Methods to Calculate the Number of Reproducible Spot Colours for Different Printing Processes

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Abstract

This experiment tests the number of PANTONE+ Solid Coated spot colours that are within the printable gamut of different printing processes represented by the following ICC Profiles: Coated GRACoL 2006, Coated SWOP 2006 Grade 3, Coated SWOP 2006 Grade 5 and a custom profile for the Heidelberg Printmaster 74-4-P at the School of Graphic Communications Management. This experiment does this by exploring methods to analyze the number of reproducible spot colours within particular ΔE allowances, using various measurement programs (Chromix ColorThink, Esko Color Engine Pilot and Argyll CMS V.1.6.3). By looking at the percentage of spot colours that can be reproduced by different printing processes, one can evaluate how well suited a printing process is to producing various PANTONE+ Solid Coated colours. This provides an easy to understand metric that represents the gamut volume of a device, e.g. "Device X can reproduce 60% of the PANTONE library."

Understanding the methodology behind the process of calculating the number of reproducible spot colours is important in order that this process can be applied to other situations in which the user is trying to determine the reproducible number or percentage of any set of colours in a given profile. Beyond this, this methodology can be used to compare different devices using their ICC profiles to determine which process is best suited to reproducing a specific set of colours for a specific client or job. The comparison of different methods (using different programs) of calculating the number of reproducible spot colours showed that each method returned similar results. Therefore, the choice of measurement method does not significantly impact the results. What then differentiates the programs is the ease of use, cost, and ancillary features.

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1. Introduction

1.1 Nature of the Topic

This experiment makes use of Chromix ColorThink Pro 3.0.3, Esko Color Engine Pilot Version 14.0.1, and Argyll CMS V.1.6.3 to measure the number of PANTONE+ Solid Coated spot colours that fall within the printable gamut of different printing processes, i.e., Coated GRACoL 2006, Coated SWOP 2006 Grade 3, Coated SWOP 2006 Grade 5, and a custom profile for the Heidelberg Printmaster 74-4-P at the Heidelberg Centre, School of Graphic Communications Management in Toronto, Ontario. Figure 1 shows a 3-D comparison of the gamut volume of Coated GRACoL 2006 in relation to the PANTONE+ Solid Coated library. At a glance, one can see that some PANTONE+ Solid Coated spot colours fall within the printable gamut, while others do not.

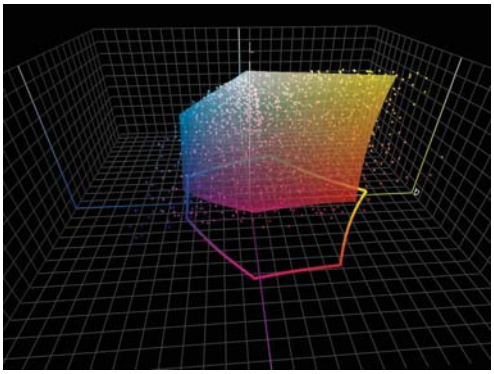

Figure 1. *3-D comparison of Coated GRACoL 2006 and PANTONE+ Solid Coated Library.*

1.2 Purpose

The purpose of this experiment is to understand the procedures and methodology involved in measuring the reproducible PANTONE spot colours of a printing process, within various ΔE^*_{00} tolerances. This experiment is relevant in understanding the process to measure how well a printing process or device can reproduce any known set of colours, whether it is a PANTONE library or not. Many printing companies market their gamut size as a competitive advantage; however, it is important to understand how to apply the gamut size data by determining the amount of colours that fall within this gamut. This experiment is also important in selecting a printing process when deciding how to run a job that is meant to be able to reproduce particular colours. By understanding the basics on how to analyze gamut size in relation to particular colour values, one can apply this knowledge to test whether their printing process is suitable for reproducing their desired colours.

1.3 Statement of the Problem

What is the process using various methods to calculate the number of reproducible PANTONE+ Solid Coated spot colours in an ICC profile representing different printing processes? How do the different printing processes differ in reproducing PANTONE spot colours and does it relate to the gamut volume? Do different programs measure this differently?

1.4 Hypothesis

Prior to conducting the experiment, the predicted results were that GRACoL would achieve the best results, producing the greatest number of PANTONE+ Solid Coated spot colours. The custom profile would produce the second greatest number of spot colours because the Printmaster 74 (PM 74) is maintained and calibrated to the GRACoL specifications. SWOP 3 would produce the second lowest number of spot colours, and SWOP 5 would produce the lowest number of spot colours. These predictions were made after observing the gamut volume of each profile in ColorThink. Predictions also included that all three-measurement methods would incur similar if not the same results for each profile.

Process	**ColorThink Gamut Volume**
GRACoL	403,137
PM 74	364,856
SWOP 3	355,586
SWOP 5	307,257

1.5 Existing Knowledge

In regards to printing PANTONE spot colours without the use of specially formulated inks, different printing processes will be able to accurately produce a number of PANTONE spot colours (Sharma, 2009). Depending on the printable gamut of each printing process, certain spot colours will fall inside the printable gamut, whereas other spot colours will not. For the spot colours that are within the printable gamut, these colours can be produced with accuracy. For the spot colours that fall outside of the printable gamut, there will be some colour difference that can be indicated by ΔE.

1.6 Description of the Experiment

This experiment makes use of three different colour management technologies. In order to conduct this experiment, a colour value list in L*a*b* format is required in order to test these colours against the different ICC Profiles (Coated GRACoL 2006, Coated SWOP 2006 Grade 3, Coated SWOP 2006 Grade 5, and a custom profile for the Heidelberg Printmaster 74-4-P at GCM). In this experiment, the colour value list consisted of the PANTONE+ Solid Coated colour library. This

colour library was used in ColorThink Pro in ICC format (generated from PANTONE Color Manager), and in Argyll CMS in a text file format. Esko Color Engine Pilot is loaded with certain colour books and for this experiment, the PANTONE+ Solid Coated book was already loaded. This existing colour book was used.

Each software followed a different procedure to generate the number of reproducible spot colours in the PANTONE+ Solid Coated library for each printing process. Esko Color Engine Pilot calculates these values quite automatically with particular settings. ColorThink and Argyll CMS follow the general format of mapping the PANTONE+ Solid Coated L*a*b* values to CMYK equivalents using the B2A table in the ICC profile and the Absolute Colorimetric rendering intent. Afterwards, the CMYK values are converted back to L*a*b* values where the differences can then be communicated by the ΔE. The ΔE values can then be analyzed in Microsoft Excel by sorting the numbers in ascending order.

2 Materials (Profiles to analyze)

- CoatedGRACoL2006.icc
- WebCoatedSWOP2006_Grade3.icc
- WebCoatedSWOP2006_Grade5.icc
- Filicetti_PM74_D50_150330.icc (measured from GCM's Heidelberg Printmaster 74-4 P)

3 Equipment

- Chromix ColorThink Pro 3.0.3
- Esko Color Engine Pilot Version 14.0.1 Build 45
- Argyll CMS V.1.6.3 for Apple OS (Experiment done using OS X Yosemite Version 10.10.1)
- Microsoft Excel (for Mac 2011 Version 14.2.0 was used)
- Microsoft Word (for Mac 2011 Version 14.2.0 was used)
- Terminal (Version 2.5)

Equipment used to create a custom profile:

- X-Rite i1iSis SN: 005165
- X-Rite i1 Profiler Version 1.5.6 software

4 Procedure

*Please note that the PANTONE+ Solid Coated ICC Profile generated from PANTONE Color Manager contained more PANTONE colours than the PANTONE+ Solid Coated ink book installed in Esko Color Engine Pilot. For this reason, consider the reproducible percentage of the library as opposed to the number of reproducible spot colours.

*Also note that the custom profile (Filicetti_PM74_D50_150330.icc) was created in i1 Profiler after measuring an IT8.7/4 target printed from GCM's Heidelberg Printmaster 74-4 P. This profile was chosen in order to compare the press capabilities to standard profiles. Any custom profile could have been chosen. The purpose of this report is not focused on how to create an ICC profile after characterizing a device; however, it focuses on the methods to measure the number of spot colours within the device gamut. These methods can then be applied to various ICC profiles to test the different device gamut in relation to spot colours, or any colour of interest.

In order to acknowledge the use of a custom profile in the experiment, the following procedure was followed using the X-Rite i1iSis and X-Rite i1 Profiler software.

1. Obtain a printed IT8.7/4 characterization target from the specified device or press (In this case, the IT8.7/4 was printed on GCM's Heidelberg Printmaster 74-4 P by Peter Roehrig, Technician at GCM).
2. Connect the i1iSis to a Mac computer equipped with i1 Profiler software.
3. In i1 Profiler, in Advanced Mode, select Profiling.
4. Select the test chart in use (IT8.7/4 R CMYK 1P ISIS XL BC).
5. Select the Dual Scan measurement mode.
6. Feed the test chart into the i1iSis after clicking Measure.
7. Once measured, set the lighting to CIE Illuminant D50.
8. In the Profile Settings tab, leave most default except:
    - Total Ink Coverage: 320
    - Table Size: Large
    - Granularity: 16 bit
    - ICC Profile version: 2 (Version 4 will not work well with Argyll)
9. Save the ICC profile as: Filicetti_PM74_D50_150330.icc

4.1 Using Chromix ColorThink Pro 3.0.3

1. Obtain a PANTONE+ Solid Coated ICC Profile from PANTONE Color Manager with 2618 PANTONE colours.
2. Import the PANTONE+ Solid Coated ICC Profile into ColorThink by dragging and dropping the ICC Profile over the ColorThink application icon. Click on Export color list.

3. Import the CoatedGRACoL2006 ICC profile into ColorThink, so that the two colour lists are adjacent to each other. Import the CoatedGRACoL2006 ICC profile into ColorThink a second time, so that the CMYK values are now listed as L*a*b* values.
4. Specify the Absolute Colorimetric rendering intent.
5. Click on the ΔE icon and make sure it is set to ΔE^*_{00} to compare the PANTONE Coated spot colours to the GRACoL gamut.
6. Save the ΔE^*_{00} list as a text file.
7. Analyze the text file in Microsoft Excel (Sort the data in ascending order to determine the number of spot colours under specific ΔE^*_{00} tolerances).
8. Repeat steps 2-7 for each ICC Profile.

4.2 Using Color Engine Pilot 14.0

1. Import the necessary ICC Profiles to analyze by going to ICC Profiles > Press > Register
2. Go to Tools > Gamut Check
   - Enter the following information
     Check Inkbook: PANTONE+ Solid Coated
     For: Profile
     Profile: CoatedGRACoL2006.icc
     Gamut Mapping: Closest Color (Classic)
     ΔE Formula: Delta E 2000
3. Specify the ΔE tolerance and record the percentage of spot colours that are reproducible.
4. Repeat steps 2-4 for each ICC Profile.

4.3 Using Argyll CMS V.1.6.3

1. Download the free software from argyllcms.com (This experiment was conducted using the executables for "Intel OS X 10.6 64 bit or later" for Apple OS X).
2. Follow the installation instructions provided by argyllcms.com
3. Export a text file of the PANTONE+ Solid Coated spot colours in L*a*b* form to use as the input values.
4. Drag the xicclu bin folder into the Terminal.
5. Use this sequence: xicclu –fb –ia profile.icc <input.txt> output.txt (Be sure to specify the location of the generated output.txt file).
   - -fb specifies the backward function, which uses the B2A (L*a*b* to CMYK) LUT (look-up table)
   - -ia specifies the Absolute Colorimetric rendering intent
6. Open the output.txt file in Microsoft Excel using columns where the data is separated by spaces. Delete all the excess data, leaving only the CMYK values (both clipped and unclipped).

7. Use this CMYK list as a new input file when following this sequence: xicclu –ff –ia profile.icc <inputCMYK.txt> output.txt. This will result in the L*a*b* values of the clipped and unclipped CMYK values.
    - -ff specifies the forward function, which uses the A2B (CMYK to L*a*b*) LUT.
8. Compare this L*a*b* list to the original PANTONE+ Solid Coated text file in ColorThink Pro in order to generate a ΔE*00 list. Before importing the text files into ColorThink, convert the text files into ANSI CGATS format by adding BEGIN_DATA as the header and END_DATA at the end of the data list, in addition to specifying the format between BEGIN_DATA_FORMAT and END_DATA_FORMAT.
9. Follow steps 4-8 for each of the ICC Profiles.

5 Results

Raw Data

	ΔE^*_{00}									
Process	**Less than 1**		**2**		**3**		**4**		**5**	
	#	%	#	%	#	%	#	%	#	%
GRACoL	1360	52	1640	63	1872	72	2076	79	2264	86
SWOP 3	1104	42	1440	55	1670	64	1910	73	2128	81
SWOP 5	958	37	1226	47	1422	54	1660	63	1880	72
PM74	1366	52	1708	65	1932	74	2086	80	2228	85

Table 1: *Using Chromix ColorThink Pro 3.0.3 (Total of 2,618 PANTONE spot colours observed)*

	ΔE^*_{00}									
Process	**Less than 1**		**2**		**3**		**4**		**5**	
	#	%	#	%	#	%	#	%	#	%
GRACoL	932	51	1069	59	1202	66	1350	75	1487	82
SWOP 3	804	44	953	52	1083	60	1221	67	1378	76
SWOP 5	693	38	815	45	925	51	1071	59	1211	67
PM74	935	51	1091	60	1236	68	1347	74	1464	81

Table 2: *Using Color Engine Pilot 14.0 (Total of 1,799 PANTONE spot colours observed)*

	ΔE^*_{00}									
Process	**Less than 1**		**2**		**3**		**4**		**5**	
	#	%	#	%	#	%	#	%	#	%
GRACoL	1388	53	1654	63	1858	71	2086	80	2260	86
SWOP 3	1160	44	1460	56	1674	64	1906	73	2118	81
SWOP 5	994	40	1248	48	1452	55	1678	64	1888	72
PM74	1442	55	1712	65	1932	74	2092	80	2226	85

Table 3: *Using Argyll CMS V.1.6.3 (Total of 2,618 PANTONE spot colours observed)*

6 Observations

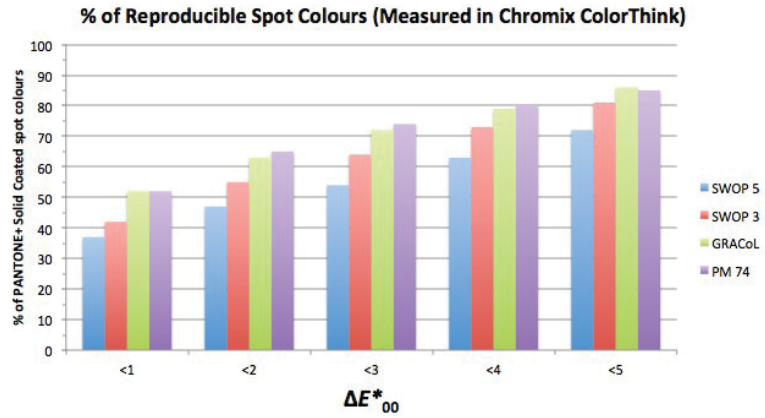

Figure 2.

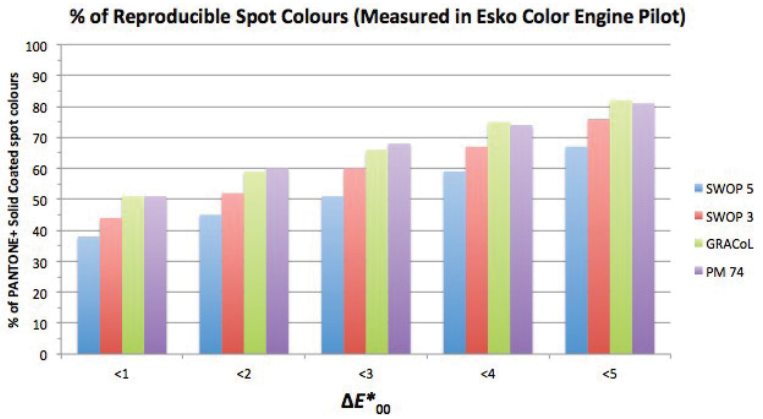

Figure 3.

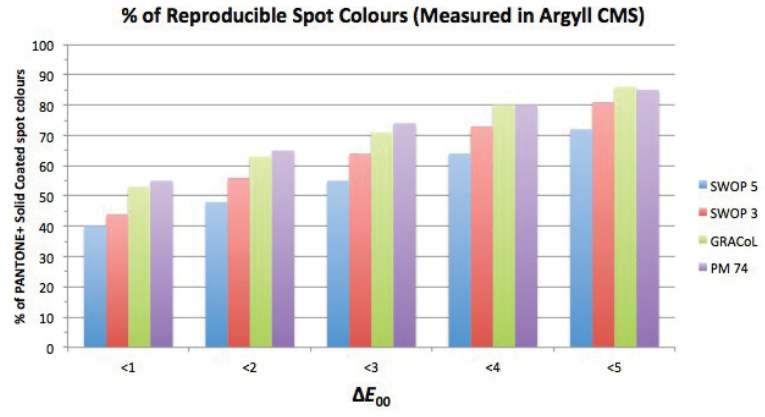

Figure 4.

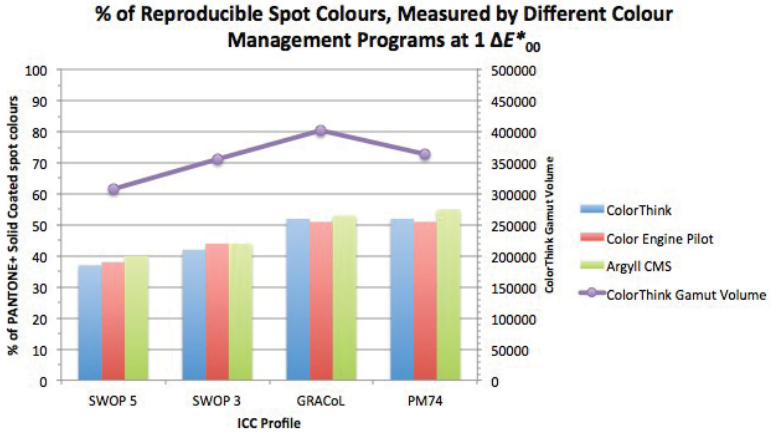

Figure 5.

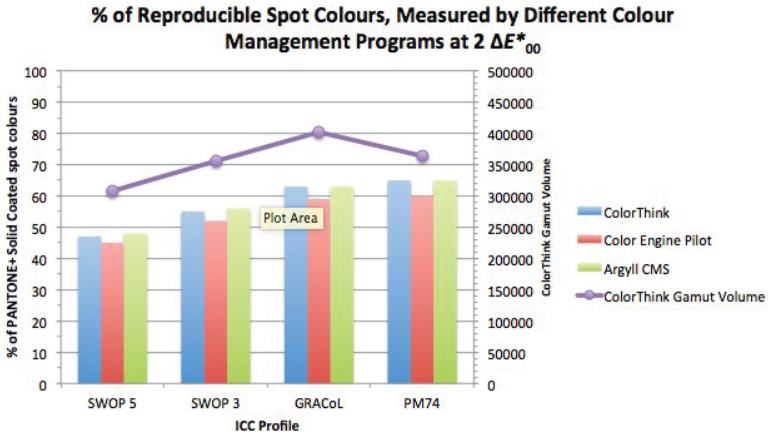

Figure 6.

7 Discussion of Results

Between the different methods (Chromix ColorThink, Esko Color Engine Pilot and Argyll CMS V.1.6.3), the process to calculate the number of reproducible spot colours differed. All three methods shared similar results, which show that both a packaged shelf solution such as ColorThink or Color Engine Pilot and a command line solution will be able to generate the desired results. There are certain advantages and disadvantages to each method, which are further discussed in the report.

7.1 Chromix ColorThink (as shown in Figure 2)

In order to measure the number of reproducible spot colours in ColorThink, a ΔE*00 list between the PANTONE+ Solid Coated L*a*b* values and the ICC Profile L*a*b* equivalent is analyzed. In order to do this, the process requires that

the PANTONE+ Solid Coated spot colours be mapped to CMYK values using the B2A look-up table of the Absolute Colorimetric rendering intent in the ICC Profile in use. Chromix ColorThink does this automatically when the PANTONE colour list is dragged into the workflow, followed by the ICC profile that is being tested. It is important to set the rendering intent to Absolute Colorimetric to utilize the look-up table that will give the most accurate colour conversion when the PANTONE L*a*b* values are being mapped to the CMYK equivalent in the profile (Dharavath & Uttam, 2014). This rendering intent matches the original colours when possible and maintains the white point of the source profile; therefore, will not affecting the colours further by mapping them to a different white point (Sharma, 2004).

In the conversion from PANTONE L*a*b* to the CMYK equivalent in the profile, there will be some changes in the colours as they are moved into the gamut of the ICC Profile. Those colours that were already within the gamut will be matched. Once this is complete, the CMYK values must then be converted back to L*a*b* in order to compare the colour to the original PANTONE+ Solid Coated colours and generate ΔE^*_{00}. To do this, the ICC profile is dragged into the workflow in ColorThink a second time, and ColorThink automatically computes and outputs the L*a*b* values. Again, ensure that the Absolute Colorimetric rendering intent is selected. At this point, ΔE^*_{00} can be calculated. By simply clicking on the ΔE button in the top left hand corner of the workflow, this can be accomplished. Ensure that ΔE^*_{00} is selected.

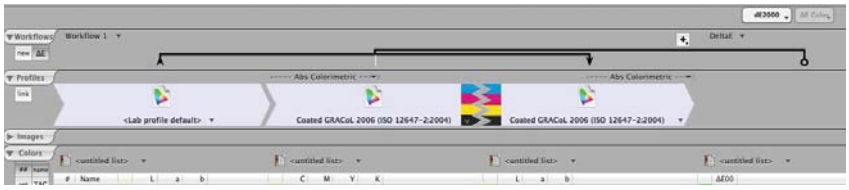

Figure 7: *This is a snapshot of the workflow.*

Export the ΔE^*_{00} list, by right clicking and using "Save List as." Once exported, the list can be opened in Microsoft Excel. For analysis purposes, delete the header information, so that only the ΔE^*_{00}values are left. By sorting the data in ascending order (Data > Sort), identify the precise number of colours that are below 1, 2, 3, 4 and 5 ΔE^*_{00}.

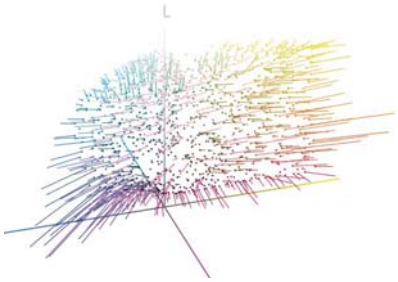

Figure 8.

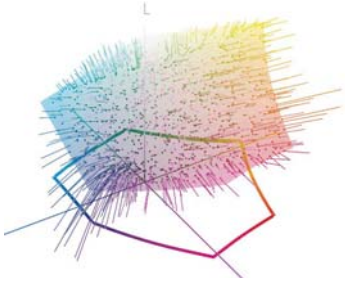

Figure 9.

Figure 8 shows the path taken by the PANTONE+ Solid Coated spot colours as they are mapped into the gamut of CoatedGRACoL2006.icc. In Figure 9, the GRACoL gamut volume is displayed in order to better visualize the PANTONE+ Solid Coated origin and destination in comparison to the GRACoL gamut volume. The points with the furthest trip or the longest line, indicate that PANTONE colours that are the furthest outside of the gamut and will generate the highest ΔE^*_{00} values.

Chromix ColorThink Pro performs this process very automatically and does so in a very visual manner. In ColorThink, the gamut volume can be mapped in a 2-D space or as a 3-D volume. This can be compared to individual PANTONE spot points, as shown in Figure 10 and Figure 11 using the Coated GRACoL 2006 ICC profile. Very quickly, the user can visualize the spot colours that are within and outside of the gamut.

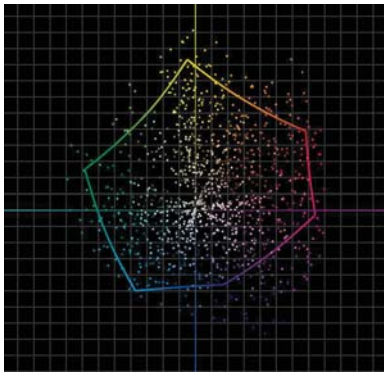

Figure 10: *2-D view of gamut volume.*

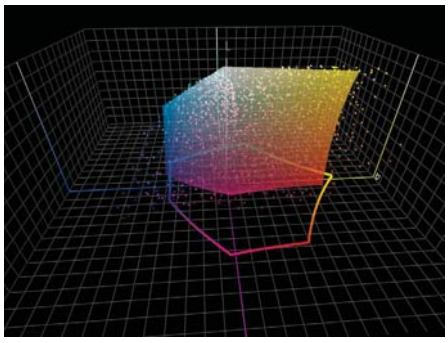

Figure 11: *3-D view of gamut volume.*

Figure 12 graphs all four ICC profiles at once in comparison to the PANTONE+ Solid Coated spot colours. This image allows the user to visualize the gamut to improve understanding of the relationship of gamut volumes between profiles, rather than comparing the number given to describe the gamut volume.

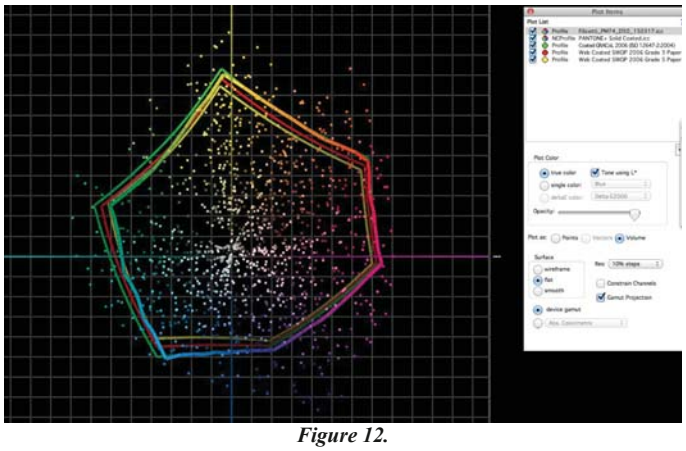

Figure 12.

7.2 Esko Color Engine Pilot (as shown in Figure 3)

Esko Color Engine Pilot offers ease of use with a user-friendly interface and convenience for the user. In order to determine the number of reproducible PANTONE+ Solid Coated spot colours in each ICC profile, the ICC profiles should first be registered in the ICC Profiles module as shown in Figure 13. Once this has been completed, Color Engine Pilot offers a tool called Gamut Check (as shown in Figure 14) which displays the percentage of colours in an ink book that are inside the gamut of different profiles. "Delta E 2000" must be selected as the ΔE formula for this experiment. At the bottom of the window, the ΔE^*_{00} value for which is being tested can be selected to give the percentage of colours in the ink book that are under this selected ΔE^*_{00} value. The data can be further analyzed if desired by clicking "Save As" on the bottom right corner of the Gamut Check window. Here a text file can be exported to view the ΔE^*_{00} values in addition to the original input L*a*b*, the CMYK equivalent of the profile and the output L*a*b*.

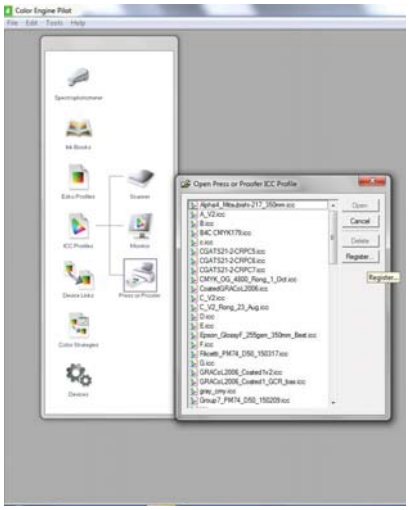

Figure 13: *Window for selecting ICC Profile.*

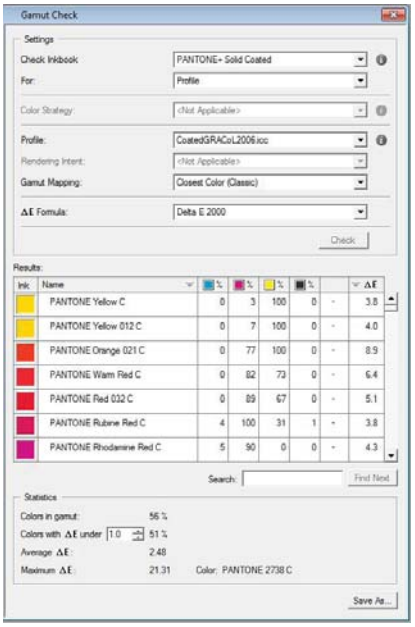

Figure 14: *Gamut Check Window.*

7.3 Argyll CMS (as shown in Figure 4)

A weakness of measuring the number of reproducible spot colours in Argyll CMS is the interface. Using the Terminal and command lines on the Mac OS in order to perform the functions of the application can be very difficult to understand for first time users. Installation of Argyll CMS is a manual process in which the downloaded folder is placed in the Applications folder of the Mac OS. The executives are then retrieved from the bin subfolder in the Argyll_VX.X.X folder where X.X.X is the

version number (Gill, 2014-a). Also, performing colour conversions in order to observe colour differences is a more tedious process in Argyll CMS than it is in ColorThink or Color Engine Pilot.

Using the xicclu executable from the bin folder offers the function of looking up individual colour values through any ICC profile in addition to reversing the look-up tables (Gill, 2014-b). In order to measure the number of reproducible PANTONE+ Solid Coated spot colours in different profiles, a properly formatted text file containing the L*a*b* values of the spot colours being tested, is required. The lines of the text file should end with CR/LF (Carriage Return / Line Feed). The CR/LF line ending is used by Windows and is compatible with the Argyll CMS software, allowing the data to be read correctly (Miessler, 2015). The text files created on a Mac use the CR ending only; however, when used in Argyll CMS, the data output will not return all of the lines. In order to fix this, the text file can easily be saved in Microsoft Word in the file conversion dialogue box as shown in Figure 15.

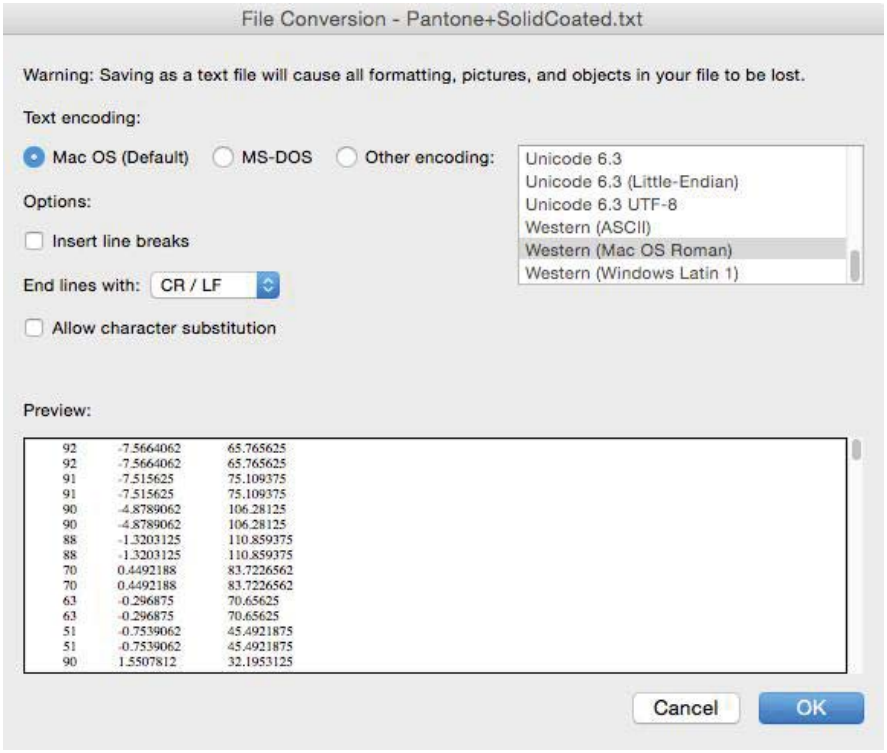

Figure 15.

This properly formatted text file can then be used in the Terminal with the xicclu executable. In order to export the PANTONE spot colour CMYK equivalent in each profile, –fb (backward function) and –ia (absolute intent) will be selected in the command line to use the Absolute Colorimetric B2A look-up table. There will be some colour difference between these CMYK values and the original PANTONE spot L*a*b* values because the spot colours had to be mapped to the gamut of the specified profile. The spot colours that were originally out of the gamut of the profile are specified by Argyll by displaying 'clip'. In order to quantify the colour difference or the amount by which the colours moved, the L*a*b* equivalent of the mapped CMYK values is required in order to calculate ΔE^*_{00}. This is performed by using –ff (forward function) and –ia (absolute intent) in the command line in order to utilize the A2B look-up table in the same ICC profile. This will deliver the L*a*b* values that can be further analyzed in Chromix ColorThink Pro to compute ΔE^*_{00}.

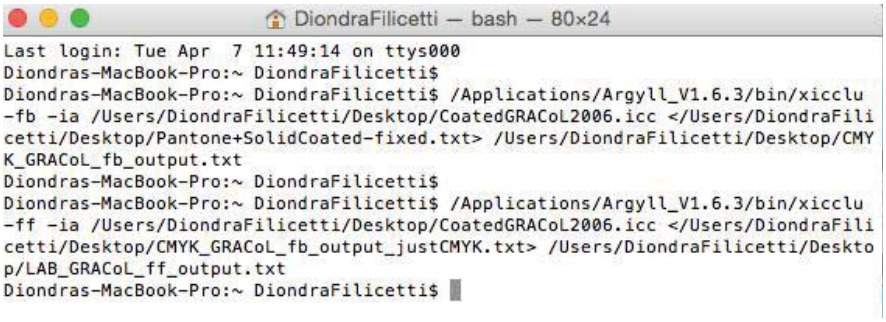

Figure 16: *Screenshot of the functions that are in use in the Terminal. Information on file location must be included and specified.*

It is important to consider that ColorThink requires the text file to be formatted according to the CGATS standard. By default, Argyll CMS does not output CGATS text files. The ANSI CGATS.17-2009 is the standard text file format for exchanging colour data where BEGIN_DATA is placed before the data begins and END_DATA is placed after the data ends (ColorWiki, 2012). In addition, the data format must be specified between "BEGIN_DATA_FORMAT" and "END_DATA_FORMAT", an example is shown in Figure 17.

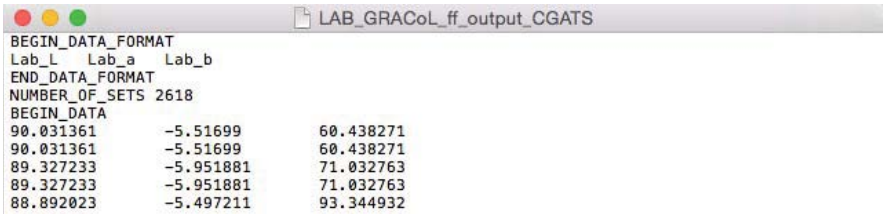

Figure 17.

Once correctly formatted, the clipped L*a*b* data from Argyll can be directly compared to the original PANTONE+ Solid Coated L*a*b* data in ColorThink to compute ΔE*00, and export a ΔE*00 list to further analyze in Microsoft Excel.

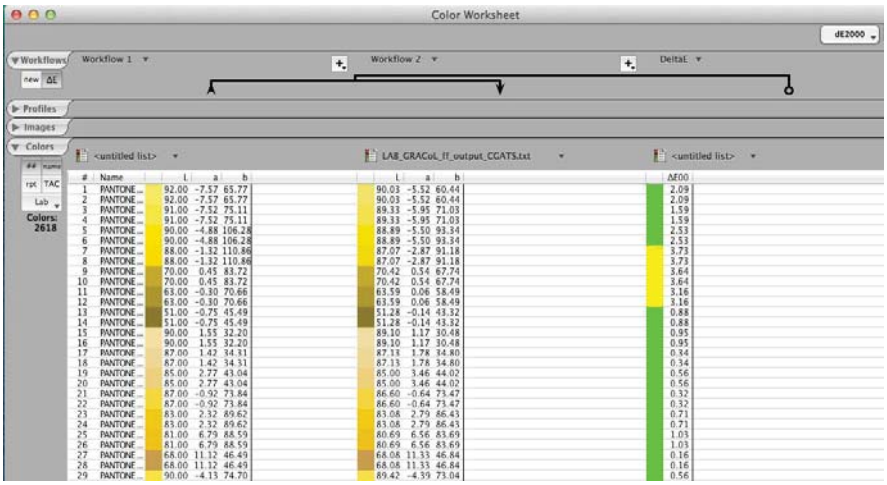

Figure 18.

Figure 18 shows a ΔE*00 comparison between the original PANTONE+ Solid Coated L*a*b* values and the clipped L*a*b* values through the GRACoL profile from Argyll.

7.4 Comparison of Software

In a comparison of the three different colour management programs, it is evident that they generate similar results. As apparent in the bar graphs on pages 8-9, the measurements from Argyll CMS and ColorThink were slightly higher than measurements in Color Engine Pilot software programs. This difference was proportional as there were similar increases in % of spot colours between different Δ*E* tolerances.

Although there were different processes in each software program, the colour management concept is the same behind all the processes. This concept is a measurement of the colour difference (measured with ΔE^*_{00}) of the PANTONE+ Solid Coated spot colours when they are mapped into the gamut of various ICC Profiles. The mapping process occurs via the Absolute Colorimetric rendering intent in order to achieve the closest colour match. The colour difference can then be prioritized and a percentage can be calculated after calculating the number of PANTONE+ Solid Coated spot colours are below ΔE^*_{00} tolerances of 1, 2, 3, 4, and 5.

The results confirm the original hypothesis in which similar results were achieved by all programs (ColorThink, Color Engine Pilot and Argyll). In addition, SWOP 5 is capable of producing the lowest number of spot colours and SWOP 3, the second lowest number of spot colours, agreeing with the gamut volume measured in ColorThink. Conversely, the custom press profile was able to reproduce a similar, if not greater, amount of spot colours than GRACoL, whereas the gamut volume of GRACoL was greater than that of the custom profile.

The percentage of spot colours that were reproducible by each printing process was related to the gamut volume of each ICC profile. Generally, the larger the gamut, the higher the percentage of reproducible spot colours. This held true for all ICC profiles except for the custom press profile measured in ColorThink and Color Engine Pilot. The custom profile measured in ColorThink and Color Engine Pilot was often equal to or slightly higher than the number of reproducible spot colours using GRACoL. This phenomenon can be explained by the existence of different methods to calculate gamut volume. Different calculation methods can result in slightly different results. Changes in gamut volume calculation do not change the calculation of the number of reproducible spot colours within a gamut because the number of reproducible spot colours is calculated via look-up tables (Pope et al.). Therefore, the calculation of gamut volume by Chromix ColorThink may differ from another measurement software, which could deliver measurements that align with the results of this experiment, showing that GRACoL and the custom press profile have more similar gamut volumes.

The three different software programs make use of different Colour Management Modules (CMMs). The CMM is the engine that performs the conversion between colour spaces using device profiles (Sharma, 2004). CMMs are available from different vendors and the choice of CMM has a slight effect on the output colours due to variations in the intent of the CMM and the technology that went into the construction (Adams, 1999). The slight differences in results obtained from each software can be attributed to the difference in CMM. Argyll CMS is a CMM on it's own, Color Engine Pilot uses a CMM, which is named Color Engine Pilot, and ColorThink uses Little CMS. Little CMS is a publicly available open source colour management engine that uses the International Color Consortium standard (Saguer, 2015).

Using ΔE is a good measure of print quality because it is an objective, numerical measure. In regards to quality standards, a ΔE of up to 2 constitutes a small difference and is usually acceptable at a top quality level (Breede, 1999). In regards to the a ΔE^*_{00} of 2 in this experiment, an average (between software programs) of 47% in SWOP 5, 54% in SWOP 3, 62% in GRACoL and 63% in the custom press profile, of PANTONE+ Solid Coated spot colours were reproducible.

7.5 Purpose of Results

Comparing the three procedures for calculating the percentage/number of reproducible PANTONE+ Solid Coated spot colours is important to determine whether there are differences in the method one chooses to calculate this metric. These results show that there is very little difference between the three software programs. Depending on the intention and needs of the user, the selection of a software solution should not be determined by the accuracy of results because as proven, all three software programs generated similar results. The choice of software will be based on the functionality and cost. Chromix ColorThink Pro and Esko Color Engine Pilot are more costly "off the shelf" solutions that offer the user an easy to use visual experience and user-friendly interface. Argyll CMS is offered for free download; however, it is more difficult to use and understand. This is relevant because users who might be students or small print shop owners might choose to use this solution over ColorThink or Color Engine Pilot, where they do not have the resources to purchase the larger "off the shelf" solutions. Larger companies or colour researchers might choose ColorThink or Color Engine Pilot as these solutions might be more affordable for them and more inline with their usage intention, especially if they require more graphical visualization of the workflow.

8 Conclusion

In this experiment, there are various methods to calculate the number of reproducible spot colours through an ICC Profile. The three tested methods generated similar results, which show that all three methods are viable solutions. The measured spot colour percentages were in agreement with the relative gamut volume (measured in ColorThink) of each profile, except for the custom press profile. SWOP 3 reproduced the lowest number of PANTONE+ Solid Coated spot colours and had the lowest gamut volume, followed by SWOP 5. GRACoL 2006 and the custom press profile were able to reproduce the most spot colours; however, the custom press profile had a lower gamut volume than GRACoL. The gamut volume is subject to change based on calculation method; therefore, a different method of calculating gamut volume in a different program could have generated different results.

The general conclusion that a greater gamut volume insinuates a larger reproducible percentage of spot colours aligns with the fact that a larger gamut (the range of colours that a device can produce) can reproduce more colours (Sharma, 2004).

The results confirmed the original hypothesis in that, in general, the greater the gamut volume, the higher the number of reproducible spot colours in each process. The similarity between the results of custom press profile and GRACoL profile was surprising. The custom press profile had a lower gamut volume than the GRACoL profile; however, at certain ΔE^*_{00} tolerances, the different programs measured a slightly higher number of reproducible spot colours in the custom press profile

than in GRACoL. Due to the fact that the PM 74 is maintained and calibrated to GRACoL specifications and gamut volume measurement changes between calculation methods, the hypothesis is acceptable in spite of the one misalignment of the custom press profile and its gamut volume.

A weakness of this experiment is the difference in PANTONE+ Solid Coated libraries used. In Esko Color Engine Pilot, the PANTONE+ Solid Coated ink book that was available contained only 1799 colours, whereas the PANTONE+ Solid Coated library tested in Chromix ColorThink and Argyll CMS was an expanded library with 2618 colours. In order to overcome this weakness, the focus was placed on the reproducible *percentage* of spot colours rather than the number. This allowed comparison between the three methods.

By assessing different methods to calculate the number of PANTONE+ Solid Coated spot colours that are reproducible by various printing process within specific ΔE tolerances, this methodology can be applied to various situations. This methodology can be used to check whether one specific colour is within the printable gamut of a specific device, or can be used, as in this experiment, to determine the percentage or number of colours that are reproducible on various devices. This is important to understand the capabilities of the equipment in regards to colour reproduction. In addition, the public can more readily understand communicating colour capacity in terms of the reproducible percentage of a PANTONE book rather than communicating gamut volume numerically. Therefore, by measuring the percentage of reproducible percentage of a set of colours by a printing process through the use of an ICC profile, a printing company can offer their customers an easy to understand metric that speaks to the gamut volume of the device. Printing companies can also use this measurement as a selling point or a key metric if their customer is interested in being able to produce certain spot colours. The customer could then evaluate the printing company based on the percentage of a particular spot colour library, depending on their colour requirements.

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Appendix

Here is a link to access the ICC Profiles Used:
https://drive.google.com/folderview?id=0B7lM0SGZof4dOHU1LUgwLWpnR0U&usp=sharing