software package, ColorSynergy, was used in this study to make the images device independent. Employing the Color Management system reduces the mottle error to less than 4%. We will present results of calibration software providing improved scanner to scanner consistency in measurements of the lightness values, and consequently mottle values.

Materials

The items used for this study consist of the sample prints, image analysis software, a color management system, and flatbed scanners (connected to a computer).

Sample Selection

A set of twelve Gravure Acrylic prints was used to evaluate the effects of scanner calibration on mottle measurement. This set of prints included the four process colors (cyan, magenta, yellow, and black, CMYK) printed at three different densities (light = 1, medium = 2, and dark = 3). These prints covered a full range of color and densities, in addition to various levels of mottle.

Image Analysis Software

The software used for this study was NIH Image. Measurements of images can be done in batches, which can be saved to a data file for calculation and analysis. Adobe Photoshop was also used for image cropping and converting color space.

Calibration Software

The calibration software for the scanners used in this study is ColorSynergy. This compares a scan of a Kodak Color Target (IT8) against the reference levels for each color square in the target. A transformation profile is made, based on the difference in the scanned color and the reference values, that can be used for batch processing of images.

Scanners Evaluated

Five scanners were evaluated to simulate the variety of scanners that different locations might use for mottle evaluation. The details of the scanners are given in Table 1.

Table 1. Summary of Scanner Specifications.

Manufacturer	Optical Resolution	Color Bit Depth	Software
AGFA StudioScan II	400	30	FotoLook
Hewlett Packard ScanJet 3c	600	24	DeskScan
Microtek* ScanMaker III	600	30	Scan Wizard
Microtek* ScanMaker III	600	30	Scan Wizard
Epson Expression 636	600	36	Epson Scan!

*Two Microtek scanners were used at different locations, The University of Michigan and the Flint Ink Research Center.

Experimental Method

Scanning

A mask was placed over each print set with square openings slightly larger than ½ inch over each color and density (twelve openings on each mask). This ensures that the same area is scanned each time on all scanners, reducing any variability effects due to sampling.

Each scanning software was set to the default settings (full density range, no sharpening, etc.) In addition, a resolution of 500 ppi was used (The Epson Scan software did not have a 500 ppi setting. Therefore, the closest resolution, 480 ppi, was used.) This was chosen to capture the detail of the print mottle, yet keep the file sizes at a reasonable size, 228 KB per color square.

The calibration target and each set of prints were scanned, each in a single pass. This process was repeated five times for each scanner. Each scan was saved as a RGB image using the TIFF format. In Adobe Photoshop, 250 by 250 ppi squares were cut from each color square on the prints and stored them as individual images (using the same RGB-TIFF format). Data from the five scans was used to evaluate the consistency of a single scanner, in addition to providing data for average values used to compare the different scanners.

Calibration

The scan of the target was imported into ColorSynergy. The image was compared with the reference file, and a profile was created. This profile was used to make a transformation in the ColorCircuit application (packaged with ColorSynergy), for batch processing of images. The ColorCircuit application transformed the RGB images into device independent Lab images. These new Lab images were stored as separate TIFF files.

Mottle Measurement:

Mottle, using the scanner method, is defined as the lightness "variation" divided by the average lightness (see Equation 1). The average lightness is calculated from the lightness values of each individual pixel. The variation is taken as the standard deviation in lightness values for all the pixels in the image. The lightness scale, 0 = black, 255 = white, was chosen because the paper is generally white. For

this reason, lighter values of the same color will have less of a contrast between the ink and paper.

$$\text{Mottle} = \text{variation/average} \quad (1)$$

The images were imported into NIH Image. The average lightness values (the L component in Lab) and the standard deviations were measured. The mottle value, expressed as a percentage, was calculated from the variation and the average value.

To maintain the Lightness measurement for the images that were not transformed, the RGB images were first converted to Lab images in Adobe Photoshop. Note that these images are still device dependent because they have not been transformed with a calibration profile.

For purposes of this study, I did several transformation methods:

1. The first method transformed each scan using its corresponding transformation profile.
2. The second method transformed each scan using only the third transformation profile. This is to determine if a single calibration is necessary per scanning session.
3. The third method transformed the third scan using all five transformation profiles. This is to determine the consistency of the calibration profiles.

Table 2. Comparison of the Uncalibrated and Calibrated consistencies. Averaged data from the five scanners was used to calculate the standard deviation of the mottle parameters.

Acrylic Samples	Uncalibrated	Calibrated
Standard Deviation Range in Lightness	9.0 - 32.2	1.6 - 8.1
Standard Deviation Range in Variation	1.2 - 4.3	0.8 - 4.0
Standard Deviation Range in Mottle	0.5% - 9.7%	0.3% - 3.4%

Results

Scanner to Scanner Consistency

The calibration techniques improve the scanner to scanner consistency in mottle measurement by improving the consistency in lightness and variation measurements. The standard deviations in lightness measurements for the acrylic prints ranged from 9.0 to 32.2 levels of lightness (out of 256 levels) for the uncalibrated scans. Once the scans were transformed, the standard deviations ranged from 1.6 to 8.1 levels of lightness. The standard deviations in the variation measurements ranged from 1.2 to 4.3 for the untransformed, acrylic samples. Once transformed, the standard deviation in variation ranges from 0.8 to 4.0 levels. These calibration improvements change the standard deviation ranges in mottle from 0.5% - 9.7% mottle to 0.3% - 3.4% mottle. Table 2 summarizes these results. In addition, Figure 1 shows the changes in consistency (based on the standard deviation of the five scanner measurements) that the calibration transformation makes to the lightness measurements. Figures 2 and 3 show the improved consistency in mottle measurements between scanners before and after the calibration transformation.

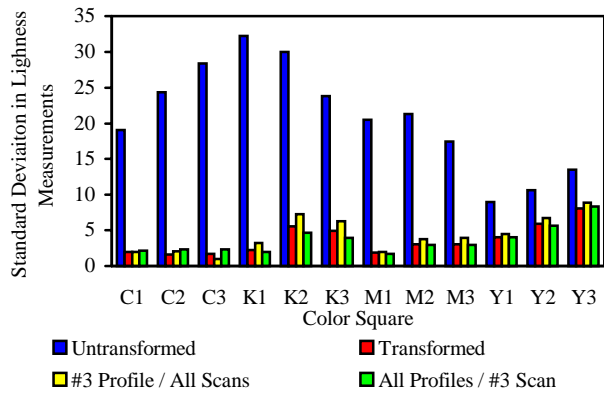


Figure 1. Standard Deviations in Lightness Measurements for the Acrylic Prints

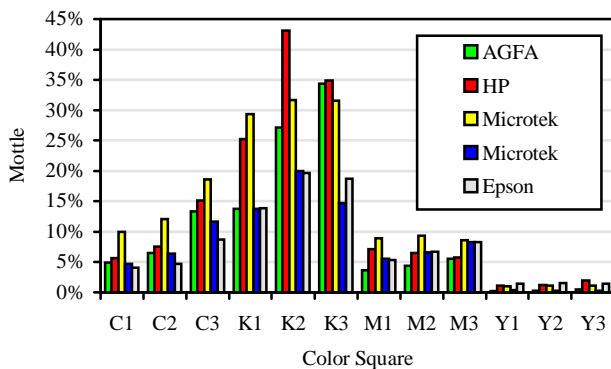


Figure 2. Comparison of Mottle values for the untransformed images from five different scanners.

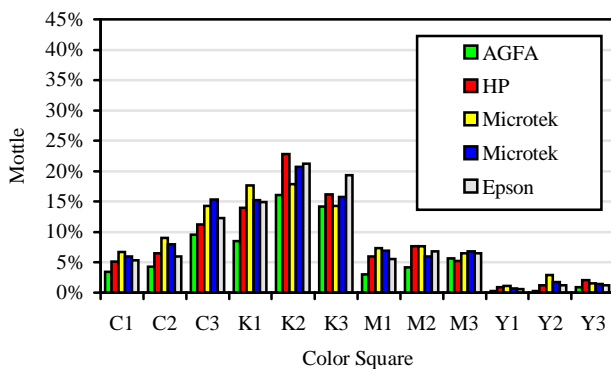


Figure 3. Comparison of Mottle values for the transformed images from five different scanners.

The effects of calibration were most dramatic in the black samples. The inconsistencies in mottle measurements for the black prints are reduced to about a quarter of the uncalibrated values. The inconsistencies in the cyan prints were reduced to about half the uncalibrated values. The

inconsistencies in mottle measured for the magenta and yellow prints were reduced to about three quarters of the uncalibrated values.

Although the consistency of mottle measurement for yellow is improved, one needs to be aware of the mottle values, to determining whether a comparison is valid. This is because the mottle values for yellow are so low that it approaches the inconsistency values. If the mottle value is less than about 1% in yellow, the measurement may be valid only when compared with measurements from the same scanner. This is not considered to be a problem because yellows are rarely measured for mottle. For black, cyan, and magenta, minimal values are 3%, 2% and 1.5%, respectively. At these low mottle values, mottle is typically not apparent.

Effects of the Calibration on Consistency of a Single Scanner

The calibration transformations introduce varying levels of improved consistency (lower standard deviation). When the images were transformed using all five profiles (as in transformation method 1), the improvements in lightness consistency numbered slightly under half. Although there are some measurements that had more inconsistencies, the increases were slight, and they introduced less than an additional 1% error in average lightness (less than 3 lightness levels). This is much smaller than the error introduced by using different scanners without calibration (as indicated in Table 2, up to 32 levels of lightness). In reference to the variation measurements, only about a quarter of the measurements improved. However, only 4 of the 60 measurements result in inconsistencies above 1 lightness value. Results from transformation method 3 were similar. This is likely because all profiles were used for this method also.

When only one calibration profile was used (as in transformation method 2), two thirds of the lightness measurements improved in consistency. In addition the remaining one third of the measurements had an increase in inconsistency of less than 1 lightness level. Variation measurement consistency improved in half the number of measurements. Only four of the remaining measurements had inconsistencies above 1 lightness level. Again, an important factor is that if there is any greater inconsistency, it typically changes by less than 0.5 lightness levels. This is small compared to inconsistencies introduced by uncalibrated multiple scanners (up to 4.3 levels).

Field Example

Heidelberg Standards Measured

Heidelberg has a series of magenta samples that is used to visually compare prints. I have tested these samples, applying our scanner and calibration method, to verify the correlation between digital analysis and visual assessment. The samples were a set of magenta prints ranked from 1 to 11 (odd numbers only) in the order from highly mottled to no mottle. I tested the sample using the Microtek Scanner. The data from the standard shows a correlation with the visual ranking (see Figure 4).

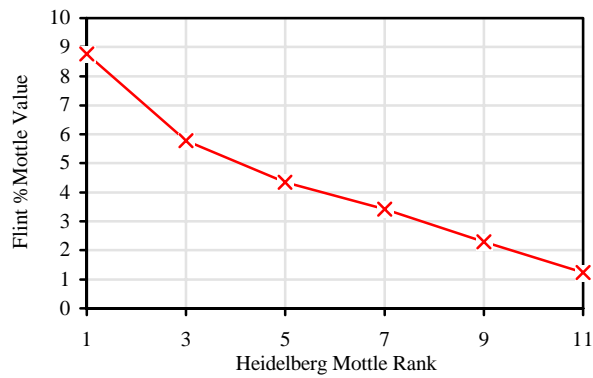


Figure 4. Comparison of Mottle values measured digitally (Flint Ink method) and visually (Heidelberg Rating).

Conclusions

1. Calibration of the scanner improves the consistency in lightness measurements between scanners.
2. Slight improvements in the consistency in the variation of the print density were seen with the calibration.
3. The net result of scanner calibration is an improved consistency in the mottle value.
4. The mottle measurements correspond with visual ranking, based on the standard used by Heidelberg.
5. Although it is possible to have a slight increase in inconsistency between measurements of a single scanner, it is offset by the improved consistency between multiple scanners.

Scanning parameters are recommended below.

1. Use the maximum optical resolution of the scanner. A resolution of 600 ppi should be sufficient to capture the details of the print. Any higher resolution may just provide larger file sizes without any additional mottle information.
2. Use the default color, tone correction, and lighting settings of the scanner software. If there are no default

presets, make sure there are no color filters or sharpening. If a tone correction must be applied, use the liner correction. Using the default settings allows multiple users to scan using the same settings. A color management system should be able to overcome the variations in the settings as long as a scan of the calibration target is scanned under the same settings as your samples.

Biographies

William Lim received his BS in Material Science and Engineering from the University of Michigan in 1994 and joined the Physical Sciences lab at the Flint Ink Research Center. His research interests involve dispersion characteristics of inks and developing routines to quantify print quality. Some of the primary techniques he uses for the above research are particle size analysis, image analysis, and microscopy.

Dr. Suresh Mani received his Ph. D. from the University of Massachusetts, Amherst, in 1992. Since then, Suresh has been the Technical Manager of the Physical Sciences Lab at the Flint Ink Research Center. Under his direction, the Physical Sciences lab works on a number of projects that focus on developing a fundamental understanding of the printing process. These include flow properties of inks, ink-paper interactions, surface energetics and chemistry of the printing plates, and quantifying print quality.

References and Acknowledgments

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