Device Link Profiles / Repurposing CMYK

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Abstract

In many color managed workflows it is necessary to convert or repurpose CMYK files. There are several ways of doing this. Conversion using two ICC profiles is the most well known of these. The traditional profile conversion process uses one ICC CMYK profile as the input profile and another CMYK profile as the output profile. Another less common way of doing this conversion would be to use an ICC device link profile.

Each of these conversion methods has its own limitations; with a device profile conversion there is no control over the preservation of color or inks. With a device link profile conversion specialty software is needed to do the conversion. A new technology has been developed for the conversion and repurposing of CMYK this is Alwan Color Expertise's CMYK Optimizer. This product can convert and repurpose CMYK files without additional software or the problems associated with traditional device profile conversions. Another important feature of CMYK Optimizer is that it will analyze each CMYK file individually so that adjustments can be made based on the individual files composition.

To evaluate CMYK to CMYK conversions a variety of tests were developed. The evaluation tested the ability of the profiles to keep the purity of the inks, the colorimetric accuracy, the smoothness of transitions, the quality of photo reproduction, and ink consumption. The evaluation was broken up into two phases.

In the first phase of the evaluation, nineteen device link profiles were created with six different programs. Device link profiles were made that would test different combinations of features that are available in each program. To incorporate old methods and new technology into the evaluation a device to device profile conversion in Adobe Photoshop and Alwan Color Expertise CMYK Optimizer were run through the evaluation. The programs that were used to create the device link profiles were Alwan Color Expertise LinkProfiler, Chromix ColorThink, GretagMacbeth ProfileMaker, Heidelberg PrintOpen, Left Dakota Link-o-Lator, and MonacoPROFILER. The evaluation involved converting a PDF file that contained several images from SWOP (Adobe's US Web Coated (SWOP) V2 profile) color space to the color space of an Epson Stylus Pro 4000 printer using the Apple CMM. The resulting images were analyzed for color purity and ink consumption. The images were then printed on the Epson 4000 and evaluated for smoothness of transitions, quality of photos, and the colorimetric accuracy.

In the second phase device link profiles were made with Alwan Color Expertise LinkProfiler, GretagMacbeth ProfileMaker and Left Dakota Link-o-Lator; Alwan Color Expertise CMYK Optimizer and a device to device profile conversion in Adobe Photoshop were also used in this phase of the evaluation. This phase consisted of converting several images on a test form from SWOP (Adobe's US Web Coated (SWOP) V2 profile) color space to the color space of a commercial Man Roland sheet-feed press using the Apple CMM. The images were then printed and evaluated for color purity, colorimetric accuracy and ink consumption.

Introduction

There are many color-managed workflows where users may want to apply a specific sequence of ICC profiles repeatedly. If a user always requires a given combination of device profiles it can be safer and more convenient to merge the separate device profiles into a single profile called a device link profile. Device link profiles are an official ICC profile type and are used to concatenate together a series of profiles and their settings.

Device link profiles convert directly from one device color space (i.e. CMYK, RGB) to a different device color space without the use of a profile connection space (XYZ or L*a*b*). This is in contrast to an ICC device profile which converts from a color space to the profile connection space (PCS) and from the PCS to a color space.

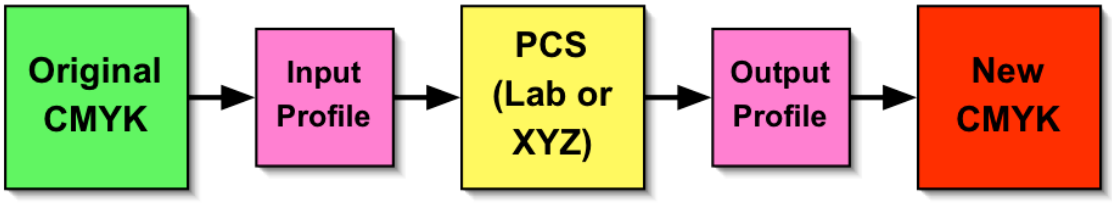

Figure 1: Processing image data using an input and ouput profile.

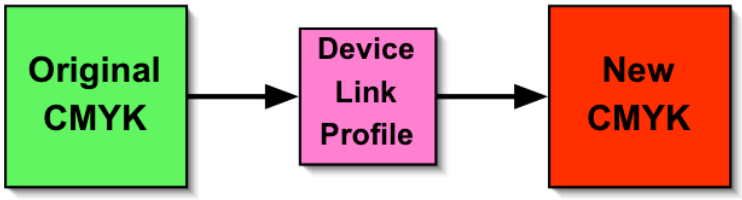

Figure 2: Processing image data using a device link profile.

Device link profiles describe a unidirectional conversion instead of the color characteristics of a device. Since device link profiles do not describe a device's color space they cannot be embedded into images, as can device profiles. Device link profiles concatenate a series of device profiles and their settings, including rendering intent; therefore only one device link profile is need for a conversion in contrast to the minimum of two profiles that are needed for a conversion using device profiles.

One use of device link profiles is in the printing industry where it is necessary to repurpose a CMYK image file from its original destination color space to output to a different destination CMYK color space. For example, images may have been separated for SWOP CMYK but may need to be converted to the CMYK color space for the press actually being used. The direct CMYK-to-CMYK color transformation provided by device link profiles can produce accurate color and make for an efficient color production workflow.

There are several software applications on the market that are capable of creating device link profiles. The software varies greatly in pricing and in functionality. There is one thing that all of the software has in common; in order to create a device link

profile you must have two device profiles that will be linked together. Some device link software, less commonly, allows for the linking of three or more device profiles.

The color management module (CMM), is the engine that allows ICC profile conversions to be made. The CMM plays an important role in the creation and application of device link profiles. The CMM does the actual math behind a profile conversion; each CMM will do this math slightly differently thus having an affect on the conversion. This also holds true when creating a device link profile, the CMM doing the calculation will have an effect on the device link profile being created.

The CMM is used at two places in a device link profile workflow. First the CMM is used in the creation of the device link, where it does the calculations to link the two profiles together. It is also used when the device link profile is applied to an image, where it does the calculations to apply the changes to an image. So if a low quality concatenation is done by the CMM in the creation stage the device link profile will always have low quality results regardless of how good the CMM conversion is when it is applied. However if a good quality concatenation is done when creating the device link profile the quality of the conversion can be affected by the quality of the CMM doing the application; so if a low quality CMM is used to apply a good device link profile the results may be low quality.

In common with device profiles, device link profiles contain look up tables. A look up table (LUT) is a table of input values with their corresponding output values. An example of a device link profile LUT would be converting proofer CMYK to press CMYK; in this case a proofer CMYK value (C10 M20 Y25 K5) would be looked up in the LUT and the corresponding press CMYK value (C9 M18 Y23 K4) would be found. Since all possible input and output values cannot be built into a LUT the LUT is built with varying number of quantized steps; the number of steps between 0% and 100% are often described as grid points. So a profile with a LUT with 11 grid points would have steps a 0%, 10%, 20% ... 100% and points in between these defined steps will be determined by interpolation by the CMM. The larger the number of grid points used in a LUT the more accurate the conversions in the profile can be. The LUT grid size is set by the software creating the profile and different software allows for different levels of control over the grid size. It should also be noted that the number of grid points affects the file size of the profile.

Advantages

As device link profiles do not use the PCS they provide better control over the transformation in a CMYK to CMYK color conversion.

One result of greater control is that device link profiles provide the ability to preserve pure colors. This feature is useful when processing images that, for example, contain 100% black text (C0 M0 Y0 K100), or drop shadows. In a standard device profile conversion, the pure black would be converted to a four color black (i.e. C75 M65 Y65 K85) this can cause printability and color issues. The reason device profiles are unable to preserve CMYK values is because the CMYK is first converted to three channels in the PCS and then back to CMYK. In this type of conversion it is difficult to ensure that any CMYK value will be converted cleanly. The many different programs used to create device links offer different options for preservation of colors

some programs offer no options while others offer preservation options for primary & secondary colors, registration marks, tints and solids.

In a device profile conversion details can be lost due to gamut compression. Some colors may intially have different CMYK values but when converted to the PCS the values may become the same and when the color is converted back to CMYK the difference is lost.

Several applications that create device link profiles allow the user to adjust the UCR/GCR when creating a device link. Without this feature it becomes necessary to edit or recreate the original device profiles which can take extra time and can result in undesirable results.

Since they are created using device profiles, device link profiles will generally provide a good colorimetric match. Some features, such as purity preservation and UCR/GCR edits, can reduce the colorimetric accuracy but they will yield better visual appearance or printability.

Since only one device link profile is needed for a conversion the confusion of rendering intents and multiple profiles is avoided. This can enable a workflow where all of the color correction is done so that it provides a good proof; then after the proof is approved the colors are converted via a device link profile from the proofer CMYK to the CMYK color space for the press. Using device profiles at least two profiles would be needed to convert the proofer CMYK to press CMYK and the rendering intent will need to be selected for each profile, leading to many potential ways to make the conversion. With a device link the conversion from proof to press only requires one device link profile and there is no need to worry about rendering intents.

Disadvantages

There are also disadvantages associated with using device link profiles. One of the problems is that they are unidirectional so once the profile is applied there is no easy way to undo the application. In such instances it may be necessary to work on a copy of the original image.

Unlike device profiles, device link profiles are not supported by all software applications. In particular Adobe Photoshop CS does not support device link profiles. Plug-ins are available that will allow the use of device link profiles in Photoshop. Other applications that support device links are some color servers (i.e. GretagMacbeth's iQueue), and some RIP systems.

In the same way that a separate device profile is needed for every different set of conditions (paper, ink, press, etc.); similarly different device link profiles are needed for conversions between different conditions.

New Technology

Alwan Color Expertise CMYK Optimizer is a software product that uses new technology to repurpose files which traditionally would have been subjected to a profile to profile conversion or a device link profile conversion.

The main use of this software is repurposing and standardizing CMYK files. Repurposing CMYK involves taking CMYK files that are prepared for one CMYK printing process and preparing them for another CMYK printing process. Standardization of CMYK files involves processing CMYK data that may have been prepared for different CMYK processes or using different UCR/GCR settings and adjusting them all to a single standard CMYK.

CMYK Optimizer includes features such as dot gain compensation and Total Area Coverage (TAC) adjustment so that no additional device profiles are necessary for different paper stocks or different printing presses.

The most unique feature in CMYK Optimizer is the dynamic TAC adjustment. CMYK Optimizer individually analyzes and adjusts each image so unlike traditional device links each conversion is optimized for an individual image. This dynamic adjustment also permits CMYK Optimizer to look at individual areas of an image and make exceptions to the TAC settings; this can allow for small areas that will not cause printability problems to have higher TAC, it can also limit TAC in large areas that could cause problems to less than the stipulated TAC setting.

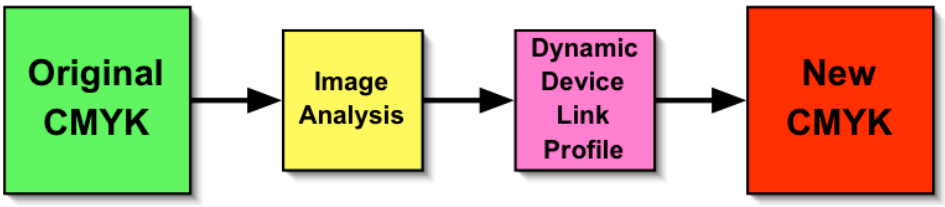

Figure 3: The conversion process in CMYK Optimizer .

Another feature that sets CMYK Optimizer apart from traditional device link software is that it processes images without the need for a conversion utility such as a color server.

Testing

Purpose

There are many different programs that will create device link profiles, thus an evaluation can be done to determine the relative quality of device link profiles from each vendor. Applications that were chosen for the evaluation are:

- Alwan Color Expertise – LinkProfiler 1.8
- X-Rite – MonacoPROFILER 4.6
- GretagMacbeth – ProfileMaker 5.01
- Chromix – ColorThink 2.1.2
- Heidelberg – PrintOpen 5.1
- Left Dakota – Link-o-Lator 2.01

Of these software packages, LinkProfiler and Link-o-Lator, are specialty software designed for the purpose of creating device link profiles. Three of the software packages, MonacoPROFILER, ProfileMaker and PrintOpen, are ICC profiling software that will create device profiles as well as device link profiles; ProfileMaker however sells the device link profiling capability as an add on to the device profiling package. ColorThink is a popular profile evaluation tool that has the ability to create device link profiles.

A device to device profile conversion was evaluated along side the device link profiles in order to determine if the device link profiles provide comparable results.

Alwan Color Expertise CMYK Optimizer is a new technology that is designed for repurposing files which would traditionally be subjected to a device to device profile conversion or a device link profile conversion. This technology was also evaluated to see what type of results it was capable of achieving.

Method/Results

This evaluation consisted of two phases. The first phase was designed to evaluate device link profiles in the proofing portion of a workflow. The second phase was used to test device link profiles in the press portion of a workflow.

Phase 1

To evaluate CMYK to CMYK conversions a variety of tests were developed. The evaluation tested the ability of the profiles to keep the purity of the inks, the colorimetric accuracy, the smoothness of transitions, the quality of photo reproduction, and ink consumption. In phase 1, nineteen device link profiles were created with six different programs; profiles were made that would test different combinations of features that are available in each program. Additionally a profile to profile conversion in Adobe Photoshop was evaluated. The programs used to create the device link profiles were:

- Alwan Color Expertise – LinkProfiler 1.8
- X-Rite – MonacoPROFILER 4.6
- GretagMacbeth – ProfileMaker 5.01
- Chromix – ColorThink 2.1.2
- Heidelberg – PrintOpen 5.1
- Left Dakota – Link-o-Lator 2.01

The evaluation used a test form (PDF file) that contained several photos, text, an ECI 2002 test chart and color ramps. The image file was converted from SWOP (Adobe's US Web Coated (SWOP) V2 profile) color space to the color space of an Epson Stylus Pro 4000 printer. This conversion was applied using a color server using the Apple CMM (OS X 10.3). The resulting images were analyzed for color purity and ink consumption. The test form was then printed on the Epson 4000 and evaluated for smoothness of transitions, quality of photos, and colorimetric accuracy. In each category the highest ranking device link profile from each software was used for the purpose of ranking the software packages therefore for each different test software may be represented by different particular device link profiles.

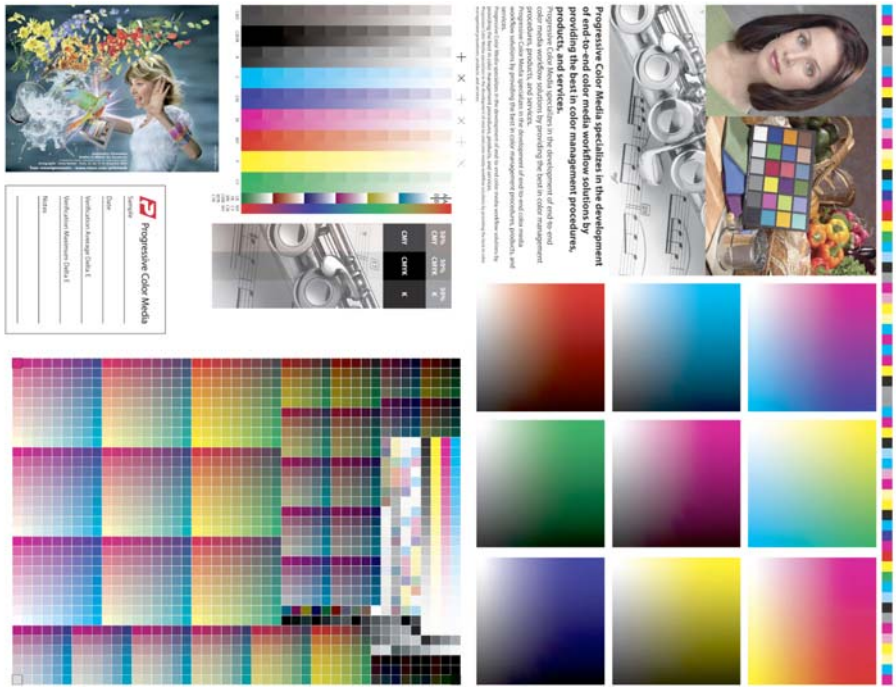

Figure 4: The test form that was used in phase 1 of the device link profile evaluation.

Ink Purity Test

Unlike device profiles, device link profiles have the ability to preserve pure colors. Therefore a test was designed to test the device link profiles' color preservation ability. One of the images on the test form was designed to test the device link's ability to preserve primary and secondary colors, black and color combinations, black text, registration marks, 3 color black and white paper. All of the categories in the purity test were judged on a pass/fail basis receiving one point for passing and zero for failing so the device link with the highest score (25 possible) was considered the best for purity preservation. The primary (C M Y K) and secondary (CM CY MY) colors were judged for purity at the solid (100%) and tints, three color black was also judged at the solid (100% CMY) and tints, black and color combinations (CK MK YK CMK CYK MYK) were judged at tints of 50% black and 100% color; the color was judged to be pure if there was no contaminate colors in the test image. The remaining categories were judged on the device link's ability to keep paper white free from contaminate colors, keep the registration marks at 400% and keep the 100% black text at 100% black and free from contamination.

INK PURITY SCORING – PHASE 1		
		Points Possible
Primary Colors		8
	Solids 4	
	Tints 4	
Secondary Colors		6
	Solids 3	
	Tints 3	
Black & Color		6
	Primary Color 3	
	Secondary Color 3	
Three Color Black		2
	Solid 1	
	Tints 1	
Solid Black Text		1
Registration Marks		1
Paper White		1
	TOTAL	25

Table 1: This table shows how the scoring for the ink purity test was broken down. The main categories are listed in bold and subcategories are in italics.

INK PURITY RESULTS – PHASE 1		
Score	**Software**	**Profile Name**
22	Alwan Color Expertise LinkProfiler	P1DVL06
17	GretagMacbeth ProfileMaker	P1DVL11
11	Left Dakota Link-o-Lator	P1DVL15
6	Heidelberg PrintOpen	P1DVL18
5	X-Rite MonacoPROFILER	P1DVL03
3	Chromix ColorThink	P1DVL01
2	Adobe Photoshop profile to profile	-

Table 2: Results from the ink purity testing

It should be noted that the device link profiles that performed well in this test are those with settings that offer very specific options for preservation of colors. The profiles that performed best in this test gave up a great deal of colorimetric accuracy in order to achieve the high level of color preservation. Some of the profiles with high levels of accuracy introduced undesirable effects in the transitions on the test form. In a production situation it would be inadvisable to use a device link profile with every preservation option turned on; a better solution would be to select the only preservation options that you need for the job you are using the device link profile for.

Colorimetric Test

A delta E metric was used to judge the colorimetric accuracy of a device link profile. The ECI 2002 chart was included on the test form. The ECI 2002 chart from the test form was printed on the Epson 4000 and measured using a GretagMacbeth SpectroScan. The delta E was calculated between the measured L*a*b* values and the predicted values. The predicted L*a*b* values were obtained by converting the ECI 2002 CMYK chart to L*a*b* color in Adobe Photoshop using the Adobe US Web Coated (SWOP) v2 with absolute colorimetric rendering and computing the L*a*b* values for each patch using a specialty software program designed at Western Michigan University. In Table 3, a lower delta E signifies a better performance.

DELTA E RESULTS – PHASE 1			
Avg. _ E	**Max. _ E**	**Software**	**Profile Name**
2.05	7.28	Alwan Color Expertise LinkProfiler	P1DVL07
2.13	9.19	X-Rite MonacoPROFILER	P1DVL04
2.34	6.91	Heidelberg PrintOpen	P1DVL17
2.40	12.06	GretagMacbeth ProfileMaker	P1DVL10
2.42	7.18	Left Dakota Link-o-Lator	P1DVL13
6.84	11.65	Chromix ColorThink	P1DVL01
2.35	6.71	Adobe Photoshop profile to profile	-

Table 3: Results from the delta E testing

The device link profiles that performed well in this test were those that were built using options geared towards low delta E. In general this meant there was no preservation options selected.

In this test all of the software with the exception of ColorThink was able to achieve an average delta E within 0.5 delta E of the best average achieved in this test. The difference of less than 0.5 delta E is within the variation of the printer and measurement instrument. The real difference lies in the maximum delta E; here LinkProfiler, PrintOpen, Link-o-Lator and the device profile to profile conversion in Photoshop are all within 0.5 delta E of one another, this in conjunction with the average delta E shows that these software packages are the most capable of creating device links with good colorimetric accuracy.

Visual Tests

Each of the device link conversions was subjected to two visual evaluations. The first evaluation was based on the smoothness of the transitions on the test form. This was evaluated and rated by a panel of viewers.

The viewers were asked to rate each of the nine transitions on the test form for smoothness on a scale of 1-3 with three being the highest and one the lowest. The results for each transition were averaged to come up with a score for each profile. The lowest possible score is 0, and the highest/best score is 27.

There were three types of transitions included on the form they were primary color blends (C&M C&Y M&Y) primary color with black blends (C&K M&K Y&K) and secondary color with black blends (CM&K CY&K MY&K).

VISUAL EVALUATION – TRANSITIONS – PHASE 1		
Score	**Software**	**Profile Name**
18.01	Alwan Color Expertise LinkProfiler	P1DVL07
16.90	GretagMacbeth ProfileMaker	P1DVL12
16.89	X-Rite MonacoPROFILER	P1DVL13
15.41	Heidelberg PrintOpen	P1DVL18
15.03	Left Dakota Link-o-Lator	P1DVL13
13.77	Chromix ColorThink	P1DVL01
17.27	Adobe Photoshop profile to profile	-

Table 4: Results from the visual evaluation of the transitions

In the second visual evaluation the same panel of viewers were asked to rate the appearance of the photos on the test form, they were asked to evaluate flesh tones, memory colors and black and white quality.

VISUAL EVALUATION – PHOTOS – PHASE 1		
Score	**Software**	**Profile Name**
6.63	Alwan Color Expertise LinkProfiler	P1DVL08
6.51	Heidelberg PrintOpen	P1DVL17
6.38	GretagMacbeth ProfileMaker	P1DVL09
6.13	Left Dakota Link-o-Lator	P1DVL15
5.76	X-Rite MonacoPROFILER	P1DVL03
4.88	Chromix ColorThink	P1DVL01
6.76	Adobe Photoshop profile to profile	-

Table 5: Results from the visual evaluation of the photos

The results are hard to analyze for this test because it was a subjective evaluation, and what one viewer may have found acceptable a second may have found objectionable. It is clear that the LinkProfiler device link and the Photoshop conversion provided the most acceptable results in the test.

There were some interesting information that became clear during the course of this test regarding purity preservation and profile grid size; this will be discussed in greater detail in the conclusion of this paper.

Ink Coverage Test

The final test in phase 1 was an ink coverage test. In this test the converted test form was opened and the ink coverage was estimated using Alwan Color Expertise's Ink Amount Adobe Photoshop plug-in.

This test was used to determine each device link's ability to limit the amount of ink that is laid down on the paper. The Ink Amount plug-in determines the amount of ink being used with a maximum of 100% coverage for each channel (CMYK) 400% total.

INK COVERAGE – PHASE 1		
Ink Consumption	**Software**	**Profile Name**
80	Alwan Color Expertise LinkProfiler	P1DVL07
86	GretagMacbeth ProfileMaker	P1DVL12
88	Chromix ColorThink	P1DVL01
88	X-Rite MonacoPROFILER	P1DVL03
93	Heidelberg PrintOpen	P1DVL18
94	Left Dakota Link-o-Lator	P1DVL15
100	Adobe Photoshop profile to profile	-
94	Original file	-

Table 6: Results for the ink coverage testing

In this test all of the device link profile software was able to save ink over the device profile to device profile conversion done in Adobe Photoshop. Even though each device link was able to limit the ink consumption over the Photoshop conversion, which actually increased the ink consumption from the original file, the applications that produced the device links that had the greatest ink savings were those that had the capability to redo GCR.

Conclusion

Not all device link profiles are created equal. The lower end device link profiles provide very little advantage over device profiles and in some cases they are at a disadvantage. This is illustrated by device link profile P1DVL01 created by Chromix ColorThink in phase 1 of the test. This profile was unable to achieve significantly higher results in the ink purity test than those achieved by the device profile conversion done in Adobe Photoshop; in fact it was the only conversion that was unable to keep the paper white free from contaminating colors. In the colorimetric and visual tests it again failed to improve upon the results than those provided by the device profile conversion; in fact the results were much poorer than those achieved using device profiles.

The higher end device link profiles such as those made by Alwan Color Expertise's LinkProfiler, Left Dakota's Link-o-Lator and GretagMacbeth's ProfileMaker device link module are capable of creating device link profiles that can achieve better results than those of device profile conversions. All three of these products are sold for the

sole purpose of creating device link profiles, so significant development efforts have gone into their capabilities.

In the ink purity test these three programs were the top performers this is due to the fact that they have the most extensive options in this area. The product with the most options for purity preservation, LinkProfiler, created a device link profile, P1DVL06, which achieved a score that was significantly higher than any other device link profile tested in phase 1. LinkProfiler has options for preserving secondary colors at tints other than the 100% solid as well as black and color combinations no other device link profiling software offers these features. Although LinkProfiler offers all of these options they are grouped together in a way that does not allow for selection of individual colors or combinations of color to be preserved.

A ProfileMaker device link profile, P1DVL11, achieved the second highest score in phase 1 of the evaluation. ProfileMaker when compared to LinkProfiler or Link-o-Lator has few preservation options; in fact it only has two; clean primaries and clean black. The clean primaries option is limited to the solid 100% primary (CMY) and secondary (RGB) colors. Even though it lacks options for preserving tints it still is able to do a good job of purity preservation if both the inks of the output device and the gamut mapping of output device profile used to create the device link profile are free from hue shifts.

Link-o-Lator, which placed third in the ink purity test, was the only software in the evaluation that provides controls over the preservation of the individual color channels, so for example yellow could be kept pure while cyan was allowed to become contaminated. It also allows for the preservation of secondary (RGB) colors at the solid 100%. Two possible factors that limited Link-o-Lator from making a device link that achieved a higher score are that there are no preservation options for tints of secondary colors, there are no options regarding handling of black and color combinations.

Neither X-Rite's MonacoPROFILER nor Heidelberg's PrintOpen provided ample options for preservation of pure colors; both only provided options for the preservation of the black channel. MonacoPROFILER only preserved the solid 100% black while PrintOpen was able to preserve the tints as well.

Virtually all of the device link software was able to produce good colorimetric matching results will all of the applications with the exception of ColorThink achieving average delta E numbers between 2.0 and 2.5. The real difference lies in the maximum delta E; here LinkProfiler, PrintOpen, Link-o-Lator and the device profile to profile conversion in Photoshop are all in between 6.7 and 7.3 delta E, this in conjunction with the average delta E shows that these software packages are the most capable of creating device links with good colorimetric accuracy

In the visual evaluation of phase 1 no clear pattern appeared as to what program was capable of creating the most pleasing visual results. However there were two insights that emerged from this testing. The first being that device link profiles created with too many purity/preservation options turned on can create undesirable artifacts or effects in the transitional areas of color. This is because by trying to preserve too many colors a device link profile's ability to transition smoothly is compromised because the preservation settings are too restrictive.

A second insight comes from the transition portion of the test. It was found that the number of grid points in a device link profile will have an effect on the size of these artifacts; when a larger number of grid points are used the size of artifacts can be reduced because the accuracy of the LUT is increased and the amount of interpolation is reduced. By increasing the size of the LUT it may be possible to eliminate or negate undesirable artifacts in images. Link-o-Lator and MonacoPROFILER allow for the selection of the number of grid points used in the LUT of device link profiles they create, with Link-o-Lator providing for the most flexibility in this area. LinkProfiler also allows for some selection in this area however the user can only limit the number of grid points used. The number of grid points used is either the smaller of the two device LUTs being concatenated together or a user selected number not exceeding 21. LinkProfiler chooses the smaller of the two.

In the ink coverage test each of the device link applications tested was capable of creating device link profiles that achieved better results than those provided using a device profile conversion in Photoshop. LinkProfiler again created the highest ranked device link profile P1DVL07. This particular device link profile was also the profile used in the visual evaluation for transitions and the delta E test. This proves that LinkProfiler is capable of achieving good colorimetric and visual results while limiting the amount of ink used.

Phase 2

The purpose of phase 2 of this evaluation was to analyze device link transformations from a generic CMYK profile (Adobe US Web Coated (SWOP) v2) to a custom profile created for a commercial press. One device link profile was made using each of the three software packages decided upon for further testing. The software used for phase 2 of the evaluation was:

- Alwan Color Expertise – LinkProfiler 1.8
- GretagMacbeth – ProfileMaker 5.01
- Left Dakota – Link-o-Lator 2.01

These device link profiles were applied to images on a test form with a color server using the Apple CMM (OS X 10.3). The test form was then printed on press and evaluated for purity, delta E, visual characteristics and ink coverage. For comparison the test form was printed out in CMYK with a device to device profile conversion done in Adobe Photoshop. To test new technology the test form was processed using Alwan Color Expertise's CMYK Optimizer.

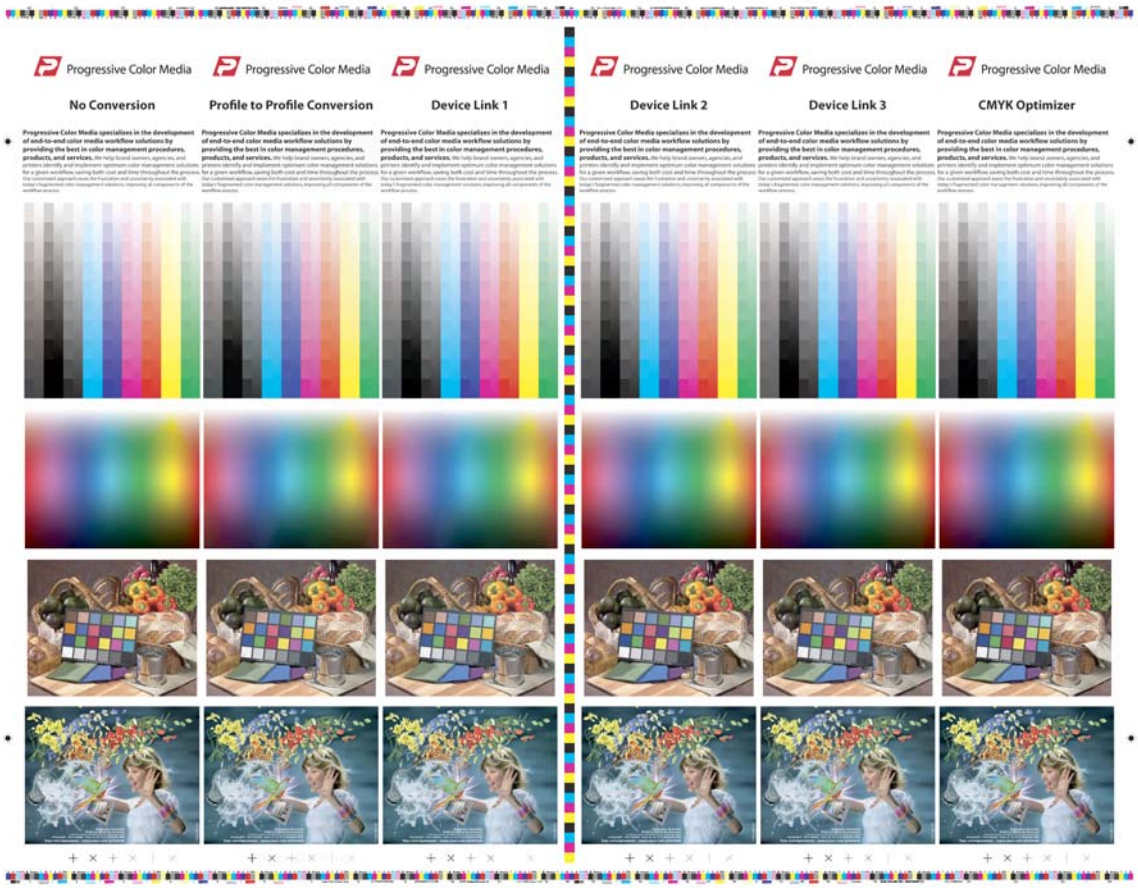

Figure 5: The test form used in phase 2 of the device link profile evaluation

All three of the device links that were used in phase 2 were created using similar options available in all three applications, the settings in CMYK Optimizer 1.6 were also set to be similar to those of the device link profiles. The settings used were; preserve primary colors (solids & tints), preserve secondary colors (solids only), and preserve registration marks. Each software had its own way of setting these options and not all options were available in all of the applications, see the appendix for details on settings used for each profile.

Ink Purity Test

A purity test was performed in phase 2 of the evaluation. It was scored the same as phase 1 with the difference being that the black and color combinations (CK MK YK CMK CYK MYK), and three color black were omitted so the highest possible score was 17. (These portions of the test were removed due to size considerations for the press sheet and the limited value that they would provide.)

INK PURITY SCORING – PHASE 2	
	Points Possible
Primary Colors ***Solids*** ***4*** ***Tints*** ***4***	8
Secondary Colors	6

Solids 3 ***Tints 4***	
Sold Black Text	1
Registration Marks	1
Paper White	1
TOTAL	17

Table 7: This table shows how the scoring for the ink purity test was broken down. The main categories are listed in bold and subcategories are in italics.

INK PURITY RESULTS – PHASE 2		
Score	**Software**	**Profile Name**
16	Alwan Color Expertise LinkProfiler	P2DVL02
16	Alwan Color Expertise CMYK Optimizer	-
14	Left Dakota Link-o-Lator	P2DVL01
13	GretagMacbeth ProfileMaker	P2DVL03
4	Adobe Photoshop profile to profile	-

Table 8: Results for the ink purity testing in Phase 2.

The device links and CMYK Optimizer performed well on the ink purity test for phase 2, as expected they outperformed the Photoshop conversion. LinkProfiler and CMYK Optimizer only lost one point do to some contamination that could have been cleaned up by preserving secondary colors. ProfileMaker and Link-o-Lator could not achieve higher scores probably because they do not allow the user to select preservation settings for the tints of secondary colors. ProfileMaker also lacks a preservation setting for tints of primary color and has no option for preservation of 400% registration marks.

Colorimetric Test

A second colorimetric test was performed on the converted images, this test was preformed by comparing the delta E of the converted images using Alwan Color Expertise's ColorPursuit. This program calculates the delta E for each pixel of the image and displays average and maximum delta E as well as what percentage of colors are within the target delta E range, 4.0. ColorPursuit also provides a visual representation of the delta E of the image. The delta E images generated by ColorPursuit for each conversion are located in appendix 3.

DELTA E RESULTS – PHASE 2			
Avg. _ E	**Max. _ E**	**Software**	**Profile Name**
0.4	3.2	Alwan Color Expertise LinkProfiler	P2DVL02
0.4	4.8	Alwan Color Expertise CMYK Optimizer	-

0.7	6.7	Left Dakota Link-o-Lator	P2DVL01
1.0	6.0	GretagMacbeth ProfileMaker	P2DVL03
0.9	7.5	Adobe Photoshop profile to profile	-

Table 9: The delta E results as determined using Alwan Color Expertise's ColorPursuit and relative colorimetric rendering intent.

All of the device links were able to achieve low average delta E numbers lower than that of the Photoshop conversion. The Alwan Color Expertise products were able to deliver the lowest average and their maximum delta E numbers were significantly lower than any of the competition.

In addition to calculating the average and maximum delta E, ColorPursuit also calculates the percent of colors that are within a set delta E limit; in this case the delta E limit was set at a delta E of 4. All of the conversions tested in phase two, device link and device to device profile, were able to achieve 98% or better colors within a delta E of 4. With the LinkProfiler device link 100% of the colors were below the delta E limit, and ColorPursuit reported that CMYK Optimizer had 100% of the colors were below the delta E limit because the area that had a delta E of 4.8 was so small it was not large enough to register $1/10^{th}$ of a percent.

Ink Coverage Test

The ink coverage test for phase 2 was performed in the same manner as phase 1; the converted test form was opened in Adobe Photoshop and the ink coverage was found using Alwan Color Expertise's Ink Amount plug-in. The Ink Amount plug-in determines the amount of ink being used with a maximum of 100% coverage for each channel (CMYK) 400% total.

INK COVERAGE – PHASE 2		
Ink Consumption	**Software**	**Profile Name**
110	Alwan Color Expertise CMYK Optimizer	-
116	Alwan Color Expertise LinkProfiler	P2DVL02
116	GretagMacbeth ProfileMaker	P2DVL03
123	Left Dakota Link-o-Lator	P2DVL01
123	Adobe Photoshop profile to profile	-
124	Original File	-

Table 10: Results for the ink coverage testing

As in phase 1 the software that has the capability to adjust the GCR had better results than the software that did not in this test. It can be noted that all of the software, except for Link-o-Lator, was able to limit the ink better than the Photoshop conversion. Although Link-o-Lator still used the same amount of ink as the Photoshop conversion it did so with purity settings such as 400% registration marks and preserving primary and secondary colors, so these were not altered as they were in Photoshop. CMYK optimizer was able to limit the ink better than any of the device link profiles.

Conclusion

Given that the device link profile software selected for this phase of testing were already known to create high quality device link profiles it was expected that the device link profiles created for this would perform well, and they did. What was unknown though was how Alwan Color Expertise's CMYK Optimizer would compare to the device link profiles.

The ink purity test in phase 2 had a smaller scope than that of phase 1 because of limited space and limited value of some properties that were being tested. Alwan Color Expertise's LinkProfiler again came out on top of this test but this time it was joined by CMYK Optimizer both loosing only one point due to a slight contamination in one of the secondary color tints, this could have been solved by selecting preserve secondary colors. Left Dakota's Link-o-Lator came in second due to contamination in the tints of secondary colors. GretagMacbeth's ProfileMaker lost one point due to the fact that it could not keep the registration marks at 400% they were instead reduced to 66% CMY and 100% Black. The other points the ProfileMaker lost were due to contamination in the primary and secondary tints.

In the colorimetric test every conversion method tested was able to achieve an average delta E of 1.0 or lower. LinkProfiler and CMYK Optimizer both achieved the lowest average delta E and maximum delta E numbers. LinkProfiler was able to keep all of the values under the delta E limit which was set at 4. CMYK Optimizer had a very small area that was over the delta E limit; this area was small enough that ColorPursuit still reported that 100% of the colors were under the limit, so the area would not be sufficiently noticeable and should not cause any problems.

Link-o-Lator was able to reduce the average and maximum delta E so that they were lower than the Adobe Photoshop device profile conversion. ProfileMaker was able to reduce the maximum delta E slightly better than Link-o-Lator but it raised the average delta E to 1.0 versus the 0.9 that can be achieved using device profiles in Photoshop. ProfileMaker was able to keep 99.8% of the colors within the delta E limit when Photoshop and Link-o-Lator could only keep 99.0% and 98.9% respectively within the limit.

In the ink coverage test CMYK Optimizer was able to limit the amount of ink better than any of the device link profiles. LinkProfiler and ProfileMaker both utilized the same amount of ink and were unable to match the limiting power of CMYK Optimizer. Link-o-Lator and the Photoshop conversion were only able to save a limited amount of ink over the original file. This goes to show that the ability to adjust GCR settings in a device link profile or with CMYK Optimizer can allow for ink savings; that would otherwise need to be achieved by editing or recreating an output device profile.

Conclusion

For CMYK to CMYK conversions device link profiles provide for much more flexibility than that of device profiles. They can allow for pure color/ink preservation, exceptional colorimetric accuracy, and ink savings.

To avail of the full benefits of device link profiles, specialized software is needed. CMYK Optimizer provides this functionality that is missing from device link profiles by processing and converting the file within the application.

Since CMYK Optimizer is processing and converting the files on its own it is able to analyze each file individually and make dynamic changes based on the composition of the file. This dynamic adjustment along with the underlying device link technology allows for CMYK Optimizer to repurpose CMYK files better than any other method that was tested in this evaluation.