Image Reproduction Practices

Emmi Enoksson*

Keywords: Color, Management, ICC, Separation, Problems

Abstract: The practical procedures for image reproduction in print have always been an issue for discussion due to the difficulties of achieving optimum results. The entire color reproduction process has to be under strict control in order to achieve an optimal print. In practice, however, this is often not the case. The aim, when implementing ICC-profiles, was to simplify image reproduction by implementing a common color language and using a color matching method suitable for the reproduction.

Two studies of image reproduction practices at printing and prepress companies in Sweden reveal some interesting results. This research concerning the practical skills in color separation and color management was carried out in 2000 and 2003.

The results indicate a significant lack of knowledge and training concerning the color management process. Original images of different categories were often reproduced with only one basic color setting. In many companies, the entire production line needs better calibration and control. In general, however, the newspaper industry was in better control of their color management process.

The study concludes that, in order to achieve optimized reproduction, there is a need for:

- knowledge in basic color theory and training in the color reproduction process
- hands-on, step-by-step training
- better access to applicable research results in an understand-able language
- a better understanding of available ICC profiling tools and systems on the market
- access to calibration/characterization tools aimed for each specific production

*University of Dalarna, Borlänge and Royal Institute of Technology (KTH), Stockholm, Sweden

- a forum for information interchange concerning color reproduction
- precise specifications for each step in the process
- improved communication among the parties involved in the quality management process.

Background

Most original images handled by the prepress departments are usually digital images in RGB-mode (Red, Green, Blue). However, in order to print an image it needs to be converted into the printable base colors, CMYK (Cyan, Magenta, Yellow, Black). The actual color conversion is called a "separation" or a "color split". This color conversion is made between colorimetrically measured color gamuts called PCS's (Profile Connection Space). The color gamuts are related to input and output units, where input units can be image scanners and digital cameras and output units usually are color monitors, printers and printing presses. The PCS's are defined by the standardized color coordinates XYZ according to CIE 1931 (Commission Internationale de l'Eclairage). The PCS of an output unit is converted to the actual color gamut produced by the output in CMYK and defined by the user's choice of total ink coverage and the relationship between black ink addition and the three color black (CMY) reduction in the reproduction. This relationship is described as UCR and GCR (Under Color Removal and Gray Component Replacement). GCR and UCR are the two main color separation techniques used to control the amount of black, cyan, magenta and yellow needed to produce different tones. Black ink can reduce or replace equal amounts of cyan, magenta and yellow to produce a similar tone. UCR and GCR replace equal amounts of cyan, magenta and yellow in neutral tones. GCR additionally replaces some CMY colors in tertiary colors. These separation techniques can be optimized for different paper stocks in order to achieve a good tone distribution. The total amount of ink used in print must normally be reduced in order to avoid printing problems such as slurring and quality problems such as lack of image detail.

In order to simplify the communication of color information between two separate platforms, a common color file format has been developed called ICC (International Color Consortium). The color format is valid for both input and output color units

All these terms and techniques place high demands on the operators within printing/prepress houses. What kind of color separation setting is optimal for a given image category or printing method? What amount of ink

is best suited for different paper stocks in combination with different image categories? Has the use of ICC-profiles simplified and improved image reproduction?

Objectives

The purpose of this study has been to investigate the level of knowledge concerning image separation and the use of ICC-profiles in the graphic arts industry. In addition, we wish to clarify the difficulties in implementing ICC-controlled printing.

The Structure of the Graphic Arts Industry in Sweden

In 2003, the graphic arts industry in Sweden consisted of 3695 companies. 67 percent were printers, 6 percent book binderies, 10 percent prepress companies and 16 percent other graphic art companies, see figure 1. The number of employees in these companies added up to 30025, see figures 2a and 2b. According to a prognosis (SCB, Central Bureau of Statistics, 2003) the total sales volume for the graphic arts industry was 37,950 million Swedish kronor in 2003. Commercial printers represent 46 percent and newspapers 40 percent of this total volume.

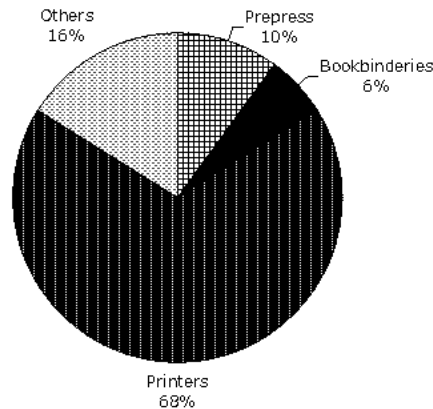**% Companies in Graphic Arts Industry, 2003**

Figure1: The diagram shows the spread of the graphic industry in 2003.
Source: GFF, Grafiska Företagens Förbund, Swedish Graphic Companies Federation
Ref. <http://www.scb.se>

Graphic Industry - number of companies 2003

Sector Industry	Company size							
	0	1-9	10-19	20-49	50-99	100-199	200-	Sum
Newspaper printers[1]	n.i	n.i	n.i.	n.i.	n.i.	n.i.	n.i.	96
Magazine printers	44	38	5	6	2	1	3	99
Book printers and other printers	1189	845	155	87	32	7	6	2321
Book binderies	104	70	23	14	4	0	0	215
Pre press	209	121	28	14	2	0	0	374
Others	281	264	32	6	4	2	1	590
Sum of graphic production	1827	1338	243	127	44	10	10	3695

[1]Companies with connections to newspaper industry (including advertising bureaus, printers etc) beeing members of TU, TidningsUtgivarna
(n.i.= no information)

Figure 2a: The table gives a summary of the graphic companies in the graphic industry, 2003.
Source: GFF, Grafiska Företagens Förbund, Swedish Graphic Companies Federation,
Ref. Ref. <http://www.scb.se>

Graphic Industry - number of employees 2003

Sector Industry	Company size						
	1-9	10-19	20-49	50-99	100-199	200-	Sum
Newspaper printers[1]	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	10700
Magazin printers	164	62	173	139	163	825	1526
Book printers and other printers	2802	2099	2620	2281	862	2141	12805
Book binderies	254	315	398	276	0	0	1243
Pre press	409	374	383	159	0	0	1325
Others	883	422	171	284	240	426	2426
Sum of graphic production	4512	3272	3745	3139	1265	3392	30025

Figure 2b: The table gives a summary of the number of employees in the graphic industry, 2003.
Source: GFF, Grafiska Företagens Förbund, Swedish Graphic Companies Federation,
Ref. Ref. <http://www.scb.se>

Methods

The investigation has involved two separate studies performed during two different time periods.

The first study was performed in 2000 when ICC-profiles were only used by a minority of Swedish printers. The actual color separation was, at that time, performed directly in image scanners or in imaging applications (i.e. Adobe Photoshop) using color look-up tables. A total of 120 companies, both printers with prepress departments and dedicated prepress houses, participated in the study. The companies are all located in Sweden, from north to south with an even geographical spread over the nation. The printers and prepress houses were also chosen based on the size of the company. However, only companies with two or more emploees were included in the survey. Semi-structured interviews were conducted with prepress representatives, normally by telephone or by e-mail. Ten company visits were made. A number of questions concerning the different separation techniques were asked in order to investigate the general level of competence

The second study was performed in 2003. Eighty sheetfed offset printers and 34 newspaper printers, evenly geographically spread within Sweden, participated in this study. Companies with only one employee were not included. As in the first study, semi-structured interviews were conducted with prepress representatives for each printer or prepress house through either a visit or by e-mail. A structured web questionnaire was also used. The questions asked concerned the use, creation and implementation of ICC-profiles. Approximately 50 percent of the printers/prepress houses participating in this study were also involved in the first study. In order to verify the findings and clarify the results, nine independent color consultants were contacted and interviewed

Study 1

The first study – **the use and knowledge of the different separation techniques**

In this study, a total of 120 companies, both printers with their own prepress departments and dedicated prepress houses, participated. During 2000, prepress representatives of these companies were interviewed.

The main questions asked were the following:
  • Color separation method used in the company, GCR and/or UCR?

- Level of black usage in percent?
- Approximate use of UCR vs. GCR in the production?
- Total ink coverage in shadow areas for different paper stocks (glossy, semi matte, matte, uncoated and coated)?
- Type of scanners and scanner applications used in the production?
- Experience of the different separation techniques.
- Difficulties?

Results

Knowledge of the different separation techniques varied. A few of the companies (approximately 20%) were well aware of what settings to use in order to control image separation and optimize the print. In general, the control of the image separation was poor among the printers. Also, default presettings were used for color separation and an understanding of these presettings was limited.

The interviews indicated the following problem areas:

1) Lack of instructions

"We do not have the time to test our method – several test prints are usually necessary. Can someone give us "how-to-do" guidelines?"

"If we ourselves think this is complicated, how is it possible for us to explain the technique to our customers?"

70 percent of the companies participating in the study thought that:
- there ought to be "step-by-step" instructions and thorough guidelines for the different separation techniques
- it is very time consuming to test a method by using different separation settings in combination with different paper stocks
- a better information interchange would improve communication between the paper developers and paper vendors on one side and prepress houses and printers on the other
- results from test prints should be more easily obtainable and written in a way that is understandable for non-experts.

2) Access to literature

"Little is written on this subject and what's written is rather complicated!"

70 percent of the participants thought that there was a lack of literature concerning print comformity and on image separation.Also:

- that avialable literature is either written in an advanced manner, making it hard to understand; or on the contrary, in a basic style making the information useless
- there is a need for quality technical literature and manuals in the native language. Language barriers are a problem when quality literature is written in a foreign language.

3) Applications

"What is the difference between PCR, ICR, UCR, GCR? I have seen some of these abbreviations in our application, not understanding the meaning of them"

"What is the total amount of ink used in shadow areas of our images? I do not know; where in the program can I see this?"

Different color management applications tend to appear alike, but they make color calculations according to program specific algorithms. This often causes variations in color results. The employees at the printers experienced poor support from the retailers concerning the performance and possibilities of a color management application. In order for a customer to receive information from a retailer about the color separation settings in a particular application, he/she must specifically ask for it. This information about the application should be provided by the retailer prior to purchase.

The same separation technique is named differently by different software producers. This confuses the end-user. For instance, GCR (Gray Component Replacement) has several names depending on the application used: PCR – Polychromatic Color Removal, ICR – Integrated Color Removal, PIR – Programmed Ink Reduction. These terms can make the user believe that there are many different separation methods.

4) Poor communication

"We prepress companies are waiting for the press operator to tell us which separation to use. They say nothing . . ."

"The press operator has difficulties understanding GCR. When he runs the press, he often watches the text to control the black ink. If we start using GCR, he may ruin the image by adding more color"

There is often poor internal communication within companies, most often between the press operators and the prepress staff working with imaging. The press operators are rarely aware of the possibilities that a program has for optimizing an image for print. The prepress department is also often unaware of the press parameters they need to consider when producing the press separation profile. This lack of knowledge is therefore often a barrier when communicating color information to a customer. The communication between the color consultants and the companies could also be improved.

5) Education

"The prepress department has nothing to gain, the press operators must tell us what to do"

"We do not use GCR - because of poor knowledge! Let us know when this study is finished"

More than 50 percent of the printers asked for dedicated technical training in their field. It is important to provide targeted training where press operators and prepress operators get a chance to discuss problems, strengths and weaknesses. Education in basic color theory and digital imaging is also of importance. There is a need for process thinking and for clarifying how different processes are linked together.

Study 2

A study **of ICC profiles; creation, implementation and usage.**

During 2003 a study was done in Sweden focusing on the creation, implementation and use of ICC-profiles. Eighty sheetfed offset printers and 34 newspaper printers participated in the study. The interview study was carried out through e-mail, mail, web, telephone and personal visits.

The main questions were as follow:
- Are ICC-profiles used in your production?
- What kind of profiles are used?
- Are the profiles created inhouse or by consultants?
- How are the profiles produced?

- Are the contents of the profiles known to the company (separation method, total ink coverage etc.)?
- What application is used for separation creation?

Results

Eighty-three percent of the newspapers participating in the study were using ICC-profiles for the print process (2003). Six percent were in the introductory phase. ICC-profiles were introduced in Swedish newspapers in the mid-1990s. and an increase in use can be seen after the introduction of a standard profile in 1997 by the Swedish Newspaper Publishers' Association (TU). TU produced an average ICC-profile based on normal print runs from a number of Swedish newspapers. TU has also run a campaign focused on helping newspapers to increase their overall production quality.

Eighty sheetfed offset printers participated in the survey, located throughout Sweden. The results show that 70 percent of sheetfed printers use ICC-profiles. The larger printers and printers close to the capital Stockholm tend to use profiles more. The number of different paper stocks in sheetfed printing is large and therefore the separation settings vary more than in coldset printing. Using several paper qualities requires specific separation settings for each paper stock and is therefore more complicated to control.

A summary of the survey results is given below:

1) Profile use

The majority, approximately 70 percent, of the participating companies are today using profiles in their production. The remaining companies are mostly smaller companies with no resources for using ICC-based color management, or their production is mostly one or two color.

Eighty three percent of the newspapers in the survey use an ICC-based color workflow. Another six percent are currently introducing color management based on ICC-profiles.

2) Profile creation

The survey indicates that external consultants play an important role in the creation of ICC-profiles. Approximately 70 percent of the participating printers use external help from consultants in this matter. How the consultants present their work in the companies is important for the under-

standing, e.g. by written reports or by oral presentation. Many companies are not aware of the contents of their own printing profiles. The study also indicates that companies who have built their own profiles are less knowledgeable of the color management process than the companies who have used consultants. Larger printing plants are generally more knowledgeable of their ICC-workflow.

Sixty five percent of the newspapers have used consultants in their color management work, despite the existence of a general newspaper color profile.

3) The number of profiles

The number of profiles used at the different printing plants vary. There is a common mistrust in having too many profiles. According to the companies, fewer profiles make it easier to organize them in a manual color management system. Generally, sheetfed offset printers use two profiles; one profile for coated paper and one profile for uncoated paper. When more profiles are used, they are normally customer specific for a matte paper and or a yellowish paper.

4) Choice of tools for profile creation

The application used for ICC-profile creation and modification is often one recommended by a color consultant. The consultants also often influence the choice of ICC test chart, color measuring instruments and other instruments for calibration.

5) Accuracy and Precision

A number of calibration and characterization instruments are used in the graphic arts field. These instruments often do not give the same measuring values. The reason for this can be outdated calibration cards, dust on the optics, or different measuring areas.

6) Separation choice in the profile creation

Paper quality and offset method (heatset, coldset) often determine the separation settings. Images of different categories are usually separated in the same manner as in a color conversion from RGB to CMYK. There is a commonly accepted image classification defining three main image categories: hi-key, normal-key and low-key. A category specific separation could provide color optimization. However, time and effort involved in more com-

plex profile handling are two main factors preventing this. The choice of separation settings is in 70 percent of the cases based on recommendations by a color consultant.

7) Confusion of terminology

Terminology confusion is common in the graphic arts business. Technical abbreviations from different languages such as CIE, ICC, UCR, GCR and TIC create problems. Commonly used graphic arts terms such as: calibration, characterization, and white calibration can also cause confusion in a discussion. The study shows that many prepress staff members use the terms incorrectly or mix them up.

8) Lack of communication

There is often a lack of communication between printer personnel and prepress personnel. This can cause problems and misunderstandings. The two main reasons for this are different technical backgrounds and poor knowledge of each other's processes. Communication is also insufficient between the printer personnel and the color consultants as well as between the printer personnel and the customers. There is a need for d o cumentation and a clear explanation of the color process from the color consultants to the printer and prepress personnel

Conclusion and Discussion

The first study concluded that in 2000 knowledge concerning image separation and press optimization was inadequate in Sweden. The graphic arts industry was asking for better literature written in an understandable way. Companies also wanted a better dialogue with the color management retailers. There was a common hope that an ICC implementation would solve the major color reproduction difficulties. The study indicates that the companies needed more adequate education, a thorough explanation of settings in different applications, and step-by-step instructions.

The second study concluded that ICC-profiles have made printers more aware of color managament in optimizing the process. The introduction of an ICC workflow has also opened up a dialouge between the different participants in the color reproduction process. However, the need for training and improved skills is still high. The newspaper industry is more up-to-date than the commercial offset printers regarding knowledge of ICC color management. A possible reason for this is a more demanding

printing process (coldset) with low quality paper which requires good knowledge in color preparation in order to avoid e.g. set off and bleeding. The total ink coverage is important since the paper stock can not hold more than 240 percent for an acceptable result. This low total ink coverage makes the reproduction process more critical than for a commercial offset printer using a sheetfed press and using a better paper stock which can hold a higher percentage of color.

Both studies conclude that there is a need for further education in the graphic arts industry. Ninety five percent of the companies experience an improved print quality after a color management workflow with ICC-profiles has been introduced. However, the overall knowledge about ICC profiles and separation methods is insuffient. Before the ICC-profiles were introduced, separations were made directly in scanners or in imaging applications using color tables. Default presettings for separations were often used. Insufficient knowledge of the different separation techniques is indicated by the first study where 80 percent of the companies had no control of their separation process.

Both studies indicate a serious problem in the graphic arts industry. The problem concerns both insufficient knowledge of color management and lack of communication. The knowledge part indicates a lack of competence and a shortage of literature and instructions which could help printers better understand the technology. The communication part indicates in the lack of a common language. This is mainly caused by the different backgrounds and experiences of the people involved.

Knowledge of the other people's field of expertise is necessary to establish better communication between prepress and printing personnel.

There is a lack of knowledge regarding what resources are needed to establish a color management system and what the outcome of the process will be. Companies which have a certified quality system to build upon have a head start when implementing a color management system in their production process. A certified quality system requires a description of the processes having an impact on the overall quality. An analysis of the critical production steps directly affecting the product quality must be performed. Measurements and tolerance specifications must be incorporated in the critical production steps. The frequency of measurement must also be specified. The aim is to obtain statistics on production variations and to handle deviations from tolerance values in a controlled manner. These measurements and calibrations form a basis for characterization of the color units in the production set-up.

There is a common belief that the use of printing profiles (ICC) alone can solve the problems with color transformations. The ICC-profile is one part of color management describing the color gamut of each color unit. The profile itself does not improve color quality or color agreement. However, by having a description in a common language of all color units, a chain can be established throughout the process and considerations can be taken of the weaknesses or deviations of the different color units.

It is simple to create an ICC-profile, but more demanding to achieve an optimized printing profile functioning correctly within normal printing deviations. Tolerance settings are easily overidden if the calibration and control procedures are neglected.

Based on the results from the interviews in the two studies, certain general assumptions can be made concerning the prerequisites for the successful introduction of a color management workflow based on ICC-profiles. Establishing a production workflow based on ICC-profiles is a long term process. It takes time to implement and it must be optimized for each specific color workflow. Process descriptions and demand specifications must be written. The processes affecting quality must be measured and documented. Requirement specifications of this kind can improve the understanding of the process, help avoid missunderstandings and improve the quality. Both internal and external requirement specifications can bring together the process for the staff and create a better understanding by visualising the links between the processes. Meaningful information interchange can be achieved in the various departments through requirement specifications.

Target directives must be formed and an organization must be created for the implementation task. Consultants involved in profile creation should document each step in their work to ensure a basis for a consistent level of quality. Each setting, tolerance and calibration frequency must be described and motivated. Surprisingly many companies are not aware of the contents of their own profiles. Well thought-out requirement specifications by the printers to the consultants would have simplified the color communication. The color management process must be implemented consistently throughout the process from original to final print. Quality meetings should be held regularly in order to prevent process changes challenging the overall print quality. If this is not done, the effects of the profile will disappear. By using profiles in a structured way, the overall color quality can be improved. A basis for a functioning color management system throughout the process is trained personnel with the right tools for continuous process control.

To fully implement ICC-profiles, the following is needed:

- optimization of the color units' performance
- suitable instruments for process control
- routines for statistical process control to ensure a stable production
- provide detailed work specifications to consultants and customers
- training for the entire company regarding ICC-profiling
- detailed specifications for each process step

References

Fred.W Billmeyer and Max Saltzman
  1981 "Principles of Color Technology", Second Edition
      Wiley Interscience, New york, USA

Richard M. Adams II and Joshua B. Weisberg
  2000 "The GATF Practical Guide to Color Management",
      Second Edition, GATF Press, Pittsburgh, USA

Bruce Fraser, Chris Murphy and Fred Bunting
  2003, "Real World Color Management", Berkeley, USA

Gary G. Field
  1999, "Color and Its Reproduction", Second Edition,
      GATF, Sewickley, USA

Herschel L. Apfelberg and Michael J. Apfelberg
  1999 "Implementing Quality Management in the Graphic Arts"
      GATF Press, Pittsburgh, USA

SCB, Central Bureau of Statistics, <http://www.scb.se>