# Generation of an ICC Profile from a Proprietary Style File

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In color imaging technologies one of the major parts of the scanning procedure is processing the raw RGB scanner data to make it suitable for printing on a given CMYK output device. The processing typically involves applying a number of technical and aesthetic, iteratively developed edits. These edits are stored in a proprietary file format, i.e. a type of vendor-specific macro file. There has been a recent shift from this closed loop type of color control to the open system of color management such as that specified by the International Color Consortium (ICC). ICC color managed workflows can only use a universally agreed file called a profile, and not proprietary user edit files. It may have taken a long time to perfect the proprietary edits and users will not want to lose them when they migrate to the new ICC workflows. This article describes a process that allows users to convert color edit information from a vendor-specific proprietary edit file into an ICC profile. The proposed system works by analyzing the proprietary edit information and then incorporating this information into an input profile. The application of the input profile and an output profile then produces a set of processed CMYK values that, when printed on the target printer produce essentially the same result as that achieved through the proprietary route. As a major part of the process relies on the generation of an accurate input profile, a polynomial fitting process and an empirical process are investigated for use in generating the transform relationship. This research also considers the reversibility of the output profile and a process to ensure accurate reversibility of the output profile is presented. A discussion is presented on the choice of rendering intents available and the different situations where each would be appropriate to use. Experimental results are presented for the whole process based on a test transparency that contains an image of a Macbeth ColorChecker chart. Quantitative results are presented to show how an ICC profiled system can be created that mimics a given proprietary reproduction style to within $2\Delta E$. This research demonstrates how novel image engineering applications can be constructed from within the ICC framework.

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## Introduction

In color imaging technologies one of the major parts of the scanning process is editing and processing the raw RGB scanner data to make it suitable for printing on a given CMYK output device. The changes may be technical, e.g., to alter the tone reproduction curve so as to extend differentiation in the shadow areas or aesthetic, e.g. a particular user may prefer very saturated colors, like very green grass or strong blue skies. These user edits have until now been stored in a proprietary file format, i.e., a vendor-specific macro file that can only be used within each manufacturer's own environment. These proprietary files are part of the so-called 'closed' loop color imaging systems where the input and output are known. There has been a shift in recent years to move away from the closed loop system of color control to an 'open' color managed system. In an open color managed system such as that specified by the International Color Consortium (ICC), a profile provides a universally agreed file format for the user edit information. Most new color management software complies with the ICC profile format and will not accept the older proprietary user edit files. This poses a major problem as users will have spent many man-hours iteratively developing color edits and will want to be able to retain these edits within the new ICC workflows. This article describes a process that allows users to convert color edit information from any vendor-specific file into an ICC profile and thus migrate effortlessly from a closed loop proprietary system to an open color managed system. In this research the edits being referred to are 'image global' edits such as color corrections, spatially localized edits such as image sharpening are not included in this study.

The current research uses as an example the common situation of an RGB input device such as a scanner and a CMYK output device such as a printer. Consider an image placed on a scanner that produces RGB data, Fig. 1. The scanner data is processed according to some user edits so as to generate processed CMYK data that is in a format suitable for printing on an output device. The data has been modified so that when printed on the specific target printer it will produce results that meet technical specifications and/or are visually pleasing. The edit file may have taken a long time to perfect and typically may incorporate many modifications to suit individual customer requirements. The process described in this article is concerned with replacing the user edits of the proprietary file with an input profile. Then the application of

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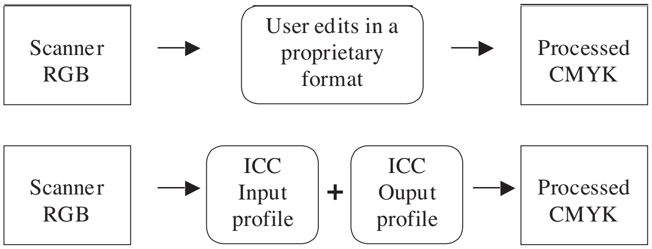


**Figure 1**. The aim of the current work is to replace a proprietary edit file with an ICC input and output profile.

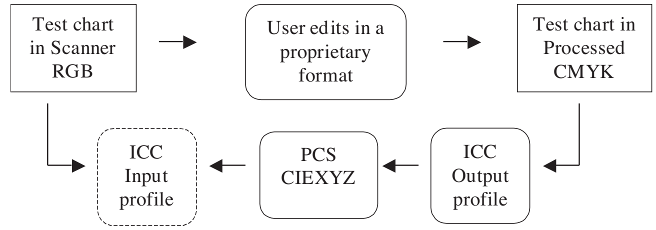


**Figure 2**. A test chart is processed to CMYK via the proprietary edit file. The CMYK patch values are converted via an output profile to XYZ. A new input profile is made between the RGB scan of the test chart and the new XYZ values.

the input profile and an output profile produces a set of processed CMYK values that when printed on the target printer produce essentially the same result as that achieved through the proprietary route.

The principles of a color managed workflow are now well established.[1–4] For the purpose of this research 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). Data in the PCS can be defined in terms of CIELAB or CIEXYZ. Device characterization information is stored in profiles such that an input profile provides a mapping between input RGB data and XYZ values and an output profile provides a mapping between XYZ values and output CMYK values. Of relevance to the current work is the ability to use output profiles in a ‘forward’ or ‘reverse’ direction. This is taken to mean that the output profile can be used in the forward mode to convert XYZ into CMYK and in the reverse mode to convert CMYK into XYZ data.

The proposed system works by analyzing the proprietary edit information and then incorporating this information into an input profile. How is this special input profile created? An input profile stores a transform relationship between scanner RGB values and PCS XYZ values. Normally 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 tristimulus XYZ data. A mathematical relationship is then derived between the scanner RGB values and the corresponding tristimulus data. This transform constitutes the normal input profile. The special input profile is created in a different manner, Fig. 2. A test chart is scanned to RGB and also converted to processed CMYK in accordance with the proprietary user edits. A normal ICC output profile, appropriate for the target printing device is then selected. The CMYK chart data is converted through the output profile to XYZ data. It can be seen that instead of the XYZ data normally obtained from the measurement of the chart we have different XYZ values obtained from the reverse processed CMYK data. It is now possible to compute a relationship between scanner RGB and the new XYZ data, thus creating the special input profile. Once created the special input profile can be used as a normal input profile. In subsequent usage, when an image is scanned the special input profile will map the RGB values to XYZ that will then use the forward part of the output profile to convert from XYZ to CMYK. It can be seen that application of the (special) input profile and output profile will thus produce results that are equivalent to those previously obtained using the proprietary user edit file.

A major part of this process relies on the generation of an accurate input profile, i.e. determining an accurate transform relationship between scanner RGB values and the specially manufactured XYZ values. The transform relationship can be considered to be a special case of the more general scanner characterization process that seeks to relate device color space to some device independent CIE measurement. 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.[5] The simple first-order matrix can be computed from only a few target values, whilst a higher order polynomial attempts to fit all the training set data. It is possible to use parametric *dye modeling* that uses mathematical models to predict the color produced on a film when specific amounts of each dye are present.[6] Finally, an approach that generally provides higher levels of accuracy is to *empirically* construct a lookup table.[7] Each method may have further parameters to consider such as the number of patches to use in the characterization, issues relating to fit accuracy, colorimetric accuracy of the transform, etc.

Due to the unique nature of the XYZ data in this research, it was necessary to carefully consider which type of transform mapping to use. Initially a polynomial data fitting process was used. It was found that the limited number of points (288) on the standard input scanner characterization chart did not provide enough information to adequately mathematically describe the user edits involved. The process was therefore also implemented using an empirical method with a custom made chart with 4096 patches whose usage was better able to represent the relationship between RGB scanner data and XYZ data. The empirical fitting technique was used to generate a 3-dimensional relationship between RGB and XYZ data using the custom made chart.[8] The polynomial fitting process and the empirical process are described in separate sections of this article.

This research also considers the reversibility of the output profile. The output profile is used initially in the reverse mode to convert CMYK to XYZ and then in the forward mode to process image data from XYZ to CMYK. For the system to work the forward and reverse procedures need to provide inverse results. An iterative improvement process to ensure accurate reversibility of the output profile is therefore presented. Under the ICC the output profile is allowed to have a number of rendering intents. A discussion is presented on the choice of rendering intents available and the different situations where each would be appropriate to use.

Experimental results are presented for the whole process based on a test transparency that contains an image of a Macbeth ColorChecker chart. Quantitative results are presented to show how an ICC profiled system can mimic a given proprietary reproduction style to within a couple of $\Delta E^*_{ab}$ for the reproduction of color patches of a Macbeth ColorChecker chart.

## Generating the Input Profile Using Polynomial Regression

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 and storing this transform is called characterization. The transform relationship is stored as a lookup table and constitutes the ICC input profile. The normal process for input profile generation has been described above. The current process differs from the normal process only in the way that the XYZ values are obtained.

Polynomial regression methods are widely used to calculate the transform between scanner RGB and XYZ. 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.[9] It is therefore generally 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 XYZ. 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 and produce local maxima and minima which lead to 'roll around' problems in processed image colors. The order of the polynomial therefore 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.[10] The training set data can often be made more linear by processing it to a different domain. When transformed into another domain a lower-order polynomial can provide an adequate fit thus avoiding the erratic tendencies of the higher-order polynomial. Finding the domain for the data that best approximate a lower-order fit may include taking logs or other conversions to the data set. Kang[11] shows it is possible to obtain gray balance curves using measured luminance Y or lightness L* from the gray patches of a test chart. The gray balance curves are then used to linearize the data by transforming scanner RGB into gray balanced RGB and finally it is the gray balanced RGB that is correlated with XYZ data.

In this experiment a standard IT8.7/1 Fujichrome transparency test chart with 288 color patches was used. The chart was scanned on a FujiFilm C-550 Lanovia flatbed CCD scanner. The scanner RGB values were obtained by averaging 64 pixel values that corresponded to each scanned patch. A scan of the chart was also processed in accordance with the proprietary edit file and the averaged CMYK chart values were processed through a reverse output profile to get XYZ values for each chart patch. The data was linearized and then a relationship between the scanner RGB values and the XYZ values was obtained using a polynomial least-squares fitting process. The polynomial equation was used to construct data for an input profile lookup table. It is generally necessary to estimate the accuracy of the transform. The accuracy of the transform can be measured by the fit error (correlation coefficient) or by using the transform to process the training set RGB values to XYZ. The difference between transformed XYZ and the target XYZ is calculated and can be expressed as an error in $\Delta E^*_{ab}$. Data for the accuracy of the transform is given in the results section.

## Generating an Input Profile Using Empirical Methods

An empirical approach was developed to improve upon the accuracy of the polynomial regression results. In the input profile generation method using the empirical approach, the function (in this case XYZ) is directly measured over RGB control values. A 3-dimensional lookup table is then used to represent the relationship between RGB and XYZ. Each cube node is described by an RGB triplet and an XYZ value is stored at that node. To get good characterization it is necessary to use a large number of samples typically ranging from 200 to 4000 data points.[10] The lookup table in this research consisted of 16 cube nodes in each direction giving a total of 4096 cube points. A chart image was made with 4096 patches where the RGB pixel value for each patch corresponded to an RGB node value. The chart was printed and then scanned and processed through the proprietary edit file to produce a CMYK image. Each patch was averaged and the CMYK value thus obtained was converted through the reverse part of the output profile to produce an XYZ value. Thus the RGB node values could be matched to XYZ values and this pairing empirically establishes the contents of the desired ICC input profile lookup table.

As described above a TIFF image with 4096 patches was constructed. Each patch in the image had pixel values that corresponded to one of the RGB node values of the lookup table. The TIFF image was output on transparency film and then scanned. Despite adopting best practices, the RGB values in the scanned image are extremely unlikely to be the same as the RGB node values that we started out with. In the following RGB(e) refers to the regularly spaced theoretical nodes that formed the original 'exposure' whilst RGB(s) refers to the RGB values that are obtained when the chart is actually 'scanned'. When images are scanned they are effectively in RGB(s) space, therefore the aim of the process is to produce a lookup table that maps the RGB(s) values to XYZ. It will be noted that due to the practical processes involved the RGB(s) values will not be regularly spaced. So if a lookup table is formed using the procedure described above, the cube nodes will be irregularly spaced. In theory the lookup table between irregularly spaced RGB(s) and XYZ is an accurate representation of the scanner response and as such is a perfectly valid mathematical representation of the situation. However in most color image processing software including ICC color management systems, samples must be evenly distributed along each axis.[12] What is required is reformatting of the information to present it on a regular grid. The following section describes a process that allows the RGB(s) data to be transformed from an irregular to a regular grid and the procedure used to calculate the corresponding change in the XYZ node values.

Figures 3a through 3e show a graphical representation of the lookup tables. For simplicity, RGB and XYZ are shown as 1-dimensional parameters. In the figures, the lookup table node address is shown within the grid and the content of the node is shown above the grid. Consider the RGB scan of the test chart and the relationship between the starting, regular RGB(e) and the irregular RGB(s). Since the location of each patch on the test chart is known, the original exposure value RGB(e) is known. Analysis of the scanned image provides RGB(s), so we can construct a lookup table that relates RGB(e) -> RGB(s), Fig. 3a. This lookup table has the regular RGB(e) values forming the cube addresses, with the irregularly spaced RGB(s) values as the contents of each address. It is possible to reverse the lookup table through a mathematical inversion process to give a lookup table that works the other way round and relates RGB(s) -> RGB(e), Fig. 3b. The inversion of the lookup table places RGB(s) on a regular grid. Now consider the processed CMYK test chart. The test chart is processed to CMYK in accordance with the user edit file and then processed via the reverse part of the output profile to XYZ. Since the location of each pixel on the test chart is known it is possible to derive a lookup table that relates RGB(e) -> XYZ, Fig. 3d.

The next step can be described as a lookup table concatenation process where two lookup tables are combined to produce a third lookup table. (Basically if A is related to B and B is related to C, by combining lookup tables we can relate A to C.) The RGB(s) -> RGB(e) lookup table is concatenated with the RGB(e) -> XYZ lookup table so that we get a final lookup table relating RGB(s) -> XYZ, Fig. 3e. This final lookup table relates RGB(s) to XYZ and represents the ICC input profile we are seeking. Importantly in this final lookup table the RGB(s) data is now expressed as regularly spaced cube nodes.

Consider a numerical example to illustrate the intricacies of the above process. Firstly consider the inversion of the lookup table that converts from RGB(e)->RGB(s) to RGB(s)-> RGB(e). Consider for example how to calculate the contents of node 45 using Fig. 3a and 3b. Simple linear interpolation can be used to calculate the RGB(e) value that should occupy node 45, Fig. 3b.

Ratio of RGB(e)/RGB(s) $= (45 - 30) / (53 – 36)$

$\Rightarrow$RGB(e) at node 45 $= [(45 - 30) / (53 – 36) * (45\text{-}36)] + 30$
$= 37.9$

Now consider the concatenation process. We have a lookup table Fig. 3c, relating RGB(s) -> RGB(e) and another lookup table Fig. 3d, relating RGB(e) -> XYZ. If we look up 45 in the RGB(s) -> RGB(e) table we obtain 38. This value is then looked up in the RGB(e) -> XYZ table. 38 falls between 30 and 45 so the XYZ value will be interpolated between these node values and the XYZ value is expected to be between 0.6 and 0.7. The equations below show the exact calculation for cube node 45.

Ratio of XYZ/RGB(e) $= (0.7 – 0.6) / (45 – 30)$

$\Rightarrow$RGB(s) of 45 $= [(0.7 – 0.6) / (45 – 30) * (38\text{-}30)] + 0.6$
$= 0.65$

Thus the final RGB(s) lookup table has for node 45 an XYZ value of 0.65. This process is repeated until entries for all cube nodes are found and the lookup table is completely filled.

It should be noted that whilst the final 16 point lookup table can be directly used, it is of course possible to generate an input profile with any other number of cube points. Any RGB(s) value that is not represented in the experimentally determined data is calculated using interpolation. In the results presented here the empirically determined lookup table was used in the default size, i.e. a 16-sided cube lookup table.

**Annealing the Output Profile**

It is necessary to consider the accurate reversibility of the output profile. Initially the output profile is used to convert CMYK values into XYZ for use in the input profile generation. Subsequently when the profile has been made and images are being scanned and processed, the input profile will convert scanner RGB into XYZ that

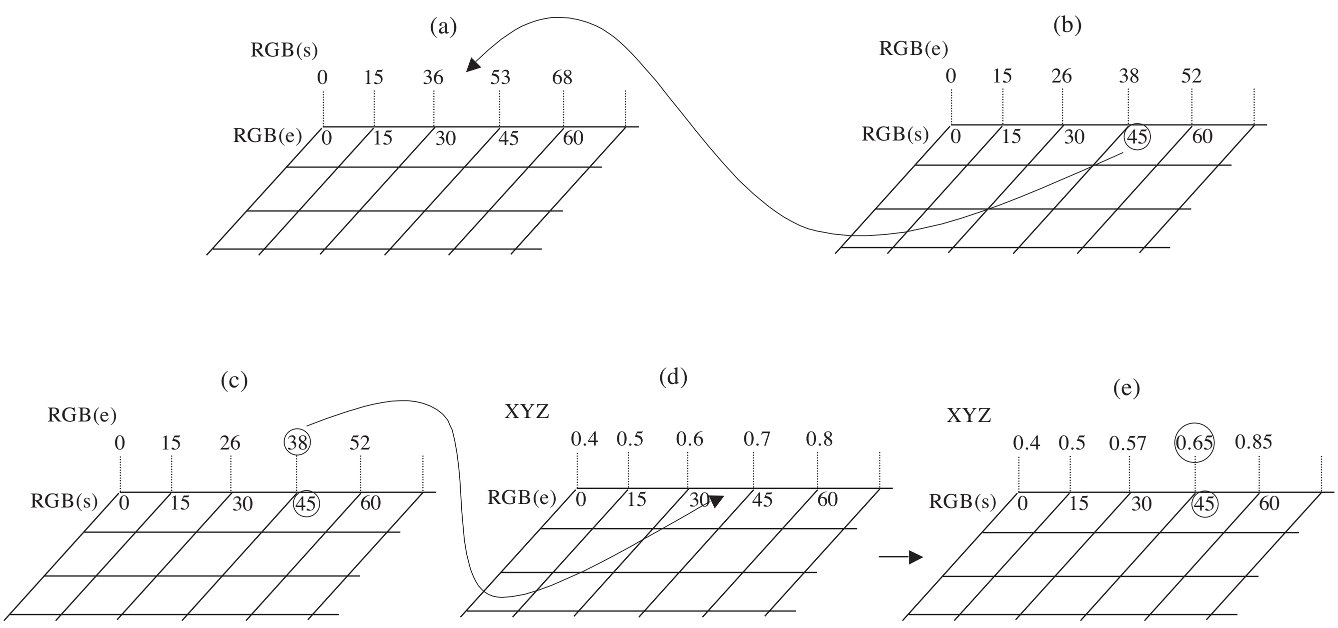


**Figure 3.** (a) It is possible to construct a lookup table between ‘exposure’ and ‘scanned’ RGB. This lookup table can be inverted (b). Concatenation of the inverted lookup table (c) with the XYZ lookup table (d) provides the final input profile lookup table (e).

needs to transformed to CMYK using the forward part of the output profile. It can be seen that for the system to work there should be little difference between the forward and reverse parts of the output profile. If CMYK mapped to some XYZ in the reverse operation then if presented with the same XYZ the output profile must map these back to visually the same CMYK. Only if this situation is true can it be expected that the ICC profiled route will produce the same visual results as the proprietary edit route.

There are a number of reasons why the output profile may not be reversible to a reasonable degree of accuracy. The output profile is essentially a lookup table and thus employs interpolation to find values not directly on the cube nodes. So use of the output profile is subject to interpolation errors. Another reason that the process may not be reversible is that the reverse mode of the output profile is normally only used for low resolution visual assessment and therefore will typically contain fewer cube nodes to minimize file size. A low resolution reverse cube will increase interpolation errors. As there are a number of such likely causes for the inexact reversal of the output profile the process was implemented with a modification to ensure reversibility of the output profile known in this context as 'annealing' the reverse engineered XYZ data.

The annealing process converted each CMYK chart value into XYZ using the output profile reverse mode. The process then tested to see if this XYZ when processed through the forward mode of the output profile would produce a new set of data called CMYK' that is similar to CMYK. If the forward process does not provide a sufficiently close value then a search is done until an XYZ is found where CMYK' is close enough to CMYK. This newly determined XYZ value is then used for the input profile generation safe in the knowledge that it will produce the required values when processed through the output profile. The data in the output profile is not changed. It is important to note that due to gray component removal (GCR) and undercolor removal (UCR) the same apparent color can be realized by different combinations of C,M,Y and K so that the dot% values of CMYK and CMYK' can only be meaningfully compared if the GCR/UCR parameters between the proprietary style file and the output profile are similar. The annealing process described was built into a computer program such that the program was presented with an output profile and the CMYK data, and the program produced suitably annealed XYZ data.

## Output Profile Rendering Intent

The ICC allows output profiles to contain four rendering intents – perceptual, absolute colorimetric, relative colorimetric and saturation. It is possible to store these intents as forward lookup tables relating PCS to device and as reverse lookup tables relating device to PCS.

The rendering intent is selected at two points in the process. The first time it is selected is when CMYK chart values are converted to XYZ via the reverse part of the output profile. The next time the rendering intent is selected is when images are being processed through the forward part of the output profile. If the priority in the application is to match the reproduction style of the proprietary edit file then it is appropriate to choose the relative colorimetric rendering intent when building *and* using the ICC input and output profiles. In this instance all that is required is a direct mapping between CMYK and XYZ (and vice versa) and this can be delivered by the relative colorimetric part of the output profile. However, if it is likely that the image will be subject to further edits or that in the ICC workflow the output profile will be changed at a later date, it would be appropriate to choose the perceptual rendering intent for both conversions. So if the same output profile is going to be used in the forward and reverse modes then either relative colorimetric or perceptual can be used. However if it is likely that the image will be edited or the output profile changed at a later date then it is advisable to use the perceptual route in and out of the output profile. It may be noted that in the proprietary route, if the output from the scan process is directed to another printer, the user edits will need to be recalculated and reapplied. With results from this research however it is possible if using perceptual rendering to change the output process and the output profile and thus easily achieve a similar appearance on a different output device. The argument in this case is that the XYZ values are what is needed to be reproduced, so by swapping an output profile, the perceptual intent will render the image appropriate for the new printing process.

Note that unlike other ICC workflows, once the special input profile has been made the rendering intent route through the output profile must not be changed. If relative colorimetric or perceptual intent was used in generating the input profile then the same intent must be used when processing images through the forward part of the output profile.

**TABLE I. Difference Between the Reproduction via the Proprietary Process versus the Profiled Processes. Error is Calculated from 24 Patches of a Macbeth ColorChecker Chart.**

| Type of input profile | ΔE (median) | ΔE (max) |
|---|---|---|
| Polynomial | 8.66 | 13.32 |
| Empirical | 2.27 | 4.08 |

## Results

The whole process was tried and a comparison made between a reproduction using a proprietary edit file and a parallel route using ICC profiles. In the ICC route two variations were explored – in one case the input profile was made using a polynomial fitting method and in the second case the empirical method was used. An image was scanned and processed to CMYK using the proprietary route and the two profiled routes. The images were all printed on a Fuji Pictrography 4000 (CMYK mode) printer and then measured to obtain CIELAB measurements. The $\Delta E^*_{ab}$ difference between the proprietary route reproduction and the two ICC routes was calculated for a number of test colors.

A FujiFilm C-550 Lanovia flatbed CCD scanner was used. The scanner is to be driven by a proprietary software program called C-Scan v5.1 and an ICC-compliant package called ColourKit v2.0. A Fujichrome IT8.7/1 chart with 288 test patches was used to make the input profile using the polynomial fitting method. The chart was scanned on the flatbed scanner. A scan of the chart was also processed to CMYK in accordance with a proprietary edit file in C-Scan. The CMYK chart patches were digitized and the data was put through the reverse part of an output profile to obtain XYZ values. These XYZ values were annealed to ensure that they could be transformed back to CMYK accurately. Finally polynomial regression was used to make an input profile be-

**TABLE II. Investigation of the Errors in the (Polynomial Based) Input Profile and Output Profile. Error is Calculated from 288 Patches of an IT8.7/1 Chart.**

| Error in profile | ΔE (median) | ΔE (max) |
|---|---|---|
| Input profile | 2.92 | 18.48 |
| Output profile | 1.06 | 8.89 |

**TABLE III. Difference Between the Reproduction via the Proprietary Process versus the Profiled Process for Different Rendering Intents. Error is Calculated from 24 Patches of a Macbeth ColorChecker Chart.**

| Output profile rendering intent | ΔE (median) | ΔE (max) |
|---|---|---|
| Relative | 2.18 | 4.71 |
| Perceptual | 2.07 | 4.14 |

tween the RGB scan of the IT8 chart and the annealed XYZ data.

To investigate the performance of the empirical route a similar operation was employed. A custom made chart with 4096 patches was scanned to RGB and also to CMYK using a proprietary edit file in C-Scan. The CMYK data thus obtained was converted to XYZ via the reverse part of an output profile. The XYZ values were annealed to ensure accurate reversibility. Cube inversion and concatenation processes were then used to generate an input profile that related RGB scan values to XYZ values.

A transparency image that contained as part of the subject a Macbeth ColorChecker chart was used. This transparency was scanned using the C-Scan software with the proprietary edit file and the image was processed to CMYK. This image was printed. The image was also scanned in ColourKit and processed to CMYK using the polynomial based input profile and the output profile, and then again using the empirically derived input profile and the output profile. These two images were printed alongside the proprietary results. The Macbeth ColorChecker chart in the image was measured from all three reflection prints using a Gretag SPM50 spectrophotometer and the difference between the C-Scan and the two ICC profiled results noted. Table I shows the difference in $\Delta E^*_{ab}$ between the proprietary results and the polynomial/empirical ICC routes. The results show that the profiled route is able to mimic the proprietary reproduction to within 2.27 $\Delta E^*_{ab}$ for the case of the empirically generated input profile.

The larger error in the polynomial case was investigated further. The accuracy of the input profile and the output profile were investigated separately to identify the source of the error. The accuracy of the input profile polynomial fit can be measured by using the polynomial to process the training set RGB values to XYZ. The difference between the processed XYZ value and the target XYZ is calculated and expressed as an error in $\Delta E^*_{ab}$, Table II. The accuracy of the reversibility of the output profile was investigated by taking a CMYK scan of the IT8 chart and digitizing it and passing the data through the output profile to XYZ and annealing it. The annealed values were converted back to CMYK'. It was not possible to directly compare CMYK' to CMYK because of differing levels of GCR/UCR, for example patch K4 on the IT8 chart had values of CMYK 75, 100, 39, 0 and CMYK' 67, 98, 22, 20. So the charts were printed and an X-Rite DTP41 spectrophotometer was used to measure their CIELAB values and hence calculate $\Delta E^*_{ab}$ between printed CMYK' and CMYK. The $\Delta E^*_{ab}$ calculation was done for all patches on an IT8 chart and the results are shown as Output profile in Table II. The results clearly illustrate that most of the error is coming from the inability of the input profile to adequately characterize the edit information.

The whole process was repeated again, but this time the rendering intent was changed, Table III. Three cases were considered: (i) the ColorChecker chart reproduction using the proprietary edit file; (ii) the ICC profiled route with an empirically generated input profile constructed with relative colorimetric route through the output profile; and (iii) the ICC profiled route with an empirically generated input profile constructed with perceptual route through the output profile. The results indicate that the perceptual and relative colorimetric rendering intent routes in the output profile give statistically similar results.

Note that the result for the relative case in Table I and III are slightly different because the experiment was repeated and the image printed out again and measured again. The slight difference in the numbers is simply due to experimental/instrumental repeatability.

## Conclusions

A system has been described that can convert any image global proprietary user edit file into a standard ICC input profile. This allows vendor-specific edits to be retained within an ICC color managed workflow. An ICC color managed workflow offers many advantages such as soft proofing, press proofing, easily changing the printer device, etc. Using the process described in this article it is possible to retain the look and feel of the proprietary edit system within an ICC workflow. Typical differences between the proprietary workflow and an ICC profiled workflow are in the order of 2 $\Delta E^*_{ab}$ which are well within acceptable limits of the intended applications. It is worth remembering that to get the most accurate match between the proprietary edits and the ICC route, spatial image processing operations like image sharpening should be comparable.

At present most vendors only offer conversion of their own user edit files into ICC profiles. For a vendor this may be as simple as changing the wrapper around the lookup table from a proprietary format to that compatible with the ICC. Unique in this research is the ability to convert *any* proprietary user edit file into a profile. The process described in this article is able to deal with any user edit file because the process analyses the effect of the user edit and is not concerned with the format of the file that the edit is stored in. The process may be used commercially to copy one manufacturer's hardware/software configuration and allow them to change supplier without losing their proprietary style files.

It was necessary in this research to investigate polynomial and empirical generation of the input profile. It is possible to make some observations as to why the polynomial method with only 288 samples is successful for normal input profile generation but was not appropriate in this research. Normally the target XYZ values are obtained by measurement of a photographic chart. In such a situation the XYZ data is representative of measurements produced from the relatively well behaved 'characteristic curve' type response of conventional photographic materials. In this research however the XYZ values are not directly based on photographic material but have been obtained via processing CMYK values through the reverse part of the output profile. The XYZ values in this research therefore embody any user edits contained within the proprietary edit file. A typical proprietary edit file may contain very extreme but narrow bandwidth edits which means that the XYZ data can be expected to be very non-systematic. The fitting process needs to be robust to cope with such non-systematic data produced from exotic proprietary edit files. Great care is therefore needed in choosing the transform fitting mechanism between RGB scan data and XYZ data. The data shows that the polynomial based transform produced unsatisfactory results while the empirical process produced much better results.

Normally one of the problems with an empirical method is the tedious and error prone requirement to measure a large number of chart patches. However in the current process it is not necessary to physically measure the chart patches because the software process generates the required data. This means that the data for 4096 samples was automatically generated from a scanned image and the advantages of higher accuracy of the empirical method is obtained without the onerous requirement of making a large number of measurements.

A further application of the current process is that it can be used to compare the CMYK values between proprietary systems and ICC profiled systems. In this instance an output profile should be constructed such that it has a similar level of GCR/UCR to that of the proprietary edit file, then other parameters of the reproduction routes can be compared.

This research demonstrates how ICC architectures and the ICC framework can be used in new situations that operate within the rules of the ICC yet allow the construction of novel image engineering applications.

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