Diagnosis for Differential Gloss in Color Hard Copy Outputs

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Abstract

For hard copy technologies using separate multiple layers of colorants to form the final output, differential gloss is a quality attribute that the ink formulator or toner process engineer must manage. In 2001, the standards committee from INCITS W1.1 issued in 2001 40-patch multicolor test target for the evaluation of differential gloss. The use of this target typically involves reporting the maximum and minimum gloss readings among the 40 color patches. This paper proposes a methodology to interpret the extent of differential gloss in terms of just noticeable differences, or JNDs, and to diagnose how gloss level changes with color or lightness levels. Examples of several electrophotographic and inkjet outputs will be used to illustrate the standard target and the methodology.

Introduction

There exists gloss measurement standards, and some proposed standards, regarding differential gloss.[1] Differential gloss, DG, is the dynamic range of the measured gloss or the difference between the maximum gloss, G-max, and the minimum gloss, G-min, on a page.

$$DG = G\text{-}max - G\text{-}min \quad (1)$$

Further, a **JND increment** for differential gloss has been evaluated for 60 degree gloss.[1,2] At any gloss level G', the JND increment as a function of G' is:

$$JND(G') = 0.14 * G'^{0.96} \quad (2)$$

Having just the DG number is not sufficient to compare two prints for differential gloss because the JND increment is a function of gloss level. For the same DG, the print with a higher average gloss would not seem to have as much differential gloss as a print with a lower average gloss. In order to compare the perceptual impact of two prints, one must convert gloss data to JND units. Another use for gloss data, in terms of number of differential gloss JNDs, is the analysis where there is noticeably lower gloss. In this paper, we will share data for three EP outputs and three IJ outputs:

Table 1. EP Outputs and IJ Outputs

EP1	CMYK dry toner on coated paper
EP2	CMYK liquid toner on coated paper
EP3	CMYK toner on coated paper
IJ1	CcMmYK dye-based ink on microporous media
IJ2	CMYK dye-based ink on swellable media
IJ3	CcMmYK dye-based ink on swellable media

This paper is presented as an interactive poster to show many plots, some of which are difficult to reproduce in the proceedings. In the proceeding, we will illustrate the methodology with one printer and include summary data for six printers. In the poster session, the methodology will be illustrated for all six printers.

Analysis of Differential Gloss Target

The differential gloss target used in this study is the 40-patch RGB target[3] that can be found in www.incits.org. Figure 1 shows the differential gloss target. The printed target depends upon how the printer interprets code values assigned to the color patches; therefore, correlations with gloss results should be made with the measured color patches rather than image file code values. For each of the six examples, the 40 patches were measured on a Gretag Macbeth Spectrolino SpectroScan. The CIE L*, a*, and b* parameters of the reflectance spectra were used for color analyses of the target. The a* and b* values allowed us to calculate the hue angle for each color patch. Figures 2 and 3 show the distribution of the printed colors with the associated lightness and saturation for sample EP2.

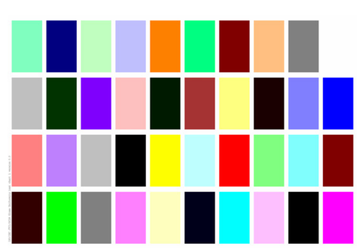

Figure 1. RGB Differential Gloss Target

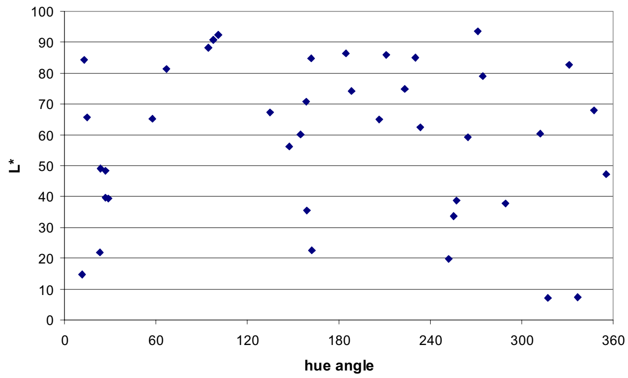

Figure 2. L vs hue angle*

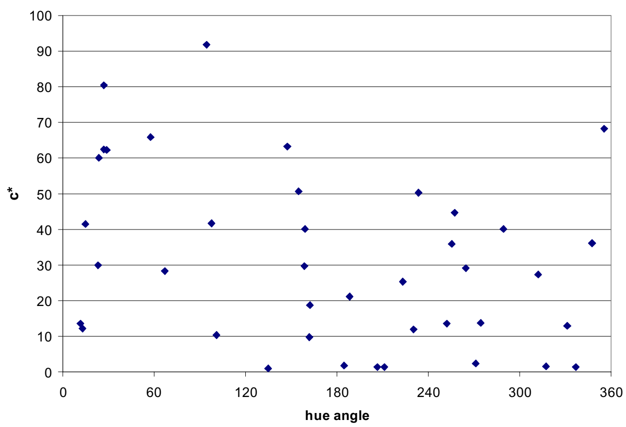

Figure 3. c vs. hue angle*

There was an attempt in the design of the target to assess different colors. One can see there are limited data for yellow (hue angle 60–120°) and cyan (hue angle 180–240°) in the low L* region because it is difficult to obtain dark yellows or dark cyans. In the c* vs hue angle, the yellows had a range of saturations. With 40 points in the data set, there is sufficient data to draw contours to show how gloss changes and to model the data to find which aspects of color may be a factor driving gloss. Although not the subject of this paper, the plots generated in this analysis can be an estimation of the color space or color gamut. One can overlay the boundary of the L* vs hue angle plot from different printers and compare the color space, and likewise with the c* vs hue angle plots.

Basic Analysis of Gloss Data

The data in this study are 60-degree gloss and are appropriate for the range of gloss on the prints. The gloss measurement instrument is a BYK Gardner Tri Gloss Meter. Before showing how to draw gloss contours in color space, we offer the process for preliminary analysis of gloss data. We plot the 40 patches and look for any spatial patterns. There have been instances where one section of a print has lower overall gloss because of systematic printhead problems. The last patch is the media gloss, and we note if the media gloss is the G-max or G-min or a point within the dynamic range.

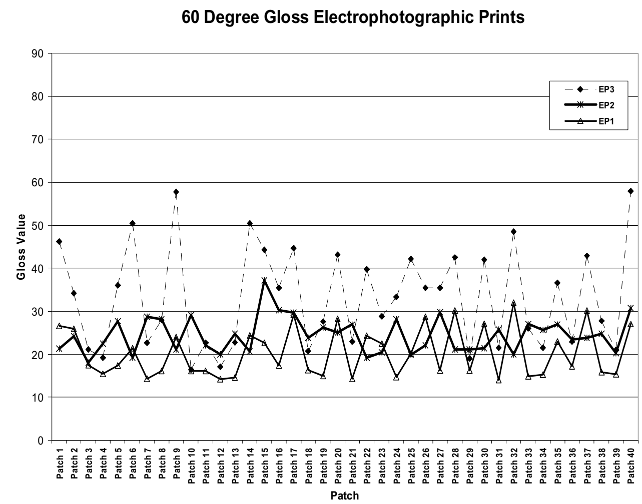

Figure 4. Examples of EP Output Gloss Data

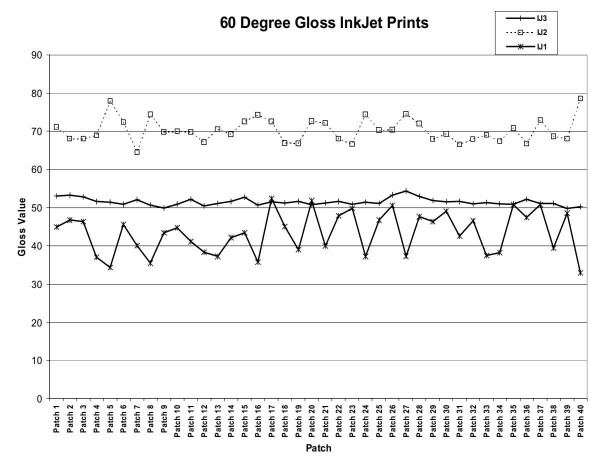

Figure 5. Examples of IJ Output Gloss Data

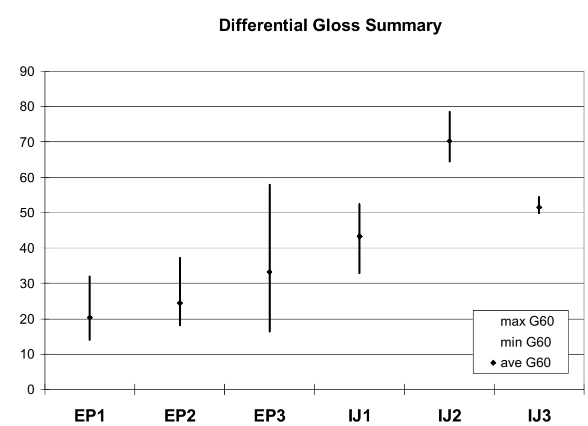

Figure 6. Gloss Summary

This raw data gives a feel for how gloss varies in the 40 patches. The printed gloss is generally lower than the media gloss, with the exception of IJ1, which shows higher gloss than its media gloss. A simple way to summarize the data would be to show the G-max, G-ave, and G-min as in Fig. 5. The average or overall gloss, G-ave, is calculated from the average gloss of the 40 patches. The span from G-max to G-min indicates differential gloss.

Advanced Analysis of Gloss Data

Samples EP2 and IJ1 have a similar number of gloss units for differential gloss, 19.1 and 19.5, respectively. The DG number is an analytical number. A more meaningful indication of the perception of differential gloss is the number of noticeable gloss levels within the G-max and G-min boundary. Assigning G-max as the reference position, all data will have the same sign to facilitate comparisons. An infinitesimal change in G' is divided by the JND increment at G' to yield an infinitesimal portion of a JND.[4] The infinitesimal portions of JNDs are integrated up to point G to yield the cumulative JNDs between G-max and G. At gloss G, the number of JNDs from G-max is:

$$\int_{G\max}^{G} \frac{dG'}{JND(G')} = \int_{G\max}^{G} \frac{dG'}{0.14G'^{0.96}}$$

$$= \frac{G'^{0.04}}{(0.04)*(0.14)} \Bigg|_{G\max}^{G}$$

$$= 178.6*(G^{0.04}-Gmax^{0.04}) \qquad (3)$$

When G = G-max, the number of JNDs from G-max is zero. For the other 39 data points in this target, the number of JNDs for each gloss measurement would be negative numbers. The number farthest from zero is the highest number of noticeable gloss levels or the number of differential gloss JNDs. In the six samples studied, the results are shown in Table 2.

The printer with the largest number of differential gloss JNDs is also the one with highest differential gloss. However, the next highest differential gloss, in terms of gloss units, sample IJ1, is actually ranked fourth in JNDs, making a significant difference in assessments. IJ1 and EP2, with 19.5 and 19.1 gloss units in differential gloss, are perceptually very different, with EP2 showing 5.86 JNDs and IJ1 showing 3.86 JNDs in differential gloss. It would be a goal to design colorants to result in the lowest number for differential gloss JNDs.

Table 2. Number of Differential Gloss JNDs in the Six Samples Studied

	Media Gloss	Overall Gloss, Gave	Gmin	Gmax	Differential Gloss	Differential Gloss JNDs
	gloss units	gloss units	gloss units	gloss units	gloss units	number of JNDs
EP1	27	20.3	14	32	18	-6.67
EP2	30.8	24.45	18.1	37.2	19.1	-5.86
EP3	57.9	33.2	16.4	57.9	41.5	-10.34
IJ1	32.9	43.27	32.9	52.4	19.5	-3.86
IJ2	78.5	70.2	64.5	78.5	14	-1.66
IJ3	50.3	51.5	49.8	54.4	4.6	-0.74

Next, we discuss concepts in drawing gloss contours and JND contours on L* vs hue angle and on c* vs hue angle plots. There are basically two approaches. One is to use raw data and let software programs draw contour lines by interpolating data. Specifying the contours or contour intervals is an important facet. Depending on how the contours are drawn, one can see different features in the topography. Our approach is to draw the contours at one JND in differential gloss. The perceptual basis helps to decipher the proper interval and enable the analysis to overlook analytical differences that do not matter perceptually. Rather than plotting gloss contours, we plot differential gloss JNDs from G-max. Figure 7 shows an example of contours of differential gloss JNDs.

The darker green, cyan, and blue are the perceptually lower gloss patches. In the pastels, the green and cyan show lower gloss as well. Yellow toner increases gloss. Typical questions to consider when evaluating the contour plots include:

1. Does low coverage of colorants result in low gloss
2. Does addition of K toner/colorant lower gloss
3. Location of the D-min patch and how it impacts the neighboring contours
4. Location of the six near-neutral D-max patches and impact on neighboring contours.

Neutral D-maxes are unique because of high coverage of colorants. The tool used to generate these contour plots is JMP. The black dots indicate location of data. Any contours where there is no data should be evaluated with caution.

The other approach to drawing contours is to use models. Of the six printers, four had significant differential gloss and are good candidates for modeling. Parameters from spectrophotometry yield reasonably good models, ranging from R^2 of 0.68 to 0.90 for linear models. The topic of modeling gloss data can be the subject of future work. There needs to be special consideration for D-min and near D-max situations.

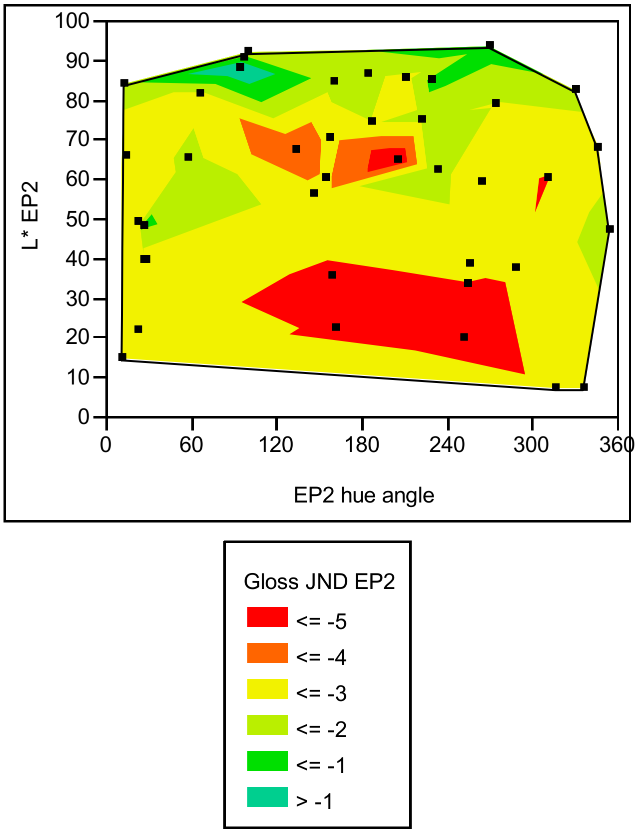

Figure 7. Differential gloss JND contour

Summary

In this paper, we have explained the reasons for, and the approach to, convert gloss data to JNDs of differential gloss. We have demonstrated the comparison of differential gloss for outputs of very different gloss levels. In the evaluations for which colors are causing differential gloss, we advocate the analysis of drawing contours that are one JND apart on L* vs hue angle and c* vs hue angle.

Acknowledgments

The authors must thank Dr. Brian Keelan for guidance in converting gloss data to differential gloss JNDs. The continuous efforts of the INCITS W1.1 Gloss & Gloss Uniformity Committee to standardize metrics have been helpful to the printing community. Their team assessment of the JND increment is the basis for this paper. We must also acknowledge Gary Rakes for numerous gloss measurements.

We acknowledge Kodak management for the opportunity to do this personal research project. The results here may or may not reflect the opinions of those directly involved with evaluating differential gloss.

References

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Biographies

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