WMU ICC Profiling Review 1.1

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Evaluating the Quality of Commercial ICC Color Management Software

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Abstract: The concepts and technology for an open color management system such as that specified by the International Color Consortium (ICC) have been around for a number of years. The adoption of this workflow by the graphic arts industry has been slow. A major contribution to the lack of popularity is that the quality and standards part of the ICC workflow is unregulated and the average user is unable to independently assess the quality of profiles and profile making software. This paper describes a process to evaluate the quality of ICC profiles and suggests that a simple, meaningful merit figure be established. A quality metric can be useful for two reasons. Firstly, it can provide feedback on how well a device has been characterized and therefore how good the device is likely to be in a color managed workflow. Secondly, a universally defined merit figure will allow the comparison of results across manufacturers. If vendor A is very good at making scanner profiles and vendor B is good with printer profiles, then the user can make informed choices appropriate for their workflow. If we are able to establish some standards for profiling, this will help to raise the quality of profiling software, assist user choice and lead to a greater acceptance of ICC color management in the graphic arts and prepress industry.

This research describes the issues that affect input profile generation and shows why input profiles may contain colorimetric inaccuracies. A Delta E merit figure for the quality of input profiles is described. Seven commercial profiling packages are used to make input profiles and the quality of the profiles is tested. It was observed in this research that four vendors construct input profiles with a Delta E of about 1. Other aspects of input profiles are also considered such as profile tags. The quality of monitor profiles is also investigated. A procedure for evaluating the quality of monitor profiles is described and eight monitor profiles are made and evaluated. The results show that for monitor profiles many manufacturers produce equivalent, good results. All tests were done on the Macintosh platform. The authors intend to continuously update this survey and re-issue the findings when new versions of manufacturer's software are released. In this review, results for input profiles and monitor profiles are evaluated. Future revisions will widen the survey to include digital cameras, LCD panels and printer profiles. In order to keep track of the findings it is suggested that this review be referred to as "WMU ICC Profiling Review 1.0".

Introduction

Color management is a recent development that has come about because lower cost computer systems have allowed digital color to come within the reach of the prepress house, the small office and even the home user. In the old days, digital color was the preserve of large, high-end systems like Crosfield Electronics (Crosfield, 1991). The same manufacturer would sell a color-imaging suite that included the monitor, software, scanner, proofer, etc. These were closed-loop systems in which all devices were designed and installed as one package and operated by skilled personnel. It was relatively easy to get, on the print, what was seen on the screen. However, those days are gone. Now prices have plummeted and everybody can have digital color on their desktop. This has created a problem because we can 'mix and match' so that parts of the system can come from different manufacturers. The nice cozy closed loop system doesn't exist anymore and no individual part of the chain can be sure what color 'language' the device before it or after it is speaking, or, what color other devices in the chain are capable of reproducing. An open color managed system, such as that specified by the International Color Consortium (ICC), addresses this situation and allows unskilled users to maintain color accuracy across a number of different input, display and print devices.

The principles of a color-managed workflow are now well established (Buckley, 1998), (Giorgianni, 1998), (Johnson, 2000), (Sharma, 2002a). A color management system can be defined as a system that uses input and output profiles to convert device dependent image data into and out of a central, device independent profile connection space (PCS). Device characterization information is stored in profiles such that an input profile provides a mapping between input RGB data and the PCS, and an output profile provides a mapping between the PCS and output RGB/CMYK values.

In a color management system, the accuracy of color from the input to the displayed image, to the printed image, depends primarily on the quality of the profiles involved. Only if the profiles represent a good characterization of the device can the system work well. However, there is no metric provided that can be used to specify how good or bad a profile is. It is suggested that, following profile generation, profiling software should report a quality metric. This will provide information on how well a particular device has been characterized. In a turnkey ICC color-imaging situation involving un-skilled personnel, a single merit figure can be used to devise a 'stop/go' decision making criterion.

A further use of establishing a metric is to judge the software program in relation to other commercially available software packages. Manufacturers are not generally interested in exposing themselves to scrutiny by publishing a metric or yardstick if it is not required. As the results of a color management profiling system are difficult to evaluate a metric would help customers decide on how much they are prepared to pay, i.e. make an informed decision on price and quality. Apart from establishing a metric, it is also necessary to give an exact prescription for how a metric is defined to ensure that all manufactures are measuring and publishing the same quantity.

The assessment of quality in ICC profiles and color reproduction is a complex issue involving everything from color science, psychophysics and image analysis to 'preferred reproduction' styles. It may be suggested that such a complex issue cannot be adequately quantified by a simple merit figure, for example colorimetric matching in the output profile can be easily quantified, whilst the quality of perceptual mapping is more difficult to evaluate. Nevertheless, as we cannot expect the average user to have advanced color-imaging expertise we need to have an indicative set of metric figures that can be used to evaluate a baseline standard.

Attempts have been made to evaluate the errors in color reproduction and results are described in the literature for the analysis of end-to-end errors in a soft-proofing system (Holub, 2000) and for evaluation of ICC profiles in relation to proprietary style files (Sharma, 2002b). Results have also been published to quantify the errors in digital camera characterization (Berns, 2001). Many of the issues that affect the quality of processed images using the ICC color management system have also been described (Zeng, 2001). An experiment similar to that described in this work was conducted by Adams and Weisberg (2000) on nine profile making software packages. However, they did not calculate the error for all patches in the test chart and did not isolate the errors of the input profile. As far as the authors are aware, a universal, simple and meaningful merit figure for the accuracy of ICC profiles has not been described in the literature.

This research proposes a metric system and uses it to evaluate the quality of a number of commercially available profiling packages, when applied to a flatbed scanner and a CRT display. First, we look at the results for an input profile. We describe why an input profile may have errors (fit issues) and then suggest a mechanism to calculate a Delta E (ΔE) metric. Following that, we use the metric to evaluate the quality of some commercial profiling packages. Some manufacturers quote their own ΔE figure. We compare these to our own and comment of the usefulness of the manufacturer's numbers. The issues regarding monitor profiles are then described. Where appropriate, the same set of companies that were used for input profile analysis is used for assessing monitor-profiling accuracy.

Input profile quality

In a color-managed system, it is necessary to provide a transformation between scanner RGB and device independent CIEXYZ or CIELAB. The process of generating this transform is called characterization. To construct the transform a scan is made of a standard characterization test chart to obtain scanner RGB values. The test chart patches are also measured using an instrument such as a spectrophotometer to provide corresponding LAB data. A mathematical relationship is then derived between the scanner RGB values and the corresponding LAB data. The transform information is stored as an ICC standardized 3-dimensional look-up table and this table constitutes the main component of an ICC input profile.

What does the accuracy of the input profile depend on and why can some vendors get better results than others? A major part of the profile accuracy depends on the transform used to determine the relationship between scanner RGB and the corresponding LAB or XYZ values. The literature describes a number of different ways to establish this transform relationship. It is possible to use data fitting processes that can range from a simple linear matrix approximation to higher order polynomial regression (Kang, 1997). Due to the non-linear relationship between dye density and tristimulus value, CCD flatbed scanners that are primarily designed to measure densities are poorly characterized by a linear transformation (Sharma, 1997). Therefore, the transform between scanner RGB and LAB is most commonly computed using polynomial regression. It may be necessary to use a higher-order polynomial least squares fit process to adequately characterize the scanner response. A least squares fit process solves simultaneous equations and, thus, determines a set of polynomial coefficients that relate scanner RGB to LAB. Because the polynomial fit process attempts to satisfy all the training set data, it is subject to fit errors even for the training points. A higher-order polynomial can introduce erratic results outside the training set region where interpolation or extrapolation occur, and produce local maxima and minima which lead to 'roll around' problems in processed image colors. The order of the polynomial needs to be carefully chosen so as to maximize colorimetric accuracy without introducing unwanted artifacts. Linearization is commonly used in conjunction with polynomial regression analysis (Kang, 1992) and often it is found that mapping RGB to XYZ is preferable to mapping RGB to LAB.

From the above it is obvious that constructing an input profile transform involves more than simple mathematical fitting of two data sets. It is not a trivial process to provide an accurate colorimetric transform between RGB and LAB and this is part of the reason that the results can show a wide variation in quality between different vendors.

What is the suggested metric for input profile quality? A ΔE metric for input profile quality is proposed. A general description of the metric evaluation process is that a scan of a standard test chart is used to make an input profile and then the *same* image is used again to test the profile and derive a ΔE metric (see Figure 1). The first part of the process is to make an input profile in the normal way. To construct an input profile a scan is made of the standard characterization test chart to obtain scanner RGB values. The data file for the test chart with corresponding LAB/XYZ reference values is obtained. The scan of the chart and the reference file are provided to a profile making software package that computes the mapping transform between RGB and LAB, populates a look-up table and saves the result as an ICC input profile. To do the test, the RGB values of the scanned chart image are processed through the input profile to arrive at processed LAB values. A program such as

Photoshop and a color management module (CMM) are used to do this. The processed LAB values are compared to the reference LAB values. Ideally, the processed data should match the reference data. Due to the fitting process described above, there is likely to be a difference between these two values. A ΔE calculation can be done between the processed LAB data and the reference LAB data and this is the suggested quality metric for input profile quality. This ΔE provides a visually relevant measure of the magnitude of color difference and is indicative of the likely errors that will be encountered in the workflow when the profile is applied to (or associated with) scanned images. As we are treating the input profile as a 'black box', the ΔE figure reflects the goodness of the underlying transform algorithm, quantization errors in the look-up table and any CMM concatenation errors. *This simple result is a useful guideline to the accuracy of the input profile and is the metric suggested in this work for assessing the quality of commercially generated input profiles.*

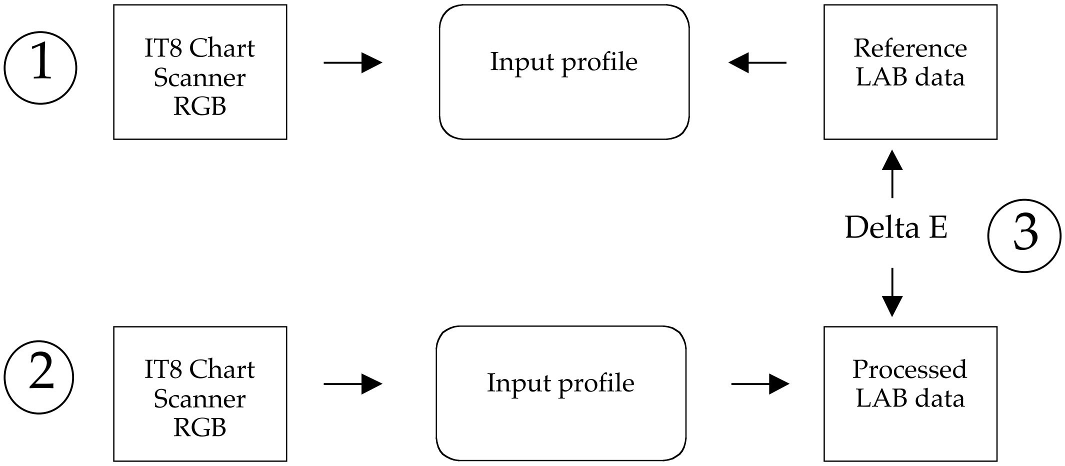

Figure 1. The proposed ΔE quality metric for input profiles. An input profile is created in the normal way using an IT8 chart scan and reference LAB data (1). Then the input profile is used to process the IT8 test chart to processed LAB (2). A ΔE calculation is done between processed LAB and reference LAB (3).

It is useful to note that whilst ΔE is a useful measure it is not an all inclusive quality measure and it would generally be necessary to consider image content issues as well. A 'busy' image may mask color errors whilst a single large color patch may accentuate the errors. Errors in mid-neutral gray may be more objectionable and easier to notice than the same error in a dark saturated color. For this reason a different ΔE metric may be more appropriate to use. Such image dependent analysis of input profile quality is implicitly contained within the suggested quality metric but not explicitly examined.

Procedure for evaluating input profile quality

An IT8.7/2 reflection test target was scanned on a Umax Astra 4000u scanner with all image correction controls turned off. The corresponding data reference file was located and an input profile was made using a number of different profile making software packages. The default option was chosen whenever any choices were offered to the user by the profiling software. The input profile was made and saved and any error figures provided by the manufacturers were noted. The following software packages were used - Gretag ProfileMaker 4.0, LinoColor ScanOpen ICC 2.1.0, Monaco Profiler 4.0, FujiFilm ColourKit Profiler 2.2, ColorSynergy 4.5, Kodak Colorflow 2.2.1. Additionally the Umax 4000u scanner, generic profile was used. The process was repeated for different IT8.7/2 targets so that at the end of the experiment, profiles were made using each manufacturer's software with an Agfa (Agfacolor paper, 1999:03), FujiFilm (Fujicolor paper, 2000:05) and Kodak (Ektacolor paper, 1997:04) reflection IT8.7/2 targets.

The raw scan of each IT8.7/2 chart image was opened in Photoshop 6.0.1 with color management Color Settings turned off. Each input profile was selected in turn using Image>Mode>Assign Profile and the image was processed to LAB using Image>Mode>Convert to Profile where the Destination Space was chosen as Lab Color. The rendering intent chosen was Absolute Colorimetric and the CMM used was Heidelberg. The Adobe Color Engine (ACE) was not used due to a bug in the current implementation. The system was using ColorSync 3.0.4. The above route was also duplicated using an Apple supplied Applescript routine called "Match to chosen profiles". It was confirmed that the Photoshop process described above and the Applescript route produced essentially identical results.

A computer program was written that opened and analyzed each IT8.7/2 test chart image. The program checked each TIFF image to see if it was little endian (PC) or big endian (Mac) image type. Next, the average LAB value of each patch was calculated. Typically, (for a 300 dpi scan) the average was done over a 36 x 36 pixel array located in the center of each color patch. The averaged LAB value of each color patch was compared to the original chart file used in the profile calculation. The average and maximum ΔE for each IT8 chart/profiling software pair was calculated. The D_{min} and D_{max} patches of the grayscale were not used in the ΔE calculation. The 'female model' part of the Kodak chart was also ignored. Thus 286 patches in the scanned test chart image were averaged for the Agfa and FujiFilm charts and 262 patches were used in the Kodak chart.

The accuracy of each vendor's program is shown in Table 1. A lower ΔE number is preferable. The manufacturers are ranked in order so that Gretag and LinoColor provided the best overall result whilst the generic profile was worst. How do we interpret these results? Profiles with a ΔE of around 1.0 (Gretag, LinoColor, Monaco and FujiFilm) are very accurate input profiles. This error is so small that it is probably not even noticeable given instrument repeatability and other system variables. ColorSynergy (average 2.86) occupied the middle ground and produced a profile that was not as accurate as the first group, but is certainly acceptable. A ΔE of up to 4 could be considered adequate so that these programs are likely to produce good results. A ΔE of greater than 4 has the potential to cause problems for color matching by graphic arts users. Kodak with an average ΔE of 8.27 should be used in non color-critical work. In color management circles, it is often asked how good is the generic profile supplied by the manufacturer? For this scanner, the generic profile, with ΔE of nearly 30 was very poor. The generic profile will not produce good results when used directly, however it can be used as the basis for profile editing as it has all the correct descriptors, tags and entries for a Umax 4000u scanner profile. In each case, the maximum ΔE should also be considered. This is likely to result from clipping in the original scan. However, a good profiling algorithm should deal with discontinuities in an elegant manner. To evaluate the implication of a high maximum ΔE it would be necessary to identify the colors in which this was occurring and then see if these colors featured prominently in the images being scanned.

A severe criticism of most programs was the lack of feedback to the user. Most programs provided very little if any confirmation that a profile of sufficient accuracy was successfully made. It is desirable that some indication of profile quality is provided. Of the companies surveyed, only Monaco Profiler, FujiFilm ColourKit and ColorSynergy reported error figures, Table 2. Monaco and FujiFilm had values that were close to our findings and it is likely that these vendors are doing an experiment very similar to that described here. ColorSynergy reported a predicted fit error of 0.0 in all cases, which was different to our calculations. A major point of this research is identified by this issue. If manufacturers quote a ΔE figure, but there is no clear specification as to how it is calculated, then the figure cannot be universally applicable. It is therefore suggested that all manufacturers agree to publish a ΔE figure and that they agree on how it is calculated.

Results for input profile quality

	Agfa IT8.7/2 Chart	FujiFilm IT8.7/2 Chart	Kodak IT8.7/2 Chart	Final result	Price
	Mean (Max) ΔE	Mean (Max) ΔE	Mean (Max) ΔE	Average ΔE	
Gretag ProfileMaker 4.0	0.85 (2.87)	0.99 (10.13)	1.23 (4.12)	**1.02**	$3,000
LinoColor ScanOpen ICC 2.1.0	0.99 (15.56)	1.12 (3.28)	0.96 (4.99)	**1.02**	Bundle
Monaco Profiler 4.0	1.19 (9.95)	0.92 (4.70)	1.19 (7.10)	**1.10**	$4,250
FujiFilm ColourKit Profiler 2.2	1.17 (3.98)	1.25 (4.53)	1.42 (3.66)	**1.28**	TBD
ColorSynergy 4.5	2.74 (11.17)	3.05 (10.09)	2.79 (10.43)	**2.86**	$1,495
Kodak Colorflow 2.2.1	6.86 (36.33)	11.20 (59.27)	6.75 (34.40)	**8.27**	$2,450
Umax Scanner generic profile	29.80 (44.55)	28.93 (42.03)	29.38 (46.67)	**29.37**	Free
X-Rite Colorshop 2.6.2	N/A	N/A	N/A	N/A	N/A
Apple ColorSync Monitor Calibrator 3.0.4	N/A	N/A	N/A	N/A	N/A

Table 1: The accuracy of each vendor's program is shown. A lower ΔE number is preferable. The last two entries in the table do not support input profiling.

Apart from the ΔE measurement described in this paper, there are other factors that could be considered when assessing input profile quality. For example, how knowledgeable and proficient are the manufacturers? Are the vendors aware of the profile quality setting and do they set it appropriately? The ICC (ICC, 2001) and ColorSync allow a quality setting within profiles. A profile is allowed to have a quality setting of Best, Normal or Draft. When a pair of profiles is presented to ColorSync, it checks the quality setting and processes the image data from source to destination accordingly. This setting provides a way to choose a concatenation that can be slow but good quality or quick but less accurate. The average user is unlikely to be aware of the quality setting tag, where and how it is set and the implications on color quality. It was useful to check all the profiles used in this experiment to see what setting the vendor placed in their profiles. This data is shown in Table 3. A sensible recommendation would be for profile making software to set the profile quality tag by default to Best. Profile using programs like Photoshop can then use their own strategy on how to use profiles, for example to override the tag and use Draft when displaying the image but to 'listen' to the profile when processing the image.

		Agfa IT8.7/2 Chart	FujiFilm IT8.7/2 Chart	Kodak IT8.7/2 Chart
		Mean (Max) ΔE	Mean (Max) ΔE	Mean (Max) ΔE
Monaco Profiler 4.0	Quoted by software	1.13 (9.27)	0.82 (4.29)	1.13 (7.54)
	Calculated in this research	1.19 (9.95)	0.92 (4.70)	1.19 (7.10)
FujiFilm ColourKit Profiler 2.2	Quoted by software	1.12 (4.45)	1.06 (4.42)	1.31 (4.09)
	Calculated in this research	1.17 (3.98)	1.25 (4.53)	1.42 (3.66)
ColorSynergy 4.5	Quoted by software	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	Calculated in this research	2.74 (11.17)	3.05 (10.09)	2.79 (10.43)

Table 2: What error did the manufacturers predict, and how did it relate to the findings of this research? Monaco Profiler and FujiFilm ColourKit agreed substantially with our research findings.

Monitor profile quality

Monitor technology is simpler to characterize than scanners or printers. The response of a monitor is generally characterized by a linear expression (the phosphor matrix) combined with a non-linear expression (the gamma curve) (Berns, 1996). Both these parameters are represented by tags within the monitor profile. With monitor profiles, a distinction can be made between characterizing and calibrating. In this context, characterizing refers to the process where the monitor profile simply represents the current state and behavior of the device. The monitor profiling process can often be extended to firstly calibrate *and then* characterize. By this we mean that the profiling software can be used to calibrate (adjust the response of the monitor to some selected condition, i.e. a chosen white point and gamma) and then characterize the monitor and save information regarding this new condition in the monitor profile. All Macintosh systems are capable of characterization and calibration, not all Windows systems are capable of calibration and characterization.

	Did the software ask the user for a quality setting?	What was the default quality setting ?
Gretag ProfileMaker	No	Normal
LinoColor ScanOpen	No	Normal
Monaco Profiler	No	Best
FujiFilm ColourKit	Yes	Best
ColorSynergy 4.5	No	Normal
Kodak Colorflow	No	Normal
Umax generic profile	No	Normal

Table 3: Hidden from most users is a profile quality tag that directs ColorSync during the color conversion stage of image processing. Only FujiFilm asked the user for this tag and only FujiFilm and Monaco set this 'correctly' to Best.

Macintosh monitor profiles are distinguished by the use of the 'vcgt' tag that is used to provide the calibration part of the system. vcgt stands for video card gamma tag and has been part of MacOS since ColorSync 2.5 (Apple, 1998). How is calibration to a user defined gamma and white point achieved? First the inherent, factory response of the system is determined. Then the software asks the user for the required gamma and white point. A correction is calculated and stored in the vcgt, such that the vcgt in conjunction with the factory response results in the user requested gamma and white point. On selection of a monitor profile, the data from the vcgt tag is downloaded to the video card and used to actively alter the system display.

For monitor profiles the suggested metric figure should confirm that the requested gamma and white point is achieved.

Procedure for evaluating monitor profile quality

The same manufacturers used in the input profile survey were used. One manufacturer (LinoColor ScanOpen) did not support monitor profiling. A 17” Mitsubishi Diamond Plus 73 CRT display was used on a Power Mac G4. To assist the profiling software the color temperature of the monitor was set to D_{65} using the external buttons on the front panel. The Gretag MeasureTool program and the Spectrolino spectrophotometer were used to set the optimum contrast and brightness for the monitor. The monitor profiles were made using different measuring instruments as shown in Table 4. Each monitor profile was made according to the manufacturer’s instructions except that where possible, the brightness and contrast were left unchanged. If offered a choice, the user selected a gamma of 1.8 and white point of D_{65}. In between each vendor, the vcgt tag was cleared by loading a profile with a linear vcgt tag. After each profile was made, it was selected as the system monitor profile. Using Photoshop 6.0.1 a series of solid patches were displayed on the monitor using an Actions script. The RGB pixel values of the patches were chosen to create a grayscale ramp as follows (0,0,0), (15,15,15) …….(255,255,255). The color management Color Settings were turned off and the RGB Working Space was set to that of the monitor profile being investigated. Each patch was displayed on the monitor in turn and the luminance Y was measured using a spectrophotometer. Log normalized RGB values were plotted against log normalized Y values. The slope of this plot gave the gamma of the display and these results are shown in Table 4.

Using a similar method to that described above, a white patch of RGB 255,255,255 was displayed and the XYZ values of the patch were measured using a spectrophotometer. The measured XYZ values were normalized to Y=100 (the color temperature is unchanged by a uniform rescaling of the XYZ values). The XYZ was converted to Lab for the chosen illuminant, D_{65}. Thus the XYZ of D_{65} converts to 100,0,0 LAB. A $\Delta E_{a,b}$ calculation was done to establish how close each profile was able to create the requested color temperature of D_{65} on the display. A $\Delta E_{a,b}$ figure was defined as:

$$\Delta E_{a,b} = (a^2 + b^2)^{0.5} = C$$

Thus, we see that the $\Delta E_{a,b}$ has a simple interpretation as the chroma, C, of the measured white point, referenced to the target white point. Finally, each monitor profile was opened in ColorSync Profile Inspector to confirm the presence or absence of the vcgt tag.

In terms of the gamma value, the monitor profiling results fell in to two camps. Profiles with a vcgt tag produced a gamma of 1.8 as requested by the user, whilst profiles without a vcgt produced a gamma of around 3.0, which is the native gamma of the display. Without the vcgt tag the profiling software merely reflects the current state of the device. With a vcgt tag, the gamma is shifted to that required by the user and a profile is then made of this new condition. When a monitor profile is loaded the contents of the vcgt tag are downloaded to the video card. If a profile does not contain a vcgt tag there is the risk that the video card may contain the contents of the last used profile. This situation can cause large errors and it is therefore suggested that if vendors choose not to implement a vcgt tag they should ensure that the video card does not contain the remnants of the last used monitor profile.

The difference between the color of the profiled monitor and the desired white point of D_{65} was calculated for each vendor. A high ΔE on a monitor is likely to be unnoticed. The ΔE between the desired and obtained white point was acceptable for all vendors.

Results for monitor profile quality

	Measuring instrument	Achieved gamma (Target gamma was 1.8)	$\Delta E_{a,b}$ difference in white point from a target of D_{65}	vcgt tag	Price
Gretag ProfileMaker 4.0	Gretag Spectrolino	1.81	0.58	Yes	$500
LinoColor ScanOpen ICC 2.1.0	N/A	N/A	N/A	N/A	N/A
Monaco Profiler 4.0	Gretag Spectrolino	1.85	0.68	Yes	$4,250
FujiFilm ColourKit Profiler 2.2	X-Rite DTP92	1.77	3.35	Yes	TBD
ColorSynergy 4.5	Gretag Spectrolino	2.99	4.07	No	$1,495
Kodak Colorflow 2.2.1	None	2.98	3.97	No	$2,450
Mitsubishi Monitor generic profile	None	2.99	3.83	No	Free
X-Rite Colorshop 2.6.2	X-Rite DTP92	1.76	5.81	Yes	$195
Apple ColorSync Monitor Calibrator 3.0.4	Visual	2.03	12.76	Yes	Part of Mac OS

Table 4: The accuracy of each vendor's program is shown in terms of the ability to match the requested gamma and white point.

Software 'bug' issues

In the process of this research a serious anomaly was discovered when using Photoshop 6.0.1 and the Adobe Color Engine (ACE).

To understand the problem we briefly review the contents of the input profile. The input profile can contain different look-up tables for different rendering intents - A2B0 (perceptual), A2B1 (colorimetric) and A2B2 (saturation). However this was not always the case. In the early ICC Profile Format Specification, input profiles used to have only one look-up table, which was called the A2B0 tag. In the 1998 specification, the A2B1 and A2B2 tags for the input profile were mentioned but were 'undefined'. In recent revisions of the ICC specification, the A2B0, A2B1 and A2B2 tags for the input profile have now been explicitly defined.

In Photoshop 6, when the Image>Mode>Convert to Profile command is used there is the option of selecting the rendering intent. When the user suggests perceptual, colorimetric or saturation intents they expect use of the A2B0, A2B1 or A2B2 tag respectively. *However the ACE CMM always uses the A2B0 tag irrespective of the user choice of rendering intent*. Heidelberg and Kodak CMMs work correctly and use the A2B0, A2B1 or A2B2 LUT in the input profile. This bug is not present in Photoshop 7 (presumably because it brings an updated ACE CMM with its installation).

Conclusions

A simple, easy to compute metric for input profile quality is described and evaluated for a number of commercial profiling software programs. Input profiles were only made on one type of scanner. This scanner is representative of a low end, consumer quality reflective flat bed scanner. It is possible that there is a variation in performance with transmissive scanners and with medium and high-end scanner systems. One such factor, which is not explicitly considered in these tests, is the behavior of the profile outside the training set data. It is possible that the training set points are constrained to give better agreement than other points in the color space. For this and other reasons it would seem reasonable to include real images in a test criterion. Whilst the described methodology does not explicitly test this aspect of input profile quality, examination of the ΔE values does reveal information about the potential behavior of the profile and provides a simple straightforward measure that should be adopted by the color management community.

In the survey some vendors fared better than others did, however this should not be taken as an endorsement of any particular manufacturer. The intent is to demonstrate that a rational metric for input profiles can be defined. With the metric defined, each manufacturer should be able to improve the quality of their profiles (possibly only by more judicious choice of "default" parameters during the profiling process).

A test for monitor profiles was described that included evaluating the gamma, white point and presence of the vcgt tags (for Macintosh profiles). There was a dichotomy amongst the results with vendors attaining the desired gamma when a vcgt tag was present or obtaining the factory condition when no vcgt tag was used. The industry needs more work in the area of monitor profiles to fully understand their usage and performance on both Macintosh and PC platforms.

We suggest that this survey be referred to as the "WMU ICC Profiling Review 1.0". Our aim is to continuously grow this survey by including manufacturers not covered in this first study. In this first part of the work results for input profiles (scanners) and displays (CRT monitors) are described. We are currently completing the next phase in which a similar scheme for digital cameras, LCD panels and printer profiles will be presented.

Color management is an important area as the increasing number of digital workflows fuels the demand for accurate, reproducible color in an open-loop color management system. This research is useful in helping the graphic arts industry get better quality profiles through a system of standards which, hopefully, will lead to a greater acceptance of the ICC workflow.

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Biographies

Abhay Sharma has a PhD from King's College London. He has been a lecturer in digital imaging at NESCOT, UK and University of Westminster, UK. Dr Sharma has worked as a Senior Research Engineer in the Colour & Imaging Technology group at FujiFilm Electronic Imaging where he was involved in developing color management technologies. He is currently an Associate Professor at Western Michigan University and is authoring a book on color management for Delmar Thomson Publishing.

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Version History

Version 1.0 Released 1 April 2002
Original release.

Version 1.1 Released 9 April 2002
One very small but significant change only in the result for Monaco monitor profiling. The monitor profiling was tested with an early beta. Monaco have supplied a newer beta version that is the release candidate for Monaco Profiler 4.0. We re-tested the monitor profiling. The Delta E in the earlier test was 8.15. In the new test this is greatly reduced to 0.68 and is representative of what will be in the final released product.