Evaluation of digital proofs using the GRACoL dataset and various color difference equations

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Abstract:
During the June 2007 IPA Technical Conference a Proofing RoundUP was conducted and it was verified that all manufacturers could match the colors of the GRACoL Coated 1 dataset based on colorimetric measurement. The IT8.7/4 target consisting of 1617 different colors was measured with a DTP70 instrument, and color differences were determined with the Comparison Tool in X-Rite's ProfileMaker software.

The test also included submissions from users, many of which also showed very similar, low differences. The criterion for evaluating the color differences was based on the ΔE_{ab} equation. The average ΔE_{ab} for all submitted proofs was 1.6.

A visual evaluation of the proofs submitted by vendors and users was also conducted. This evaluation showed that in some instances the measured data gave the same ΔE_{ab}, but visually the proofs were rated differently.

In this paper the data will be reevaluated using the color differencing equations of DE94, DE2000, and DE_{CMC}. It will be shown that it could be beneficial to use one of the aforementioned, newer color differencing equations as a criterion to rate the color accuracy of proofs. Work done in North America has focused on the use of DE94, DE2000 and DE_{CMC}, however more common in Europe is the work of the DIN and the related standards. In this paper the color differencing equation DIN99, which is specified in DIN 6176, and also in ASTM D2244-07, was used. This equation transforms the L*a*b*-color space to a more uniform color space. It applies a warping to L*, a*, b* to get L99, a99, and b99 values. This new color space is more uniform so that color differences can be computed with the normal Euclidean distance formula.

The overall evaluation of the data showed that because of all the various criteria each submission had to meet using ΔE_{ab} based tolerances, these

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tolerances are quite rigorous to give a thorough evaluation of the provided proofs.

A correlation between the visual ratings given by conference participants draws a little different picture in regards to proofs provided by suppliers and by users. For the tightly controlled vendors proofs as well as for user supplied proofs $DE_{CMC\ 1:1}$ is the color differencing equation of choice to numerical express perceived differences.

Introduction

During the 5th Annual IPA Color Proofing RoundUP held during the IPA Technical Conference, June 5 – 7, 2007 in Chicago vendors and users were invited to submit proofs of a test form. This test form was provided by IDEAlliance and contained several SCID images and the IT8.7/4 test target. The proofs to be generated had to match colorimetrically the GRACoL reference printing conditions represented in the "GRACoL2006_Coated1.txt" file. Figure 1 shows the 2-page version of the test form. There was also a 3-page version for smaller format proofing devices available.

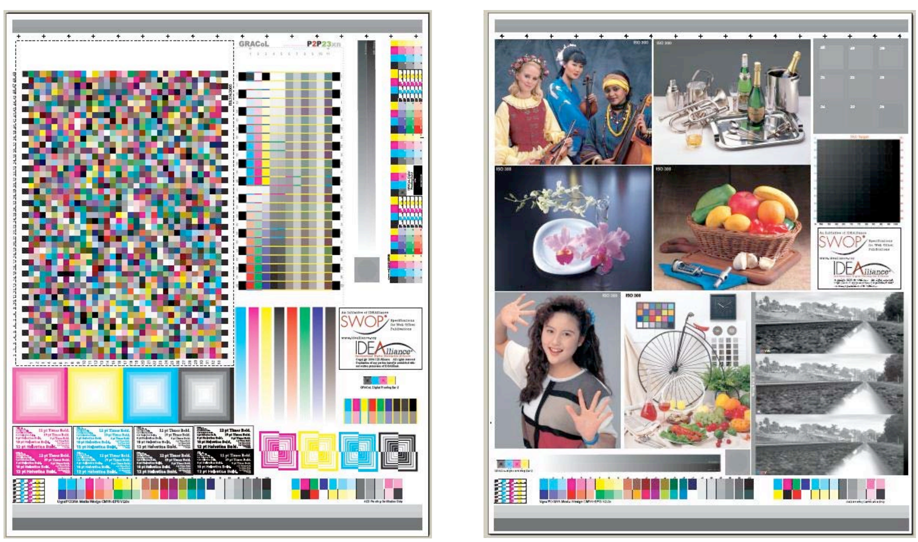

Figure 1 The IDEAlliance CMYK Test Form consisting of a technical page (left) and a visual page (right)

For accurate color reproduction it is beneficial to use ICC profiles. A source and a destination profile is required to correctly proof the test form. Participants could use an appropriate ICC profile provided by

IDEAlliance or generate their own profile from the GRACoL2006_Coated1.txt file. These two possible routes will provide the source ICC profile. It is beneficial to have also a destination profile that characterizes the chosen proofing device. The principle of source and destination ICC profiles for accurate color reproduction is well documented (Sharma 2004).

There were no good or "OK" prints or proofs supplied that had to be matched. The evaluation of the submitted proofs was done solely by measurements of the IT8.7/4 test target. The measurements were compared to a set of established criteria.

If a supplied proof would be outside of one the established tolerances the submission would be classified as failed. A typical measurement set is shown in Table 1 below, which approximately represent the IDEAlliance hardcopy proofing certification tolerances.

		ΔE_{ab}	Pass/Fail	Tolerance
IT8.7/4 (all patches)		1.12	Pass	Average $\Delta E_{ab} \leq 1.50$
IT8.7/4 (95th percentile)		2.30	Pass	$\Delta E_{ab} \leq 6.00$
Solids	Cyan	3.85	Pass	$\Delta E_{ab} \leq 5.00$
	Magenta	0.90	Pass	$\Delta E_{ab} \leq 5.00$
	Yellow	1.03	Pass	$\Delta E_{ab} \leq 5.00$
	Black	1.32	Pass	$\Delta E_{ab} \leq 5.00$
Overprints	Red	0.63	Pass	$\Delta E_{ab} \leq 5.00$
	Green	3.17	Pass	$\Delta E_{ab} \leq 5.00$
	Blue	0.87	Pass	$\Delta E_{ab} \leq 5.00$
50/40/40 Neutral Gray		1.02	Pass	$\Delta E_{ab} \leq 1.50$
Paper White Delta L*		0.43	Pass	$\Delta E_{ab} \leq 2.00$
	Delta a*	1.06	Fail	$\Delta E_{ab} \leq 1.00$
	Delta b*	0.75	Pass	$\Delta E_{ab} \leq 2.00$
Ugra/FOGRA Media Wedge		1.36	Pass	Average $\Delta E_{ab} \leq 1.50$
Sheet to Sheet Variation		0.85	Pass	Max $\Delta E_{ab} \leq 1.50$

Table 1 Evaluation criteria with a set of typical data

Altogether there were 22 submissions from vendors and 64 end-user submissions.

The average ΔE_{ab} from all vendor submissions was $\Delta E_{ab} = 1.01$, while the average ΔE_{ab} from end-users was 2.21. This is quite a remarkable result.

Despite the fact of this result it was also necessary to see how a visual judging of the supplied proofs corresponds to these ΔE_{ab} -numbers and any of the newer color differencing equations like DE94, DE2000, DE_{cmc} and DIN99.

Experimental

During the IPA Technical Conference participants were asked to visually rate the proofs supplied by vendors and suppliers. This was done on two separate days. On the first day the proofs from the vendors were displayed and on the second day the proofs submitted by users. An example of the visual judging can be seen if figure 2.

Figure 2 Display of proofs in viewing booth with D50 lighting and judges

The proofs were displayed in colour viewing booths supplied by GTI (GIT EVS-2450/FS). The fluorescent light tubes had a color-rendering index (CRI) of 93 – 95 towards the D50 illuminant.

Participants were given a ranking sheet, as can be seen in Appendix 1. Rankings had to be given for the reproduction of quarter-, mid- and three-quarter tones, as well as for flesh tones and neutral colors (gray).
These areas are encompassing all the critical elements in a printed product. Highlight and shadow areas should give detail reproduction, whilst the mid tone areas are most sensitive to possible dot gain issues.

Neutral colors and flesh tones are most perceptive to possible color imbalances.

Judges could use rankings from 1, for the lowest ranking, and 10, for the highest ranking. In order to give some kind of a guideline the rankings were split as follows:

9 – 10 points: Excellent reproduction / Excellent rendering of flesh tones
7 – 8 points: Slight shift / very good rendering of flesh tones
5 – 6 points: Visible shift / good rendering of flesh tones
3 – 4 points: Visible shift / Questionable rendering of flesh tones
1 – 2 points: Large shift / Poor rendering of flesh tones

Each sheet was evaluated by an average of 5 people. Although all vendor supplied sheets were visually evaluated this was not possible for all user supplied sheets. Out of the 64 user submitted proofs 42 proofs (~66%) were evaluated by conference participants. This was due to the large number of submitted proofs and the limited amount of space in the three viewing booths.

Conference participants work in the Graphic Arts industry and are most likely hands-on color experts. In contrast to a previously done study (Sharma et al., 2006) persons affiliated with proofing vendors were allowed to judge, since any possible identification had been removed from the proofs. The only identification on the proofs was the unique number given to each entry. Only the RoundUP team was aware who was behind each entry number and the entrants knew their own number.

The initial question was, how could the various color differencing numbers be compared with the visual ratings given by the conference participants? Each color differencing equations gives a different average ΔE and the values of all the 1617 patches show then a different standard deviation. A method for comparing different averages or means is the coefficient of variation. The coefficient of variation calculates the ratio of the standard deviation to the mean and is a useful measure for comparing the degree of variation from one data set to another, even if they have different means. The coefficient of variation is defined as:

$$\text{Coefficient of variation} = \frac{\text{Standard deviation}}{\text{Mean}}$$

This allows comparing the data with greatly varying means as they are generated by each entry and the color differencing equations.

Entries from the judging sheets were collected and averaged. These results were grouped by vendor and user submissions. These results were further divided into the five categories:

- Quartertones
- Mid tones
- Three quarter tones
- Flesh tones
- Neutrals (Gray).

This was done to see whether one color differencing equation correlates better with visual judging results.

Although many submissions had a low average ΔE_{ab} some showed a quite high maximum ΔE_{ab} . A ΔE_{ab} above 5 was considered as high and list was compiled that contained all these patches. These patches were plotted in Chromix® ColorThink software against the reference data from the GRACoL2006_Coated1.txt file. It was also tried to determine if a certain combination of software and proofing device is more bound to cause these outliers than other combinations.

In a last step of the evaluation of the visual rankings a new set of tolerances for each of the equations was set up to see if this results in fewer or more pass/fail results.

Results

Visual Rating versus ΔE equation for vendor submitted proofs

In the first step of the evaluation the visual ratings from vendor-supplied proofs were grouped by the ranking they received and the coefficients of variation were plotted against the color differencing equations that were used.

A typical plot of this can be seen in figure 3:

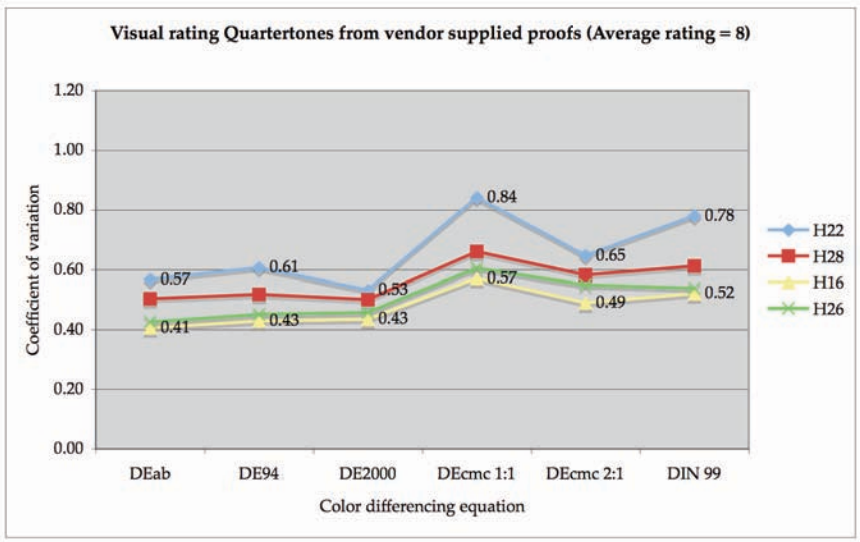

Figure 3 Visual ratings for vendor-supplied proofs in regards to the color differencing equations used

The plots for other visual ratings in the Quartertones look similar. It is interesting to see that the DE2000 equation creates a distribution profile in which the proofing systems look as though they have a similar error spread. The $DE_{CMC\ 1:1}$ creates a much different profile in which proofing system look as thought they have a very high error spread.

In the midtones, three quarter tones and flesh tones the picture changes. It seems that ΔE_{ab} results in a lower error spread in regards to the midtones, whilst for the Three Quarter tones and flesh tones it seems that it is DE94. For the neutral colors DE2000 creates the smallest error spread. For all five visual test criteria $DE_{CMC\ 1:1}$ gives the largest error spread. It would seem that having a smaller error spread is more desirable, since all data gets normalized, but, as will be shown later on, this is not got representation of the perceived visual differences.

A color differencing equation should give a good numerically representation of the differences that are present. It should not exaggerate or minimize the perceived differences

The majority of the vendor supplied proofs (65%) passed the certification with an average ΔE_{ab} of 1.01. The vendor submitted proofs that did not pass the quality assurance evaluation did so due to a failure in only one category. A list of all the categories can be found in table 1.

<u>Visual Rating versus ΔE equation user-submitted proofs</u>

What was done for the vendor submitted proofs was repeated for the user submitted proofs. The majority of the user submitted proofs did not pass the verification and had an average ΔE_{ab} of 2.21. Although numerically this is a discouraging outcome it needs to be said that there could be many factors contributing to this result. Users might operate the equipment in less than ideal conditions, the ICC profiles that were being used might not be ideal, generic ICC profiles or no profile at all were being used. Nevertheless 21 out of the 64 (~33%) user submission achieved on average ΔE_{ab} of $\leq$ 1.50. This was also quite a remarkable result. A general comment given by the judges in regards to the user submitted proofs was, "It is not as bad as we thought". Judges had the same rating categories as with the vendor submitted proofs and used the same judging sheet that can be seen in Appendix 1.

A typical plot of this can be seen in figure 4.

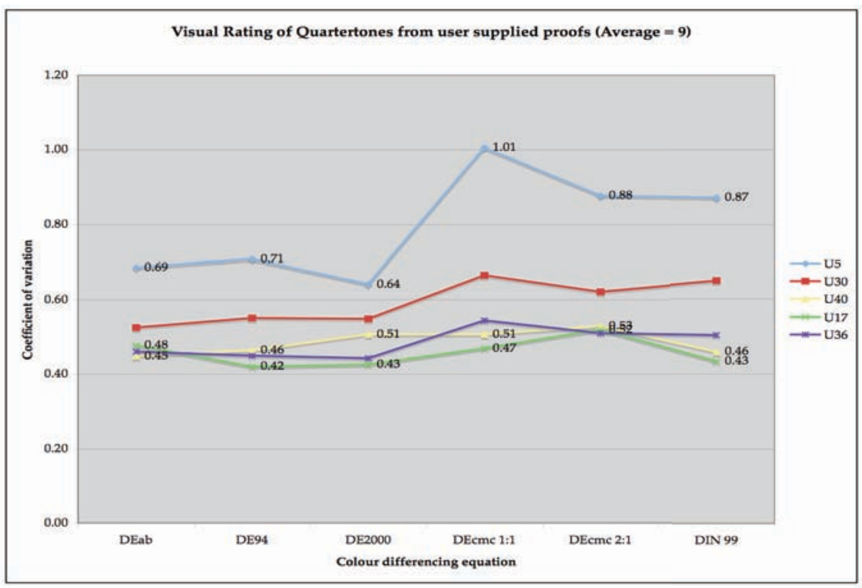

Figure 4 Visual ratings for user-supplied proofs in regards to the color differencing equations used

As seen before with the vendor submitted proofs, the DE2000 equation gives the lowest statistical error of all 5 color differencing equations. The larger spread between the lowest and highest coefficient of variation for DE2000 can be attributed to overall larger spread of the 1617 color differencing values.

The comparison of the midtone and three quarter tone ratings reveal that the DE2000 gives the lowest statistical error. The same applies for the fleshtones and the visual ratings given for the reproduction of the neutral colors.

Visual Rating versus the coefficient of variation

In the previous paragraph it was attempted to see which color differencing equation gives the lowest error spread, but is this really giving a true representation of the visual ranking given by the judges in relation to the spread of the DE-values under the five color differencing equations under investigation here.

For this purpose the ratings given in regards to quarter tones, mid tones, three quarter tones, flesh tones and neutrals were plotted against the coefficient of variation for the various color differencing equations. The coefficients of variation for proofs that received the same or very similar rating were averaged. A typical plot can be seen in figure 5.

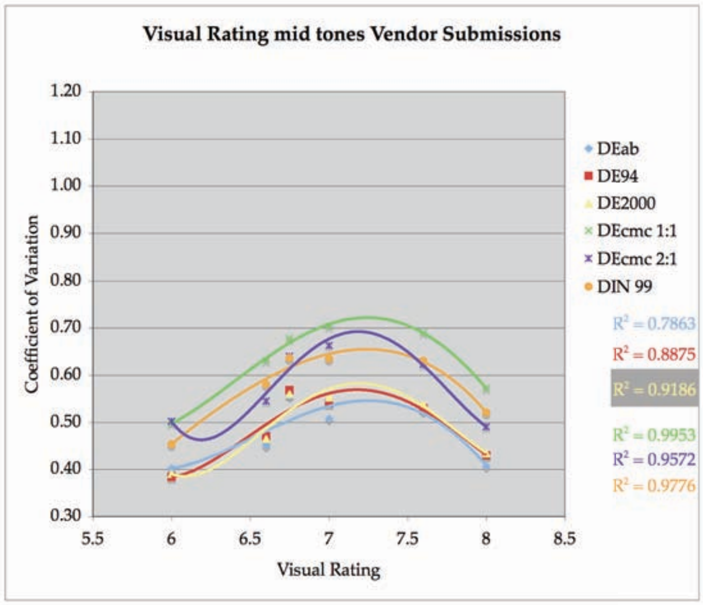

Figure 5 Visual rating for mid tones from Vendor Submissions vs. coefficient of variation

The trend lines used in this plot are 4th order polynomial. A complete list of the r^2-values listed by category can be seen in table 2.

	DE_{ab}	**DE94**	**DE2000**	**$DE_{CMC\ 1:1}$**	**$DE_{CMC\ 2:1}$**	**DIN99**
Quartertones	0.709	0.660	0.710	0.456	0.593	0.505
Mid tones	0.786	0.888	0.919	0.995	0.957	0.978
Three quarter tones	0.195	0.232	0.201	0.367	0.321	0.292
Flesh tones	0.695	0.834	0.843	0.978	0.807	0.969
Neutrals	0.631	0.774	0.762	0.683	0.785	0.667

Table 2 r^2-values from vendor submitted proofs in relation to the coefficient of variation. Maximum values are highlighted.

From this table it can be seen that in 3 out 5 cases the $DE_{CMC\ 1:1}$ equation gives a better correlation between the ratings given by the judges and coefficient of variation, which relates to the spread of the numerical color differences given by one of the color differencing equations. This means also, that the $DE_{CMC\ 1:1}$ equation gives a better reflection of how the human observers perceived differences present in the submitted proofs. For an unknown reason the correlation in regards to the three quarter tones is low. Only in the quartertones does DE2000 give a better correlation to the perceived differences. This might have to do with the fact that there was no “OK” sheet to compare to. Judges were giving the rankings based on their daily work experience and what, in their mind, is a good reproduction of the images shown in figure 1.

The above-mentioned procedure was also carried out for the user submitted proofs. The results in regards to user submitted proofs are little bit different compared to the vendor submitted proofs. All r^2-values of the 4^{th} order polynomial trend lines shown in figure 6 are listed in table 3.

	DE_{ab}	**DE94**	**DE2000**	**$DE_{CMC\ 1:1}$**	**$DE_{CMC\ 2:1}$**	**DIN99**
Quartertones	0.501	0.517	0.415	0.638	0.437	0.652
Mid tones	0.514	0.887	0.881	0.954	0.581	0.782
Three quarter tones	0.891	0.827	0.611	0.980	0.855	0.940
Flesh tones	0.751	0.851	0.720	0.696	0.692	0.661
Neutrals	0.851	0.560	0.618	0.570	0.763	0.485

Table 3 r^2-values from user submitted proofs in relation to the coefficient of variation. Maximum values are highlighted.

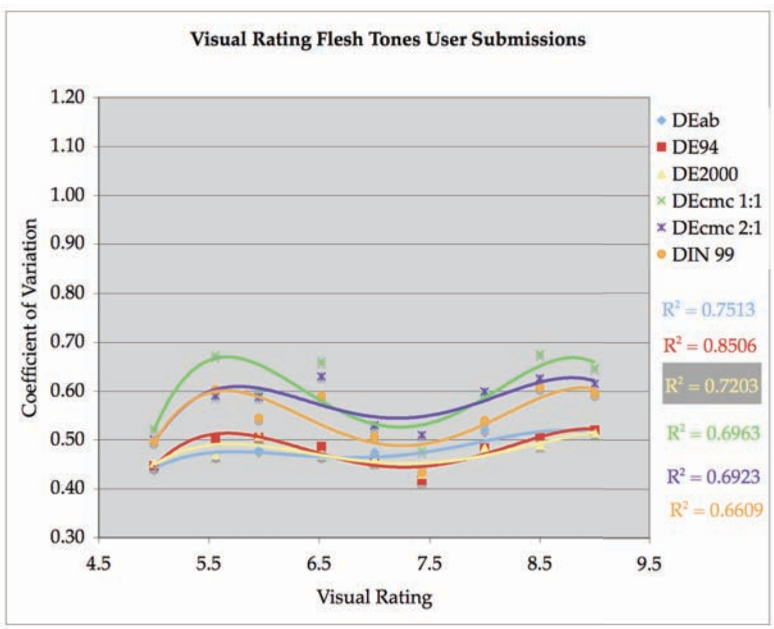

Figure 6 Visual rating for flesh tones from user submissions vs. coefficient of variation

The color differences present in the user submitted proofs were greater than in the vendor submitted proofs. In this case only in 2 out 5 cases did the $DE_{CMC\ 1:1}$ color differencing equation correspond with the differences perceived by the judges.

The DE2000 equation does not seem to correlate well with a larger spread of color differences, as they were present in the user submitted proofs. Interestingly enough the DIN99 method for expressing color differences seems to relate better than the other equations with the judged color differences.

From these results it looks like only one color differencing equation seems to stand out. This is the $DE_{CMC\ 1:1}$ equation. According to Lindbloom (Lindbloom 2008) "This method is drafted to become a new ISO standard (ISO 105-J03). This implementation uses a lightness weight of 1.0 and a chroma weight of 1.0 for use with perceptibility data." Since the data gathered for the visual judging stems from the perceived accuracy or inaccuracy in relation to the five categories mentioned above, it makes sense the DE_{CMC} equation with a lightness weight of 1 and a chroma weight of 1 gives the best correlation.

Troublesome patches

After carefully reviewing the data of the 86 entries it came to attention that some patches repeatedly showed large or very large deviations from the corresponding standard data. A large deviation is an ΔE value ≥ 5.

All 86 entries were analyzed for patches that showed the large deviation mentioned above under any of the 5 color differencing equations. If a smaller ΔE value had chosen the number of patches would be longer.

A list of 127 patches (7.9%) was generated and plotted in Chromix® ColorThink software. They can be seen in figure 7.

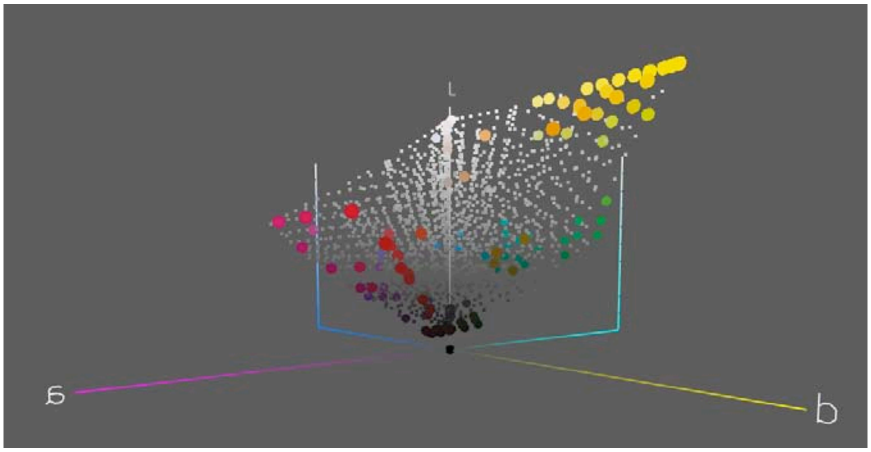

Figure 7 Patches from the IT8.7/4 target that showed a large color deviation

A list of these patches can be found in appendix 2. Not all patches were listed with the same frequency. This can be seen in figure 8.

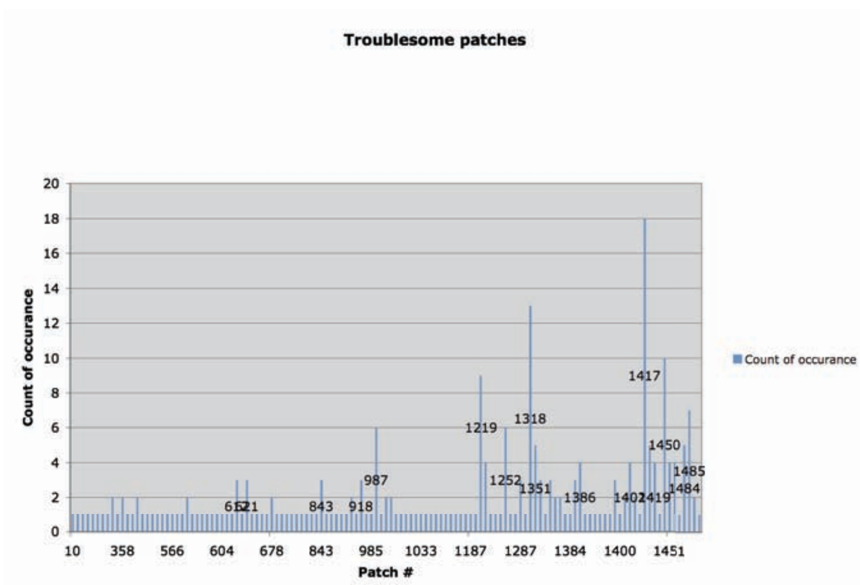

Figure 8 Patches from the IT8.7/4 target with large color differences

It is mostly very dark and very light patches that seem to cause difficulties in regards to accurate color reproduction. The two patches that stand out are patch 1417 and 1318. Below is a table that shows the L*a*b*-values and CMYK values of the patches that seem to be most troublesome.

Patch#	L*	a*	b*	C	M	Y	K
1219	9.23	14.29	2.02	0	100	0	100
1252	8.28	11.23	-0.92	40	100	0	100
1318	9.58	11.38	4.96	0	100	40	100
1386	9.61	-10.75	-3.76	100	0	40	100
1417	10.16	7.87	6.8	0	100	100	100
1450	9.06	4.93	4.38	40	100	100	100
1484	8.98	-6.73	1.74	100	40	100	100
1485	10.24	-13.05	3.39	100	0	100	100

Table 4 L*a*b* and CMYK values of color patches most frequently listed with a large color deviation (≥ 5)

A complete list of all patches can be found in Appendix 2.

It is not only users that seem to have issues with these patches, but also hardware vendors. The hardware vendors that had issues with these patches, at the time of the conference, passed the RoundUP test. The problematic color patches were just a few outliers that did not have a great influence of the overall rating of the submission. It was mostly users who had problems reproducing are certain number of test patches correctly.

The further analysis of the proofing systems that seem to be problematic revealed some interesting trends. Out of the 86 submissions 40 submissions (~47%) had issues with accurate reproduction of some of the patches. This means that any submission had some patches that had a ΔE-value of more than 5 under any of the ΔE-equations used in this study.

The following tables list these submissions by manufacturer and proofing output device. The percentages are based on the 40 submissions that showed had patches with a ΔE-value of more than 5.

Percent	Count	Supplier	Software (if information is available)
37.5%	15	CGS	Oris Color Tuner V.5.2 & 5.22
20%	8	GMG	ColorProof v4.1 – 4.1.20
15%	6	EFI	ColorProof XF V 3.0 -3.1
5%	2	Rampage	Rampage RIP
5%	2	Prinergy	
5%	2	Colorburst	Colorburst with X-Proof
5%	2	DuPont ChromaNet	

Table 5 List of proofing manufacturers with color issues

Before reading the following table it needs to be said that one manufacturer is controlling the market with 75% as the proofing output device supplier.

Percent	Manufacturer	
30%	Epson 7800	
22.5%	Epson 4800	
20%	Epson 9800	
7.5%	HP Designjet	
2.5%	Epson 4000	
2.5%	HP Indigo	

Table 6 List of proofers that were used and gave larger color deviations for certain test patches

Tables 5 and 6 have to be read carefully. It is not known under what kind of conditions these hard- and software combinations were operated. Was the equipment properly calibrated and also if custom-made or generic or no ICC-profiles were used. Users could also not have been properly trained on how to operate the proofing solution properly. Issues that might have existed with the proofing software solutions in Table 6 could or have been resolved through software updates. The list given here is representation of the information that was available during the IPA Technical Conference in June 2007 in Chicago.

New tolerances

Based on the results obtained so far it is necessary to reevaluate the data gathered during the IPA conference. Previous paragraphs showed that $DE_{CMC1:1}$ is the color differencing equation of choice when it comes to perceptual color differences. Many studies showed (Luo 2004, Johnson 2006, Habekost 2007) that the DE2000 equation gives a quite true numerical representation of a small color difference that is visible between a standard and samples.

Equations like the DE94 and the DE2000 equation are more complex iterations of the DE_{ab} equation from 1976. These equations, through their increasing complexity, are trying to compensate for non-linearity of the CIE L*a*b* color space. Recent work done in Europe takes a different approach. The DIN99 equation applies a warping to the L*,a* and b*-axis so that the resulting color space is linear and the Euclidian distance equation from 1976 can be used. The only difference is that L*, a* and b*-values have been transformed to L99, a99 and b99 (Beuth 2001).

The three equation $DE_{CMC1:1}$, DE2000 and DIN99 were used to re-evaluate the present data to see whether the main results were greatly changed or just some minor changes in regards to a pass or fail of the 86 entrants would take place.

Before this re-evaluation can take place it is necessary to set-up tolerance by which the data can be measured in regards to a pass or fail rating. In table 7 these values are shown.

Criteria	$\mathbf{\Delta E_{ab}}$	$\mathbf{DE_{CMC1:1}}$	**DE2000**	**DIN99**
IT 8.7/4 (All)	1.5	1.15	1.00	0.90
IT 8.7/4 (95Percentile)	6	5.50	4.00	4.10
Cyan	5	2.40	2.10	2.10
Magenta	5	3.10	2.90	2.50
Yellow	5	2.00	1.70	1.60
Black	5	10.00	4.50	6.50
Red	5	3.00	2.50	2.30
Green	5	2.00	1.70	1.60
Blue	5	4.00	3.60	3.50
Gray	1.5	1.70	1.50	1.20
Fogra Wegde (Average)	1.5	1.05	0.90	0.95
Paper White (Fogra)	3	3.65	2.60	2.10
Fogra Max	10	8	7	7

Table 7 Table of new tolerances used for the evaluation of all submitted entries

The new tolerances were obtained by looking up the corresponding patches in all 86 submissions. In some submissions the ΔE_{ab}-values were in close proximity to the ΔE_{ab}-values listed in table 7. At least three entries per color patch were used and their corresponding ΔE-values under $DE_{CMC1:1}$, DE2000 and DIN99 averaged. These averages were now used as the new tolerances as they are listed in table 7.

As a result of these new tolerances the ratings for some of the submissions changed from "Fail" to "Pass" but also some that passed before under the set of ΔE_{ab} tolerances received a failing grade under the new tolerances. This was also looked at in comparison to the overall visual rating some of the proofs received. The submissions that received a failing grade under the new set of tolerances received also low visual grade given by the judges. The same applies also for submissions whose grade changed to a passing grade. They usually received high ratings from the judges. This shows that it is beneficial to use the newer color differencing equations, since they reflect better how human observers perceive color differences. Examples of this can be seen in table 8.

Vendor/User ID	$\mathbf{\Delta E_{ab}}$	$\mathbf{DE_{CMC1:1}}$	**DE2000**	**DIN99**	**Visual rating**
U50	Pass	Pass	Fail	Fail	6.3
H12	Pass	Pass	Fail	Fail	6.7
H29	Pass	Pass	Fail	Fail	6.8
U35	Fail	Pass	Pass	Pass	7.6
U54	Fail	Pass	Pass	Pass	8
U49	Fail	Pass	Pass	Pass	8.4
U32	Fail	Pass	Pass	Pass	8.7

Table 8 Examples of the changed ratings under the new set of tolerances

This table shows that a low visual rating translates in most cases a "Fail" rating. The opposite applies to a submission that received a high visual rating from the judges. The initial "Fail" under ΔE_{ab} transforms into a "Pass" using any of the three newer color differencing equations listed in table 7. Therefore it is advisable that any of these three equations should be used to get a better correlation between visual perception and numerical data presentation.

Conclusions

The re-evaluation of the 86 submissions from the IPA Technical Conference proofing RoundUP in Chicago in June 2007 showed that it is useful to use the coefficient of variation to compare data with different means. When using the coefficient of variation in relation to a specific visual rating number the DE2000 equation seems to minimize the differences between the various submission that received this ratings, whilst the $DE_{CMC1:1}$ seem to amplify theses differences. If then all coefficients of variations are plotted against the visual rating score it is the $DE_{CMC1:1}$ equation that seems to correlate well with the perceived accuracy of color reproduction in the evaluated proofs.

The data set presented also the opportunity to see if certain colors seem to be more problematic to reproduce than others. The most difficult colors seem to be at the light (Yellows) and dark (certain type of blacks and browns) end of the L*a*b*-scale. Any troublesome colors were at the edge of the gamut volume that is represented by the GRACoL2006_Coated1.txt file.

Newer color differencing equations like $DE_{CMC1:1}$, DE2000 and DIN99 give a truer numerical representation of color differences as they were perceived by the judges, who evaluated the proofs. If a similar event like the IPA proofing RoundUP will be held again it is advisable to use any of the three color differencing equations listed above.

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Appendix 1:

<u>Visual Judging Sheet</u>

<u>Rankings:</u>
1 for lowest ranking
10 for highest ranking
NAME: ____________________ DATE: __________________

Proof ID#	Quarter Tones	Mid Tones	Three quarter tones	Flesh tones	Neutrals (Grey)	Com ment
Example: #H6	*3*	*6*	*7*	*5*	*5*	*Mid tones too red*

Ranking Scale:
9 – 10 points: Excellent reproduction/ Excellent rendering of flesh tones
7 – 8 points: Slight shift/ very good rendering of flesh tones
5 – 6 points: Visible shift/ good rendering of flesh tones
3 – 4 points: Visible shift/ Questionable rendering of flesh tones
1 – 2 points: Large shift/ Poor rendering of flesh tones

Appendix 2:

Test patches from the IT8.7/4 target that showed a large color deviation ($\Delta E \geq 5$) under all five color differencing equations.

Patch	L*	a*	b*
10	48.13	73.3	2.38
28	40.57	63.28	-3.18
40	80.34	7.01	6.86
86	47.93	54.27	-13.84
210	40.63	14.92	-30.09
236	46.28	-16.14	-29.77
282	54.29	-41.68	-42.06
303	77.49	16.64	38.66
306	91.39	-4.11	48.47
307	48.28	70.95	17.76
358	26.57	28.31	-25.52
368	66.46	14.01	25.03
372	83.23	-12.73	36.36
396	46.12	-36.56	-36.33
460	68.36	5.47	5.4
498	39.68	7.83	-5.61
515	34.83	22.12	-20.16
535	51.32	-37.02	-3.93
546	57.95	-45.08	-12.4
556	26.54	26.76	-21.34
566	40.73	-33.4	-13.72
567	43.56	-39.73	-12.22
568	46.4	-46.02	-10.71
569	49.1	-51.93	-9.31
570	51.83	-57.85	-7.96
579	52.53	-53.19	-19.34
599	70.88	22.91	72.4
600	75.28	15.64	77.36
601	79.85	8.28	82.53
602	84.33	1.59	87.71
604	47.74	68.72	42.12
610	80.58	8.57	70.51
611	85.06	1.78	75.08
612	89.72	-4.87	79.97
620	85.93	2.07	59.43
621	90.56	-4.57	63.58
635	80.36	-3.4	80.76
644	81.12	-3.16	68.49
654	86.36	-9.19	57.09
669	80.72	-14.57	79.08
678	81.48	-14.3	66.5

694	39.77	50.53	32.54
695	43.91	41.57	36.39
711	77.39	-19.36	59.82
713	44.67	42.92	19.91
727	37.32	44.4	27.46
754	26.41	24.17	-13.55
801	61.25	-44.98	44.89
834	55.26	-57.16	34.25
838	39.54	-18.95	9.57
843	55.81	-55.15	24.32
867	50.12	-68.43	25
875	47.93	-59.49	13.4
876	50.58	-65.74	15.69
881	40.28	-36.93	-3.88
892	33.12	46.44	32.36
902	33.79	49.48	12
912	33.57	52.7	-2.66
918	8.01	-0.22	-0.15
925	29.72	38.3	25.2
985	20.62	2.21	-11.61
987	34.28	-31.49	-4.23
988	39.14	-42.81	-0.71
990	43.82	-53.32	2.46
1001	22.34	19.71	-10.79
1006	22.45	22.09	-17.42
1011	22.48	24.95	-24.5
1017	8.48	-0.16	-0.02
1018	39.97	57.12	40.19
1024	17.43	-0.33	0.3
1033	36.54	-44.72	1.54
1048	38.47	-28.16	-36.16
1050	15.79	-1.64	-1.37
1059	38.96	10.44	38.14
1060	43.75	2.11	43.56
1072	26.66	39.98	4.1
1077	26.45	41.59	-1.73
1082	22.5	29.2	20.37
1092	35.48	4.85	31.36
1117	31.57	36.9	22.52
1187	40.62	-53.43	18.25
1205	18.86	-2.54	-20.06
1219	9.23	14.29	2.02
1221	14.95	0.19	-0.14
1237	88.69	2.11	-6.62
1239	91.06	3.89	3.03
1246	86.3	3.53	2.74
1252	8.28	11.23	-0.92

1285	6.78	6.18	-4.5
1286	8.11	-0.97	-8.34
1287	9.29	-7.09	-10.73
1292	13.29	14.63	-11.51
1318	9.58	11.38	4.96
1351	8.47	8.35	1.92
1354	18.68	22.77	16.15
1357	33	-4.67	31.72
1362	14.95	0.19	-0.14
1363	17.12	0.11	-0.22
1379	91.47	-0.11	-1.97
1381	93.59	-0.06	-1.96
1384	7.22	3.36	-2
1385	8.34	-3.97	-3.48
1386	9.61	-10.75	-3.76
1391	15.7	15.74	5.33
1391	15.7	15.74	5.33
1395	88.94	-5.02	93.17
1396	89.04	-5	91.52
1397	89.19	-4.98	89.03
1398	89.45	-4.93	84.68
1399	89.72	-4.87	79.97
1400	89.99	-4.81	74.74
1401	90.28	-4.69	69.03
1402	90.56	-4.57	63.58
1404	91.66	-3.87	43.57
1413	94.76	-0.26	0.63
1417	10.16	7.87	6.8
1418	12.32	1.42	8.68
1419	14.73	-3.68	10.78
1426	19.55	-6.69	2.95
1450	9.06	4.93	4.38
1451	10.81	-1.85	5.79
1452	12.74	-7.4	7.74
1483	8.06	0.44	0.02
1484	8.98	-6.73	1.74
1485	10.24	-13.05	3.39
1492	82.71	4.95	4.66
1515	79.82	-8.98	52.37