Colorimetric Repeatability of Continuous Tone Ink Jet Images for Pre-press Proofing

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Abstract

Four-color continuous ink jet printers are used extensively in the graphic arts industry for direct digital color proofing. One concern about using continuous ink jet for proofing is it's ability to achieve color consistency equal to analog proofs.

Experiments are described which compare the color repeatability of four-color continuous ink jet proofs to other analog proofing systems using colorimetric methods. CIE L*a*b* measurements were taken from several ink jet and analog proofs, which contained a standard test image. The test image consisted of an array of color patches with different colorant amounts. Two-dimensional probability ellipses, representing the 95% a*-b* confidence interval, were computed for each color patch and for each proofing system to assess chromatic color variations. Lightness variations were evaluated using 95% confidence intervals for L*. Results indicated that the continuous ink jet proofs were comparable to three analog proofing systems in terms of color consistency.

Introduction

The graphics arts industry utilizes three different proofing methods to simulate the quality of the four color output from press. These methods include press sheets, analog proofs, and direct digital color proofs. Of the three methods, analog and direct digital color proofs are the most commonly used today.

Analog Proofing Systems:

Analog proofing systems, such as 3M Matchprint and Dupont Cromalin, produce proofs directly from color separation fihms. Since these systems eliminate the need to produce printing plates for proofing, analog proofs offer significantly higher throughput than printing conventional press sheets. These processes typically provide better color consistency than press sheets as well. Analog proofs, however, require new sets of separations films every time changes are done to an image. The time and labor required to produce films and analog proofs is significantly higher than generating proofs using direct digital color proofing technologies.

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Direct Digital Color Proofing

Direct digital color proofing, or DDCP, is the latest proofing technology utilized by the graphic arts industry. DDCP devices make proofs directly from a pre-press work station without having to produce separation films or plates. As stated earlier, by not having to generate films or plates, direct digital color proofs can be created faster than analog proofs and press sheets. However, industry concerns over color consistency has limited the proliferation of DDCP devices.

Continuous Ink Jet Technology

Continuous ink jet printing is one image technology utihzed for direct digital color proofing. Continuous ink jet produces a continuous stream of droplets using a capillary stimulated with a piezo crystal. Droplets are selectively charged using a charge tunnel assembly, and pass through a deflection structure. A charge applied in the deflection structure directs charged droplets to a knife-edge/gutter system and allows uncharged droplets to be printed.

Four color continuous ink jet technology, as utilized in printers developed by IRIS Graphics, can produce a large number of visually distinct colors required for pre-press proofing applications. However, industry's concern over color consistency prompted IRIS to investigate the color repeatability of continuous inkjet proofs compared to other analog proofing processes. This paper, therefore, summarizes color consistency results obtained from analog and continuous ink jet proofs.

Experimental

Test Pattern Design

A test pattern image was developed to sample the color gamut of each proofing device. The pattern consisted of 376 color patches containing various amounts of cyan, magenta, yellow and black. Colors patches with high lightness and low metric chroma were emphasized in the images since these colors tend to exhibit the worst color repeatability . The test pattern image also contained a set of registration marks in order to align the printer on an automated color measurement system.

Sample Collection

Using the test pattern image, three sets of analog proofs from different proofing manufacturers and one set of IRIS proofs were produced for the evaluation. Each set consisted of five proofs which were produced on five consecutive days. This sampling plan provided color consistency data between proofs in each set. Each set of analog proofs were also made using one set of separation films.

Color Measurement of Samples

The spectral reflectance data was obtained for each color patch on each proof using a Gretag SPM-I 00 spectrophotometer mounted on a gantry stage. The Gretag SPM-100 utilizes a 45/0 measurement geometry and measures reflectance data from 380 mm to 730 nm. To ensure consistent measurements from the SPM-100, calibration and long term drift compensation was used to achieve color measurements repeatable to 0.1 hEab units. The gantry stage was equipped with X,Y, andZ axis motion so the measurements could be automated.

Colorimetric Analysis

After obtaining the reflectance data from each color patch CIE L*a*b* values (D50, 1931, 2 degree observer) were computed for each color patch using the colorimetric weights described in ASTM E308-85.1 The resulting CIE L*a*b* values were then used to assess the overall color variation in each proofing system. Based on previous work related to the specification of color tolerances,2345 chromatic variation was determined by computing 95% confidence ellipses in the a*-b* plane for each color. The general equation for the ellipse is shown in equation 1.

$$e_4=e_1 (a^*-a^*_0)^2+e_2(a^*-a^*_0)(b^*-b^*_0)+e_3(b^*-b^*_0)^2 \qquad (1)$$

where a^*_0 and b^*_0 are the coordinates of the origin, constants e_1, e_2, and e_3 determine the size and orientation of the ellipses, and e_4 is computed from the Chi-Square distribution with 2 degrees of freedom and a specified α risk. To evaluate lightness variations in each colorpattern, the 95% confidence intervals ,1. $96\sigma_{L^*}$, were computed for each color on each proof.

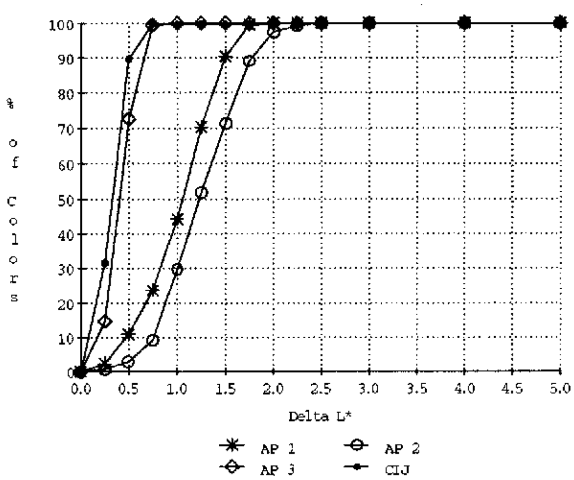

Figure 1. Lightness Cumulative Plots

Results

Lightness Variations

In order to evaluate overall lightness variations, cumula tive plots was computed for each proof set as shown in Figure 1. These plots indicated the percentage of colors on the test image which were less than or equal to a specified ΔL* tolerance. The ΔL* tolerance was the distance computed from an average L* value for a given color. After evaluating the plots, one can see that 95% of all the colors produced by the analog proof sets, AP1, AP2, and AP3, were a maximum of 0.7 to 1.9 ΔL* units from an average L* value. The continuous ink jet proofs, labeled CIJ, exhibited maximum lightness variations of .6 ΔL* units.

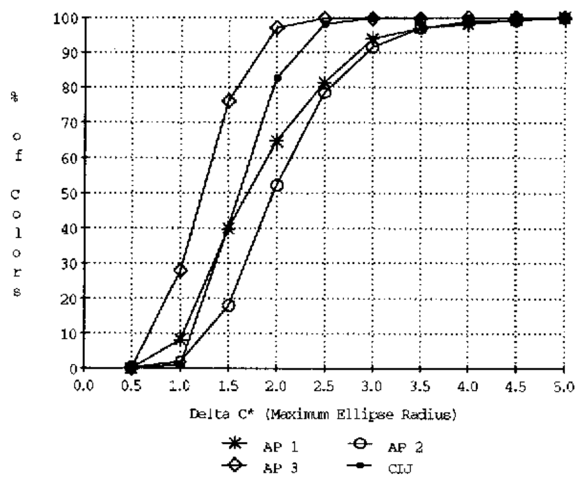

Figure 2. Chromatic Cumulative Plots

Chromatic Variations

Cumulative plots were also used to assess chromatic variations in each proof set. These plots, as seen in figure 2, indicated the percentage of colors which had chromatic variations less than or equal to a specified AC* tolerance. The AC* value for each color refers to the maximum radius for each a*-b* confidence ellipse. Test results from the plots showed that 95 % of all colors from the analog proofs varied a maximum of l.9 to 3.3 AC* units. The continuous ink jet proofs had a maximum of 2.4 AC* units.

Conclusion

Two important observations were made with respect to color consistency between analog and continuous ink jet proofs. First, the continuous ink jet proofs were as good as the best analog proof tested in terms of lightness variations. Secondly, the continuous ink jet prints were comparable to analog proofs in terms of chromatic variations. Since each analog proof set was made using one set of separations films, color variation related to the film processing variation was excluded from analog proof sets. This means that the reported color consistency numbers may be lower than expected for analog proofs. This fact also strengthens the argument that continuous ink jetproofs can achieve a level of color consistency equal to analog proofs.

References

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